Quantitative Use of 4-D Seismic to Monitor Saturation and Pressure Changes in a Producing Reservoir

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This paper examines the quantitative use of 4D seismic data to estimate the remaining oil saturation, and therefore oil volumes, by simultaneous inversion of base and monitor 4D seismic data for fluid saturation and reservoir pressure.

In order to invert for the measured 4D amplitude changes and time-shifts, the baseline seismic data and reservoir static model are first brought into close agreement through a “Close-the-Loop” seismic 3D inversion and reservoir model update effort. This effort reduces the residual mismatches attributable to a combination of seismic noise and unresolved model details. Then, synthetic seismic are generated from the baseline reservoir static model, which serves as the ‘synthetic base seismic data’. The measured 4D amplitude difference and time-shifts are applied to the synthetic base seismic data to generate a synthetic monitor seismic data. The ‘synthetic base and monitor seismic data’ are then used as inputs for seismic inversion. Synthetic seismic data conditioned with the measured 4D effects is used because residual mismatches between the static model and the real seismic (due to both lateral and vertical averaging of reservoir properties) can be of the same magnitude as the measured 4D amplitude and time shifts. Subtle changes in fluid saturation and reservoir pressures which results in changes in seismic signature, could then be masked or corrupted by these static model - real seismic mismatches. Since differences between the ‘synthetic base and monitor seismic data’ are due to only the actual 4D effects and not subtle static model mismatches, these effects can then be more accurately related directly to saturation and/or pressure changes within the reservoir.

The results from the 4D inversion are estimates of the fluid saturation and reservoir pressure resulting from the production and water injection during the production period. 4D inversion has been applied to a deepwater field to estimate the remaining oil volumes in the field; this is a critical step to quantitatively assess remaining reserves and identified by-passed opportunities which can be developed.