PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory
Strategic Center for Natural Gas and Oil

4-D High-Resolution Seismic Reflection Monitoring of Miscible CO_2 Injection into a Carbonate Reservoir

PARTNERS

University of Kansas Center for Research
Lawrence, KS

MAIN SITE

Hall-Gurney Field
Russell County, KS

IVI Minivib2 outfitted with DGPS receiver, tracking system, and Atlas high-output rotary valve.

Background/Problem

Time-lapse 3-D (or 4-D) seismic reflection surveying has been proven an effective tool during the last decade to evaluate the effectiveness of conventional EOR programs. Consistency and repeatability of 3-D surveys has been the most frequently identified problem associated with time-lapse monitoring of reservoir production. Seismic monitoring has been considered viable only for the most prolific fields, possessing the greatest potential for significant returns from identification of stranded reserves. Most U.S. Midcontinent reservoirs would not be considered candidates for 4-D monitoring using historical criteria.

Only recently has the potential of seismically monitoring the injection of miscible CO_2 into thin carbonate reservoirs been studied. Field tests of this technique to date have used conventional approaches with minimal regard to the economics of routine application or to the spatial and temporal sampling necessary for application to the size of most reservoirs found in the Midcontinent. Changes in reservoir characteristics between baseline and monitoring surveys have assumed linearity and have not been incorporated into improved production schemes. This project follows on the DOE Class Revisit being conducted at Hall-Gurney field to evaluate the feasibility of CO_2 flooding in central Kansas.

Project Description/Accomplishments

High-resolution seismic monitoring of this CO_2 flood has to date included five 3-D seismic surveys shot using the same single-patch, modified brick design. A single high-frequency vibrator has occupied each of the more than 800 shotpoints in this approximately 2.3 km^2 patch within 0.5 m of ideal using a differential global positioning (DGPS) tracking system. Identical equipment, parameters, and procedures were used for each survey. Processing has been completed using an iterative approach, where processing enhancements identified for each survey were used to improve and modify processing parameters of previous surveys.

Selected 4-D seismic attribute maps that have undergone weak-anomaly enhancement through color balancing have successfully monitored the movement of the injected miscible CO_2 front and illuminated bypassed hydrocarbon areas.

…Seismic data a potential tool for routine CO_2 sequestration

CONTACT POINTS

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TOTAL ESTIMATED COST

$2.9 million

COST SHARING

DOE	$2.3 million
Non-DOE	$0.6 million

WEBSITE

www.netl.doe.gov

The role 4-D seismic can play in the evolution of reservoir modeling and accelerating model development is being evaluated. One- and two-layer models adequately predicted primary production. Subsequent waterflooding required the introduction of more layers and lateral heterogeneity to the models. 3-D seismic revealed lateral heterogeneities that also were indicated by well interference testing but not fully quantified. 4-D seismic revealed that the movement of injected CO_2 was constrained both in response to the observed heterogeneities and the interaction of pressures generated by water-containment injectors.

CO_2 injection well with DGPS receiver and part of the distributed seismograph.

High-resolution seismic images acquired before and during this CO_2 flood have highlighted changes consistent with expected CO_2 movement, based on production data, fluid-injection volumetrics, and reservoir simulations. Instantaneous frequency of earth volumes (which include the production zone) is an excellent, quick, relatively low-resolution indicator of changes that appear consistent with changes in CO_2 saturation. Amplitude attributes have proven most sensitive to and effective in mapping changes in reservoir properties.

With injection of CO_2 continuous now for almost a year, preparations are underway for acquiring the first 2-C, 2-D shear wave monitoring survey in early December 2004. Sensitivity of several seismic attributes to changes in fluid characteristics from movement of CO_2 across this field is being evaluated. Amplitude appears to have the greatest potential to track CO_2. No attributes studied so far require inversion and therefore avoid problems of instability and non-uniqueness.

Benefits/Impacts

Successful 4-D monitoring of this multi-year EOR project will reveal critical components and considerations necessary for routine incorporation of 3-D high-resolution seismic monitoring with CO_2 EOR programs in thin, relatively shallow, mature carbonate reservoirs. Changes in production schemes made possible by incorporating nearly real-time monitoring data into CO_2 injection EOR programs could dramatically improve the efficiency and economics of that technology in many Midcontinent fields. Refinements to 3-D high-resolution reflection-imaging approaches resulting from this study could make seismic data a tool for providing assurances essential for routine sequestration of CO_2 in depleted oil/gas reservoirs or brine aquifers.