IDENTIFICATION OF RESIDUAL OIL ZONES (ROZS) IN THE WILLISTON AND POWDER RIVER BASINS

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PRESENTATION OUTLINE

• Benefit to the program
• Project overview
• Technical status
• Accomplishments to date
• Synergy opportunities
• Summary
BENEFIT TO THE PROGRAM

• Second and fourth goals of Carbon Storage Program:
  – Improve reservoir storage efficiency while ensuring containment effectiveness.
  – Develop best practices manuals (BPMs).

• Potential ROZs will be identified and evaluated for oil recovery and CO₂ storage resource potential.
  – CO₂ storage efficiency is improved through CO₂ enhanced oil recovery (EOR).

• A repeatable methodology will be developed and presented in a BPM.
PROJECT OVERVIEW
GOALS AND OBJECTIVES

Objectives:
• Identify and characterize the presence and extent of potential ROZs in the Williston Basin (WB) and Powder River Basin (PRB).
• Estimate residual oil in place and CO$_2$ storage potential (Goal 2).
• Determine potential for CO$_2$ EOR in identified ROZs (Goal 2).
• Develop repeatable methodology for sedimentary basins to be included in a BPM (Goal 4).
TECHNICAL STATUS: BASIN MODELING

Provides a complete record of the evolution of a petroleum system, including:

- Deposition and erosion.
- Pressure and compaction.
- Heat flow analysis.
- Petroleum generation.
- Fluid pressure, volume, temperature analysis.
- Reservoir volumetrics.
- Structural evolution.
- Generation, migration, and accumulation of hydrocarbons.
APPROACH

• Understand ROZs and previous work in basin modeling, both local and abroad.
• Translate geologic history of basins into an input for modeling.
• Gather data required for model construction.
1-D AND 2-D MODELING

1-D Models

• Point location examination of:
  – Burial history.
  – Temperatures.
  – Boundary conditions.
  – Generation.

2-D Models

• Investigate generation and lateral migration.
• Faster simulation times than 3-D.
3-D MODELS – STATIC

• Provides more detail than a simplified 2-D model.
• Structural models have been developed.
• Generation and migration calibration ongoing.
3-D MODELS – SIMULATION

By simulating the entire history of the stratigraphic package, models produce outputs that largely agree with known accumulations of hydrocarbons.

• Produces most accurate pressure history.
• Has a long run time.
2-D MODELS – SIMULATION

- Extracted 2-D models depict expulsion and migration throughout the Williston and Powder River Basins.
1. Compare model outputs (overlays) to known values (calibration database).
2. Adjust model inputs so model produces more accurate output.

- PetroMod software does not include calibration tools—all comparison and input adjustments are manual.
- The use of scripting in R for the comparison step of calibration results in more rapid iteration.
- Comparing all known values can identify:
  - Systematic errors.
  - Trends with a systematic solution.
- Comparing all known values eliminates issues with piecemeal changes to model inputs.
  - Local changes may have many effects.
  - Multiple simulations increase confusion.
CALIBRATION – METHODS

• Three calibration comparison scripts were built using R:
  – “2-D Calibration”
  – “2-D Compare Calibration”
  – “2-D Compare Overlay”

• Comparisons performed in the same way.
  – Simulate models with same structure
  – Overlay data as (x,y,z,value)
  – Calibration data as (x,y,z,value)
  – Compare closest overlay point with each calibration point (within bandwidth)
CALIBRATION – EXAMPLE RESULTS

WB+PRB_1000_1_X1 Pressure

Histogram of differences
CALIBRATION – EXAMPLE RESULTS

Histograms and scatter plot showing the distribution of data and model results.
PETROPHYSICAL APPROACH

Petrophysical workflows analyzing oil and water saturations from existing logs in areas of known tilted oil–water contacts will support modeling efforts.
• Example: T.R. and Big Stick Fields in southwestern North Dakota.
Field-scale models and petrophysical analyses will be used to validate and calibrate basin-scale models.
VALIDITY TESTING: CORE ANALYSIS

- Data from core will be used to support the modeling effort (e.g., calibration, validation testing).
- Multiple wells will be chosen based on literature review, modeling results, and core availability.
VALIDITY TESTING: PULSED-NEUTRON LOGS (PNLs)

PNLs will be collected near suspected ROZs to support and validate modeling and petrophysical analysis efforts.

To choose potential locations for PNLs, multiple criteria must be met:
• Currently active well
• Wells penetrate through to the potential ROZ
• Completion specifications
OUTPUT: RISK ANALYSIS

• Uncertainty analysis using Monte Carlo simulations will be performed to better understand the impact of key variables.
• Range of data for each variable will come from literature review database.
• Probabilities, confidence intervals, error bars, correlations, and calibration will be considered to find the best model fit.
• High-, mid-, and low-probability models will be used in fairway mapping.

www.brighton-webs.co.uk/montecarlo/simulation.aspx

Analyze

• Histograms
• Tornado plots
• Crossplots
• Distributions
OUTPUT: ROZ FAIRWAY MAPPING

- Create play fairway maps showing potential brownfield (existing fields) and greenfield (new fields) ROZs.
- Display high, mid-, and low probabilities.
OUTPUT: CO$_2$ EOR FEASIBILITY STUDY

- Analyze potential ROZs to determine feasibility for EOR using CO$_2$.
- Use published ranges for recovery and utilization factors for conventional CO$_2$ EOR projects.
- Make high, mid-, and low estimates.
ACCOMPLISHMENTS TO DATE

• Literature review has been completed.
• Several 1-D models have been completed, simulated, and calibrated as part of the PetroMod learning process.
• Several 2-D models have been extracted from the Williston Basin + Powder River Basin combined 3-D model and simulated.
• Calibration of lithologic properties and other input data based on 1-D and 2-D simulations is well under way.
• Reservoir simulation of T.R. and Big Stick Field 3-D model is in progress.
• Project overview has been presented in multiple venues.
SYNERGY OPPORTUNITIES

Associated Storage (EOR)

• Basin evolution modeling could be used to identify future unconventional or conventional targets.

• Collaboration between projects investigating CO$_2$ EOR in unconventional reservoirs and ROZs will help further the understanding of CO$_2$ storage associated with EOR.
SUMMARY

• Key findings
  – Current PetroMod models predict hydrocarbon accumulations that largely agree with known pools.

• Lessons learned
  – Much greater understanding of PetroMod software and relationships among variables.
  – Improved structural frameworks for the WB and PRB.
  – Delicate balance between not enough detail and too much when collecting data.

• Future plans
  – Streamline and calibrate.
THANK YOU!
BIBLIOGRAPHY

• No peer-reviewed literature to date.
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