

Demonstration of a Novel, Integrated, Multi-Scale Procedure for High-Resolution 3-D Reservoir Characterization and Improved CO₂-EOR Sequestration Management, SACROC Unit

DE-FG26-04NT15514

Goal

The goal of this project is to demonstrate the application and benefits of data-driven modeling for multi-scale data integration and high-resolution reservoir characterization for better management of CO₂ EOR floods and carbon sequestration projects.

Performers

*Advanced Resources International, Inc.
Houston, TX*

*Kinder Morgan CO₂ Company, LP
Midland, TX*

Results

Preliminary research was done to compare advantages and drawbacks of various data-driven modeling techniques currently utilized in reservoir characterization tasks. A model-based clustering system has been adopted.

Three new wells were drilled and cored. Detailed geologic analysis was performed on all three recovered cores. New well log suites were run in each cored well. Seismic attributes were calculated from real seismic traces from the SACROC unit. Exploratory data analysis has been performed using the core data, geophysical well logs, and derived seismic attributes.

Pattern recognition procedures have been applied to the data to produce a predictive model for porosity and permeability based upon well logs. A second model predicts well logs based upon incomplete log suites, thus enhancing the data richness. Geostatistics and dynamic flow modeling together with evolutionary strategy optimization methods are used to complete the reservoir characterization.

The major achievement expected from the project is a demonstration of an improved, quicker, and lower-cost procedure for multi-scale data integration and high-resolution 3-D reservoir characterization. Further, the technology will be applied to



Coring at SACROC Unit #19-12.

an important and practical problem faced by an operator (Kinder Morgan) to enhance its CO₂ EOR operations in West Texas.

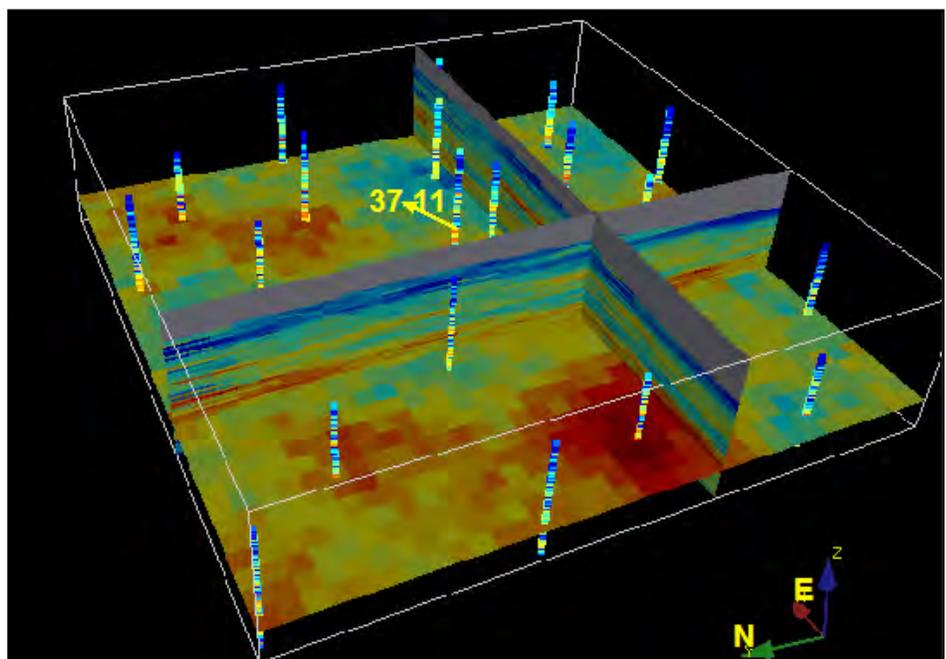
Benefits

Oil reserves in the Permian Basin are estimated at 4.2 billion barrels. If the proposed technology can be applied to only 5 percent of the reservoirs that correspond to this reserve estimate and can improve recovery on average by 25 percent (i.e., improving recovery from 40 percent to 50 percent of original-oil-in-place, or OOIP), the technology developed in this project would

facilitate the recovery of 53 million barrels of additional oil. At a conservative market price of \$50/bbl, an increase in economic activity of \$2.65 billion would result. If the local, State, and Federal government share of that economic activity were 20 percent (i.e., production taxes, employment taxes, income taxes, etc.), the government share would be \$530 million. Even if substantially reduced by the application of risk factors, the potential payoff for the project, for industry and government alike, is highly attractive.

Background

Discovered in 1948, the Kelly-Snyder field of West Texas covers an area of about 50,000 acres with an estimated OOIP of 2.8 billion barrels. The field can be divided into three broad regions: the Northern Platform, Central Plain, and the Southwestern. The SACROC Unit was formed in 1952 to facilitate coordinated waterflooding of the field. CO₂ EOR began in 1972 and has traditionally been focused in the Central Plain, where reservoir architecture is amenable to pattern flooding. The Northern Platform area contains the thickest interval, however, ranging from 80 ft at the periphery to more than 750 ft at the center, and contains the greatest concentration of oil resource. Geologic and production data from this area suggest it may be a potential candidate for gravity-stable CO₂ EOR. Kinder Morgan, the operator of the unit, is evaluating the feasibility



3-D visualization of study area.

of gravity-stable CO₂ EOR for the SACROC Unit Platform area.

From the reservoir management point of view, methods to create high-resolution 3-D reservoir characterizations integrating well log data and seismic information (3-D) remain elusive. In essence, the goal of establishing efficient relationships between data at different scales has not been achieved yet. Existing approaches attempt to tie 3-D surface seismic directly to well data via geostatistics or apply seismic inversion via rock physics relationships. However, these approaches can present considerable difficulties—including low-resolution detail of indirect indicators of the reservoir properties sought and a high degree of non-uniqueness—and are time-consuming and costly to perform.

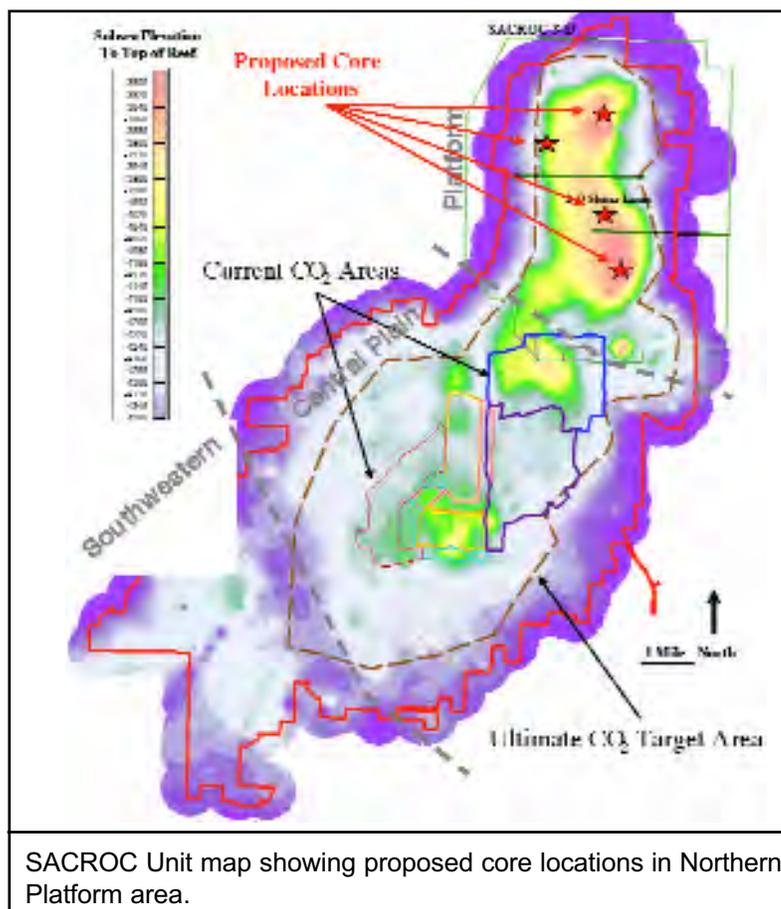
Summary

The approach being demonstrated in this project utilizes advanced pattern-recognition technologies (self-organizing maps, artificial neural networks, and fuzzy logic) to establish relationships between data at different scales, and by doing so, creating a “transform” to derive core-scale reservoir properties ultimately from 3-D surface seismic data.

This approach can overcome the shortcomings of current industry practices by:

- Utilizing intermediate frequency data, specifically cross-well seismic (if available), to bridge the resolution gap between surface seismic and geophysical well logs such that the resulting transform is more constrained.
- Incorporating core data such that the result is provided in terms of the reservoir engineering parameters needed for effective reservoir management.
- Using the increasing elastic frequency of each data type to deconvolve the surface seismic to a higher resolution.
- Doing so in a relatively direct manner, with common computing tools.

This project takes advantage of the intense data-collection efforts planned by Kinder Morgan for an assessment of gravity-stable CO₂ EOR for the SACROC Unit Platform area. This includes the collection of core over the entire reservoir interval at three locations in the Platform area and a foot-by-foot analysis for reservoir properties,



including porosity and multi-azimuth permeability, geophysical well logs, and (potentially) cross-well seismic surveys. (A 3-D surface seismic survey already exists over the entire area.) The project performer will use these data to develop a high-resolution seismic-to-core transform and apply it to a selected portion of the field for validation.

Current Status (February 2007)

Three core wells have been drilled and cored. All recovered cores had detailed geologic analysis conducted. A model-based clustering system has been adopted that combines a priori knowledge, adaptability, and fuzzy logic. The system can

predict core properties from logs and complete incomplete log suites.

The system has been applied to a 20-well area in the Northern Platform area of the SACROC Unit, and geostatistical modeling utilized to describe the interwell area. Dynamic flow modeling utilizing intelligent evolutionary-strategy optimization methods are being applied to complete and validate the reservoir characterization.

Funding

This project was selected in response to DOE’s Oil Exploration and Production solicitation DE-PS26-04NT15450-2C, February 10, 2004.

Project Start: September 20, 2004

Project End: September 30, 2007

Anticipated DOE Contribution: \$799,984

Performer Contribution: \$4,319,119 (84 percent of total)

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