FAST MODELLING AND INVERSION OF TIME-LAPSE SEISMIC WAVEFORM DATA USING INTEGRAL EQUATION METHODS WITH RAY THEORY GREEN'S FUNCTIONS

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A procedure for seismic forward modelling based on a combination of integral equation methods with asymptotic ray theory is not only efficient but also quite flexible, because diffraction effects associated with laterally inhomogeneous structures can easily be included. Such a procedure is highly suitable for inversion if the well-known Lippmann-Schwinger (LS) equation (that relates perturbations in the waveforms to perturbations in the medium parameters) is linearized by using the Born approximation (Jakobsen et al., 2010). It may be still suitable for inversion if the LS is quasi-linearized by using a (frequency-dependent) localized nonlinear approximation. It allows for strong contrasts and is derived in this contribution using a T-matrix approach originally developed in quantum scattering theory. We show this by theoretical analysis and numerical experiments based on synthetic time-lapse seismic data. The synthetic data were generated using the above procedure for seismic forward modelling in conjunction with dynamic models of a laterally inhomogeneous reservoir under production, obtained using a combination of a numerical reservoir simulator with the well-known rock physics relations of Wood and Gassmann. The numerical results that we have obtained (so far by using the scalar wave equation) suggest that one can obtain good estimates of medium parameter perturbations (due to fluid movements) from time-lapse seismic data, even in the presence of relatively high noise. We expect that proposed method, and especially its planned generalization based on the elastodynamic equation, will be more robust than conventional 4D AVO analysis, because we make use of the full time-lapse seismic waveforms (associated with the scattered field in the LS equation), rather than just the amplitudes. We expect that some variant of the described waveform inversion method will find useful applications within seismic monitoring of petroleum reservoirs during production and CO_2 storage.

References

Jakobsen, M., Keers, H., Ruud, B.O., Pšenčík, I., and Shahraini, A., 2010. Inversion of time-lapse seismic waveform data using the ray-Born approximation in the frequency domain. Extended abstract, 72nd EAGE Conference and Exhibition, Barcelona.

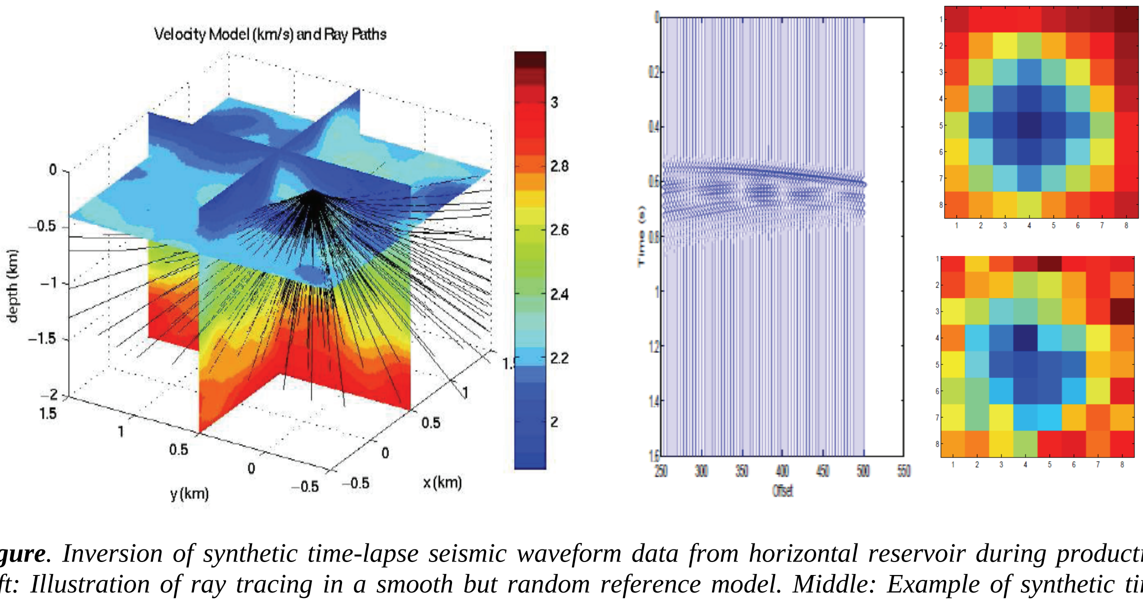

***Figure**. Inversion of synthetic time-lapse seismic waveform data from horizontal reservoir during production. Left: Illustration of ray tracing in a smooth but random reference model. Middle: Example of synthetic time-lapse seismic waveform data generated using the ray-Born approximation. Right: A comparison of the true (upper) and inverted (lower) slowness perturbations for the case of 25 percent random white noise. The initially oil-filled reservoir (seen from above) became laterally inhomogeneous when water was injected in the centre.*