Crosswell Seismic Amplitude-Versus-Offset for Detailed Imaging of Facies and Fluid Distribution Within Carbonate Oil Reservoirs

DE-FC26-04NT15508

Goal

The project goal is to provide a methodology that will allow operators of oil reservoirs in carbonate reefs to better image the interior structure of those reservoirs and to identify those areas that contain the most oil remaining after initial production.

Performers

Michigan Technological University
Houghton, MI

Z-Seis Inc.
Houston, TX

Results

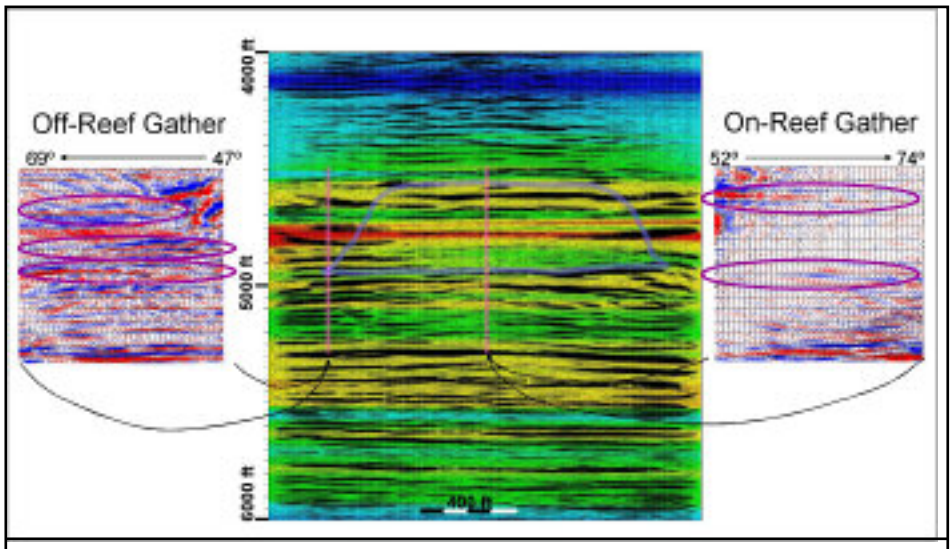
The first data set has been acquired and processed to obtain a quality image, at high resolution, of a producing reef. This data set now is being processed, analyzed, and interpreted in terms of amplitude-versus-angle to find relationships with lithologic facies and fluid content.

Benefits

Once completed, this project will enable operators of reservoirs contained in carbonate reefs (a common type of reservoir in the United States) to use their existing boreholes to image the reservoir. This has the potential of increasing U.S. oil reserves by billions of barrels with no added environmental impact, because it makes use of existing boreholes.

Background

This project is in its early stages, although it has completed acquisition of the first data set. A dedicated test site in northern Michigan was used for this, with a seismic source in one well and a string of receivers in another. A producing reef is in between the two wells. This reef is similar to thousands of others, from which a fraction of the oil in place has been recovered. High-resolution imaging of these reefs will enable operators to extract a higher percentage of the oil in place, without drilling additional wells.



The processed crosswell seismic image is shown in color, with colors representing seismic velocities, and the overlay showing the seismic reflection traces as wiggles with positive values blackened. Note that the vertical axis is depth in feet, not time. The approximate outline of the reef is sketched in. Two seismic gathers displaying the amplitudes as a function of angle are shown—one (on the left) is for a region off-reef, as indicated by the vertical line, and the other is on-reef. Some specific events are highlighted by ovals showing profound AVA character.

Summary

Researchers during the first year of the project have:

- Acquired the first crosswell seismic data set.
- Completed processing for the crosswell image.
- Initiated investigation of crosswell amplitude-versus-angle (AVA).
- Began discussions to acquire a second data set in another producing field.

The first data set was acquired, and initial processing is complete. The data quality is extraordinarily good, with signal content ranging up to 3,000 Hz. The seismic image produced by the crosswell data is excellent, and details of the internal structure of the reef seem to be apparent. The high frequency content of the data requires additional processing in order to "flatten" events prior to stacking; some events are lost in stacking due to the resolution of the data exceeding the resolution of the velocity model, but these will be recovered as part of the AVA study.

The AVA character of several key reflectors is being studied at the time of this report. A figure shows two different areas of the study, mid-reef and off-reef, and the different AVA character of the reflectors is clear. The reflector at the top of the reef decreases amplitude (to near zero) at greater angle of incidence, while the reflector at the base of the reef increases amplitude with greater angle. The scarcity of large-amplitude reflectors from within the reef is probably due to the scattering and attenuation resulting from high saturations of free gas phase, although small-amplitude, high-frequency reflectors are apparent on the pre-stack gathers.

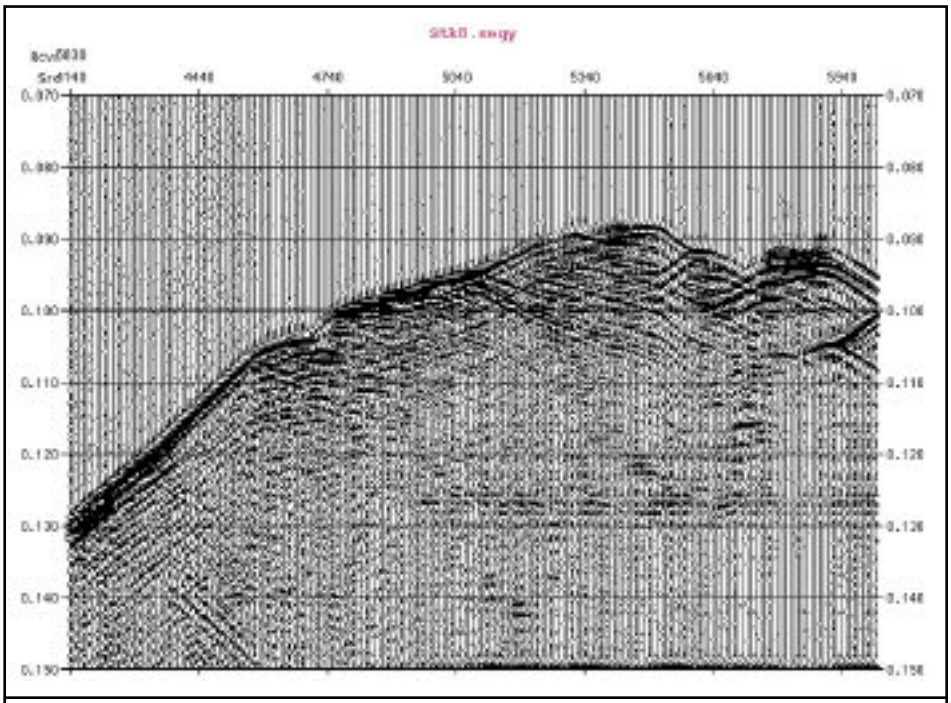
Current Status (January 2006)

The project has completed the data-acquisition and initial data-processing portions of the first phase, using two dedicated boreholes that bracket a producing Niagaran reef in Michigan. Detailed processing is underway, as is interpretation of the AVA character in terms of lithologic facies and fluid content. A second site is being pursued for the acquisition of a new data set in summer 2006.

Funding

The project was selected in response to DOE's Oil and Gas Master Solicitation DE-PS-04NT15450, focus area Advanced

Diagnostics and Imaging Technology.



A sample of seismic data showing a “fan” of data collected by a receiver at a depth of 5,830 feet in one well, from sources at depths ranging from 4,140 feet to 5,950 feet in another well. The details seen in this (and hundreds of other fans) will, after processing, yield images of the interior of the oil-bearing reef.

Publications

Pennington, Wayne D., The rapid rise of reservoir geophysics, The Leading Edge, 24, S86-S91, 2005.

Project Start: October 1, 2004
Project End: September 30, 2007

Anticipated DOE Contribution: $722,620
Performer Contribution: $180,832 (20% of total)

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