Achieving Marine-Like Repeatability in a Complex Desert Environment: 4D Seismic Acquisition and Processing Lessons

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ABSTRACT

A highly repeatable time-lapse seismic acquisition system, capable of detecting small reservoir changes related to CO2 injection, has been successfully deployed in the challenging desert conditions encountered in Saudi Arabia. The complex and changing nature of the near surface in the region adversely affects both seismic imaging and data repeatability. Using a specialized acquisition system and dedicated processing workflow, 4D noise has been reduced to a level similar to that of 4D marine data with mean NRMS of 5-6% achieved between surveys separated by more than one year. A novel hybrid acquisition system consisting of surface vibroseis sources and buried receivers was adopted to provide the optimum image quality and repeatability. Permanent buried sensors, installed at a depth of 70-80 meters, are a critical component of the system that reduces recording of surface-related noise and non-repeatability due to changes in the shallow near surface. On the source side, the positioning error between surveys should be minimized to avoid different scattering of propagating energy. Using a differential GPS guidance system excellent positioning accuracy has been achieved, with a mean horizontal error of 0.35 meters when re-occupying positions from one survey to the next. Despite deep receiver burial, significant data processing is required to drive down remaining 4D noise in the data. Linear noise attenuation and supergrouping, where groups of neighboring shots are stacked to enhance signal-to-noise ratio, provide the largest improvement in data repeatability. Additionally, simultaneous multi-survey surface-consistent processing is applied to further reduce differences between surveys caused by near-surface changes. A significant increase in 4D noise has been observed when comparing surveys acquired in the wet and dry seasons, most likely caused by changes in near surface conditions and the source response. Implementing surface-consistent matching filters may help to reduce this seasonal imprint on the data repeatability. Considering the challenging conditions, outstanding data repeatability has been achieved. Comparing dry-to-dry season surveys, mean NRMS values of 5-6% have been achieved in the reservoir of interest. This level of repeatability allows us to see injected CO2 volumes of 1,400 MMScf or less for individual wells. Integration of the 4D interpretation with reservoir simulation and modeling are reported in a companion paper.