Strategies to Include Geological Knowledge in Full Waveform Inversion

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Abstract

One of the important challenges in seismic inversion is to resolve finer structures from band-limited seismic data. Reservoir-oriented full-waveform inversion has the potential to deliver high-resolution quantitative images and is a promising technique to obtain macro-scale physical properties of the subsurface. Like for most geophysical application, prior information such as data collected in wells is available and should be used to improve the result. For this purpose we propose three new strategies for including geological prior knowledge in non-linear full-waveform inversion, which will ensure an even higher resolution in the final images. The non-linear inversion technique used in this article is an iterative process where linear inversions are alternated with updates of the total wavefield, ultimately leading to a full solution of the elastic wave equation.

The first scheme uses blocky models drawn from the prior distribution as an added constraint in the inversion. This can be seen as a geological constraint in the actual inversion process. Given the prior probabilities and covariances, this inversion gives high resolution property images. After constrained inversion, the non-blocky result is interpreted in terms of the prior model scenario.

This second scheme does not constrain the inversion but uses blocky models drawn from the prior distribution as a starting point for the inversion. After an unconstrained inversion, the non-blocky result is re-interpreted in terms of the prior model. This updated blocky model will be used as a starting model for the next iteration, this process is repeated after every iteration. This leads to a guided, nonlinear inversion process, where a geological scenario is proposed between two linear iteration steps.

The third scheme is a combination of these two schemes, where an internal geological constraint is added to non-linear inversion scheme and also a geological scenario is proposed after every iteration and used as a starting point for the next linear inversion. Given the prior probabilities and covariances, we are able to interpret the presence or absence of thin layers that otherwise could not be detected, using only bandlimited seismic data. These schemes are demonstrated on a high-resolution synthetic model based on the Book Cliff outcrop in Utah (USA).