Using 3D Vertical Seismic Profile to Monitor the CO₂ Plume in a CCUS/EOR Project

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Abstract
An extensive geophysical program was conducted in the in the Anadarko Basin in Ochiltree county, Texas, partnering with the Southwest Regional Partnership on Carbon Sequestration (SWP) and Chaparral Energy, LLC (CELLC). Implementation of a cost-effective approach includes a combination of 3D surface seismic, 3D vertical seismic-profiles (VSPs), as well as cross-well seismic surveying. The program’s aim is to utilize geophysical methods with varying imaging scales for site characterization and time-lapse monitoring of CO₂ plume movement.

Two baseline 3D VSP surveys for two wells were acquired simultaneously in 2014, and a third one in 2015. Two time-lapse surveys for one of the wells were acquired, January 2015 (~30,000 tons of CO₂ injected), and November 2016 (~60,000 tons CO₂ injected). Ray tracing based survey evaluation and design (SED) was performed to optimize acquisition parameters, reduce acquisition cost and minimize production downtime. Data from baseline and monitor surveys were processed simultaneously and time-lapse analyses were performed to identify potential 4D effect caused by the injection and presence of CO₂ in the reservoir.

Three time lapse analyses approaches were implemented, and are illustrated in this poster:
1. Amplitude analysis: Cross Correlations, Predictability and Normalized Root Mean Square (NRMS) attributes were generated
2. Displacement Field computation: Using Non Rigid Matching (NRM) to quantify depth shifts as an indicator of travel-time differences caused by fluid replacement within the injection zone
3. Z Tomography update: Use baseline velocity model as input for Z tomography update to quantify the difference in P velocity (delta Vp) as an indicator of fluid replacement

Survey Evaluation, Design, and Acquisition

Acquisition parameters were determined based on analysis of the results from the survey evaluation and design study. Optimal survey planning was determined based on existing infrastructure and accessibility within the survey area. To ensure repeatability and reduced uncertainty in analyses of time lapse attributes, baseline, monitor 1 and monitor 2 were simultaneously processed, using the same processing sequence. This approach reduced uncertainty in analyses of time lapse attributes.

Time-lapse Analysis

Several time-lapse attributes were generated to evaluate any time-lapse signature that might be caused the presence of injected CO₂ in Morrow B. Cross correlation, predictability and NRMS are qualitative attributes and are amplitude sensitive. Displacement field computed using non rigid matching (NRM) and Z tomography update (Delta V) are quantitative attributes and are velocity sensitive.

Data Processing

Baseline, monitor 1 and monitor 2 were simultaneously processed, using the same processing sequence. This approach reduced uncertainty in analyses of time lapse attributes.

Legend
Utiilization & Storage
Carbon Capture
Transportation
Oil Fields
Other CO₂ Sources
0.1 to 0.7 MT/yr
0.7 to 1.8 MT/yr
1.8 to 4 MT/yr
4 to 10 MT/yr
10 to 20 MT/yr