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[PS]Investigation of 4D Seismic Tuning and Spectral Responses to CO_2-EOR for Enhanced Characterization and Monitoring of a Thin Carbonate Reservoir*

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Abstract

Advancements, applications, and success of time-lapse (4D) seismic monitoring for carbonate reservoirs is limited by these systems' inherent heterogeneity and low compressibility. To contribute to the advancement of 4D seismic monitoring in carbonates, an investigation of seismic attributes across frequency sub-bands was conducted on a high-resolution 4D seismic data set acquired in fine temporal intervals between monitor (n=8) surveys from 2003-2006 in the Hall-Gurney Field, Kansas. The shallow (approximately 900 m) Lansing-Kansas City Plattsburg 'C Zone' target reservoir is an oomoldic limestone which fluctuates around thin-bed thickness in the study area. Tuning modeling of CO_2 fluid replacement reveals a complex phenomenon in this acoustically hard reservoir, with CO_2 driving amplitude dimming and brightening when reservoir thickness is above and below thin-bed thickness, respectively. Analysis of amplitude envelope data across frequency sub-bands via spectral decomposition identified geometric features of multiple LKC shoal bodies at the reservoir interval. In corroboration with prior geologic interpretation, shoal boundaries, zones of overlap between stacked shoals, thickness variation, and lateral changes in lithofacies were delineated in the baseline survey, which enhanced detail of these features' extent beyond capacity offered from well log data. Lineaments dominated by low-frequency anomalies within regions of adjacent shoals' boundaries suggest thicker zones of potential shoal overlap.

Analysis of frequency band-to-band analysis reveals relative reservoir thickness and property variation. Spectral decomposition of the amplitude envelope was analyzed between the baseline and monitor surveys to identify spectral and tuning changes to monitor CO_2 migration. Ambiguous tuning responses of amplitude dimming and brightening was observed between the baseline and monitor surveys in zones of known CO_2 fluid replacement. A series of lineaments highlighted by amplitude brightening from the baseline to monitor surveys is observed, which compete with a more spatially extensive effect of subtle amplitude dimming. These lineaments are suggestive of features below tuning thickness, such as stratigraphic structures of shoals, fractures, or thin shoal edges, which are highlighted by an increased apparent thickness and onset of tuning from CO_2.

Detailed analysis of these 4D seismic data across frequency sub-bands provide enhanced interpretation of shoal geometry, position, and overlap; identification of lateral changes in lithofacies suggestive of barriers and conduits; insight into relative thickness variation; and the ability of CO_2 tuning ambiguity to highlight zones below tuning thickness and improve reservoir characterization. These results suggest improved efficiency of CO_2-EOR reservoir surveillance in carbonates, with implications to ensure optimal field planning and flood performance for analogous targets.

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