AAPG Datapages/Search and Discovery Article #90254 ©2016, GEO-2016, 12th Middle East Geosciences Conference & Exhibition, Manama, Bahrain, March 7-10, 2016

Enhancing Land 4D Seismic Using Early Arrival Repeatability of Buried Receiver Data

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ABSTRACT

Land 4D seismic represents a major challenge due to poor repeatability caused by near-surface variations, noise and source signature changes. As a result, it is essential that sources of non‑repeatability are minimized as far as possible, particularly in regions where 4D signal is expected to be weak. A previous study on buried receiver data from Saudi Arabia showed a clear correlation between 4D metrics estimated using pre-stack early arrivals and post stack images around the reservoir of interest. The next step was to use this information during 4D processing to enhance repeatability.

A simple multi-survey 4D binning scheme was designed using the normalized root-mean square (NRMS) of the nearest offset trace early arrivals. If the direct arrival is less repeatable it implies that the reservoir is illuminated by different wavefields, altering the target reflections. Subsequently, anomalous shots exceeding a threshold early arrival NRMS were excluded from the processing flow. The procedure was tested on 11 repeat surveys acquired over 19 months, using data collected by surface vibroseis sources and receivers buried 30 meters beneath the surface.

The study found that the proposed 4D binning method can improve both image quality and repeatability under certain conditions. Key to this was the shape of the early arrival NRMS distribution. When the distribution exhibited a large tail, removal of the outlier shots enhanced image repeatability. Vibrator issues and high ambient noise were the probable cause of non-repeatability. Data rejection from around the main lobe of the distribution was found to yield little improvement and quickly resulted in the loss of too many shots, degrading repeatability. The main lobe likely reflects changes in the near-surface, which will need to be dealt with using other processing techniques.

These findings emphasize the importance of real-time QC of the seismic data and vibrator performance. The early arrival NRMS may provide a simple measure of shot repeatability when the full acquisition commences, which can quickly identify problems that may adversely affect the stacked image and potentially mask 4D signal. As shown in this study, it can also be valuable during processing as a means of 4D binning.