Joint facies/elastic full waveform inversion of seismic data

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Seismic Amplitude-Variation-with-Offset (AVO) inversion for elastic parameters jointly with litho-fluid discrete variables from migrated seismic data is now an established technique. Compared to conventional techniques based on adding smooth background models to impedance inversions, it has several advantages, including the ability to honour well-log data distributions, and directly image target fluids. These methods rely on Kirchhoff-style migrated images being "true amplitude", and are vulnerable to the presence of non-primary seismic energy such as mode conversions or multiples. In any deconvolutional style inversion such wave energy adds to the noise rather than the signal. To address this, it is possible to do joint elastic/facies inversion from shot records, using a full-wave modelling operation in the likelihood of a hierarchical Bayesian inversion, with optimisation performed using the expectation-maximisation algorithm. Since all wave energy is modelled, such a technique should theoretically have a higher S/N ratio than its AVO equivalent.

To illustrate, Figure 1 shows an example based on a flat, slab-like middle-east field with high impedance contrast (≈ 1.8) sequences of anhydrite, salt and limestone reservoirs. The seismic acquisition comprises shots and receivers along the top of the model. Inset (a) shows a simple 2-facies model mimicking this scenario, with scaled-down velocities but matching reflectivity; in (b) the high elastic contrasts cause standard Kirchhoff imaging methods to have serious amplitude balance problems, plus a strong coda from multiples. Inset (c) shows that standard joint facies-acoustic AVO inversion from this image is heavily infected by these artefacts. Inset (d) shows that using full-wave modelling, joint inversion can undo the effects of the multiple cascade and produce a balanced image without phantom reservoirs.

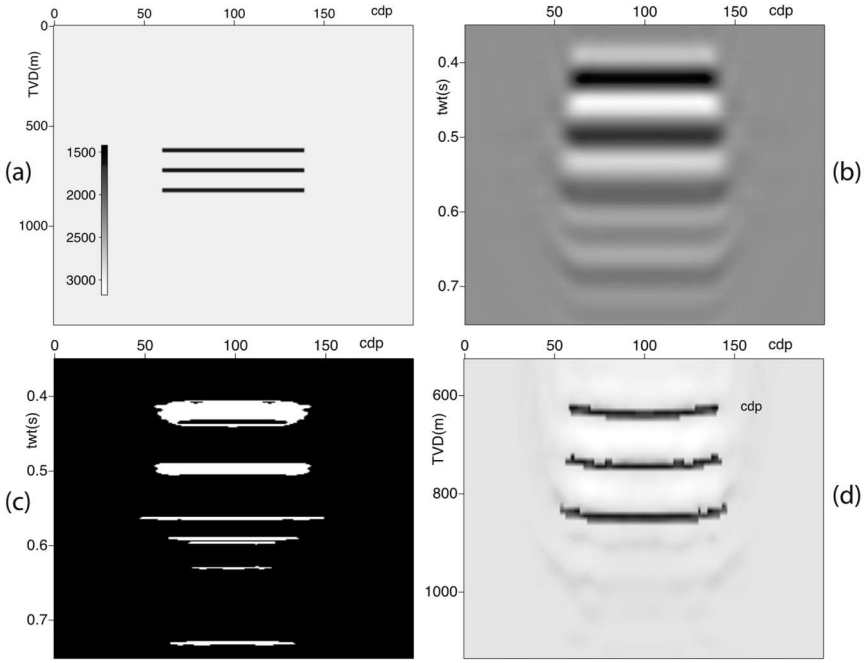

Figure 1. Example of joint facies-elastic imaging of high-contrast reservoirs. (a) true velocity model (b) Kirchkoff time-migrated image of bandlimited reflectivity (c) discrete {0,1} facies time image from AVO joint inversion, (d) velocity image from full-wave joint inversion; same scale as (a).

References

Gunning, J. 2019, Joint Facies/Elastic Inference in Waveform Inversion, in, Proc. EAGE Petroleum Geostatistics, Florence. https://onlinelibrary.wiley.com/doi/pdf/10.1111/1365-2478.12625.