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 for high-resolution 3-D reservoir characterization to address 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 neural system has been adopted.

Three core wells have been drilled and cored. All three recovered cores already have detailed geologic analysis. New well log suites were run in each cored well. Seismic attributes were calculated of real and synthetic seismic traces from the Sacroc unit.

Exploratory data analysis has been done providing descriptive statistics of the main geophysical well logs and derived seismic attributes.

Pattern recognition procedures have been applied in three cored wells to produce two local reservoir models using all types of available information: seismic attributes derived from 3-D surface seismic data, well logs information and core data.

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 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% of the reservoirs that correspond to this reserve estimate and can improve recovery on average by 25% (i.e., improving recovery from 40% to 50% of 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% (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 feet at the periphery to more than 750 feet 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 of gravity-stable CO_2-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 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 up to four locations in the Platform area and a foot-by-foot analysis for reservoir properties, including porosity and multi-azimuth permeability, geophysical well logs, and cross-well seismic surveys. (A 3-D surface seismic survey already exists over the entire area.)

Advanced Resources International 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. Validation will be performed by independently testing the existence and properties of vertical flow barriers in the reservoir section in one or more well locations (vertical interference testing), and comparing those results with the predictions based on the new reservoir characterization procedure.

Current Status (June 2006)
Three core wells have been drilled and cored. All recovered cores already have detailed geologic analysis. Four cross-well seismic surveys were programmed to be executed during the third quarter of this year.

A model-based neural system has been adopted that combines a priori knowledge, adaptability, and fuzzy logic.

A total of 17 seismic attributes were computed of real and synthetic seismic traces. Seismic attributes for the synthetic traces were computed alongside corresponding attributes from 3-D, migrated seismic traces located near each of the wells.

Statistical analysis of well logs and seismic attributes were executed to provide summary descriptions, correlations, anomalies and discrimination of most influential parameters.

Pattern recognition procedures were applied to produce two local reservoir models around cored wells. These models are prepared to derive core-scale reservoir properties from 3-D surface seismic data where no other information type is available. These models have been generated without using cross-well seismic data.

Funding
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Project Start: September 20, 2004
Project End: March 31, 2007

Anticipated DOE Contribution: $799,984
Performer Contribution: $4,319,119 (84% of total)

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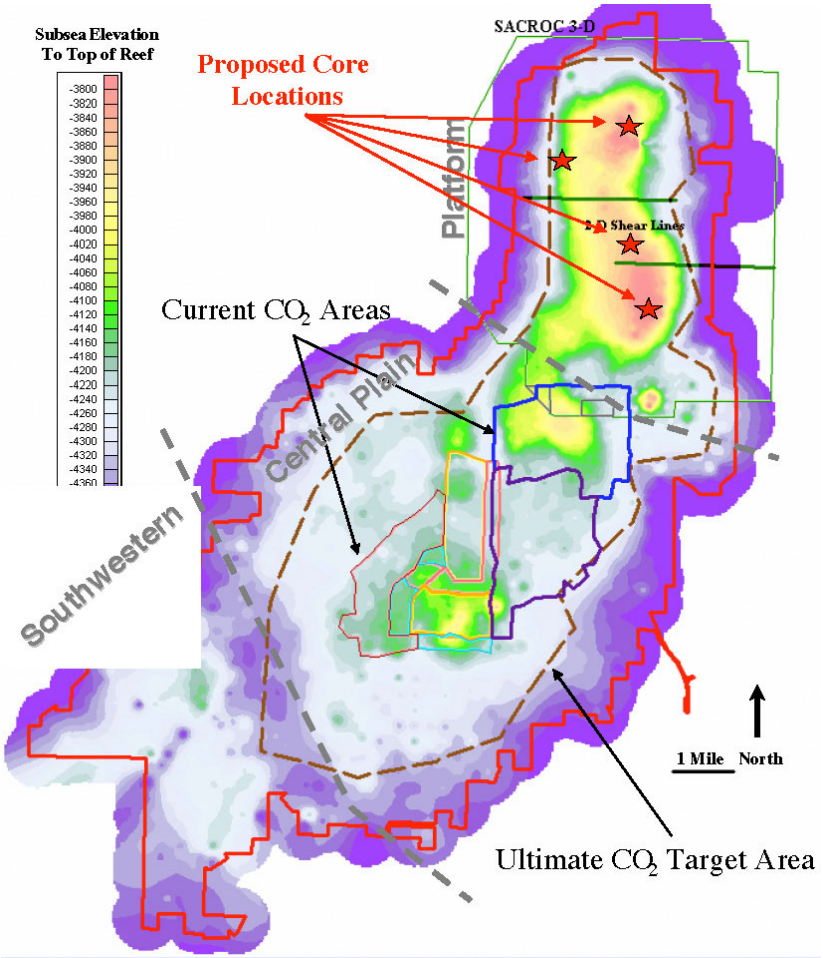
Well SACROC Unit #19-12 (June 26, 2005).



SACROC Unit map showing proposed core locations in Northern Platform area.