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Consistent Downscaling of Seismic Inversions to Cornerpoint Flow Models

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Abstract

Reservoir simulation models are constructed from sparse well data, dense seismic data, and using geologic concepts to constrain stratigraphy and property variations. Because of the sparseness of well data, stochastically inverted seismic data offer important constraints on reservoir geometry and average properties. Although seismic data are densely distributed, they are uninformative about meter-scale features. Conversely, well data reveal fine-scale features but cannot specify intrawell geometry. To build a consistent model, conceptual stacking and facies models must be constrained by well and seismic data. Stochastic ensembles of geomodels are used to capture variability associated with seismic downscaling, lateral variability and conceptual models. The resulting geomodels must be gridded for flow simulation using methods that describe stratal architecture flexibly and efficiently.

In this paper, geomodels integrate stochastic seismic inversion results (for means and variances of “packages” of meter-scale beds), geologic modeling (for a framework and priors), rock physics (to relate seismic to flow properties), and geostatistics (for spatially correlated variability). These elements are combined in a Bayesian framework. The proposed workflow produces models with plausible bedding geometries, where each geomodel agrees with seismic data to the level consistent with the signal-to-noise ratio of the inversion. An ensemble of subseismic models estimates the means and variances of properties throughout the flow simulation grid.

Grid geometries with possible pinchouts can be simulated using auxiliary variables in a Markov Chain Monte Carlo (MCMC) method. Efficient implementations of this method require a posterior covariance matrix for layer thicknesses. Under assumptions that are not too restrictive, the inverse of the posterior covariance matrix can be approximated as a Toeplitz matrix, which makes the MCMC calculations efficient. The proposed method is validated and examined using two-layer examples. Convergence is demonstrated for a synthetic three-dimensional, 10,000 trace, 10 layer cornerpoint model. Performance is acceptable (305 s on a 2 GHz Pentium-M processor).

The Bayesian framework introduces plausible subseismic features into flow models, whilst avoiding overconstraining to seismic data, well data, or the conceptual geologic model. The methods outlined in this paper for honoring probabilistic constraints on total thickness are general, and need not be confined to thickness data obtained from seismic inversion: any spatially dense estimates of total thickness and its variance can be used, or the truncated geostatistical model could also be used without any dense constraints.

Intoduction

Problem Statement. Because reservoirs are sparsely sampled by well penetrations, seismic survey results provide essential controls for modeling. However, beds thinner than about 1/8 to 1/4 the dominant seismic wavelength cannot be resolved in these surveys.[1,2] For depths of ≈3000 m, the maximum frequency in the signal is typically about 40 Hz and for average velocities of ≈2,000 m/s this translates to best resolutions of about 10 m. Besides the limited resolution, seismic-derived depths and thicknesses are uncertain because of noise in the seismic data and uncertainty in the rock physics models.[3,4] This resolution limit and uncertainties associated with seismic depth and thickness estimates have commonly limited the use of seismic data to either inferring the external geometry or guiding modeling of plausible stratigraphic architectures of reservoirs.[5]

Our objective is to use probabilistic depth and thickness information from the layer–based seismic inversion code DELIVERY[3] as input to a downscaling algorithm operating on a cornerpoint grid that may be coarser than the geomodel. Seismic constraints and priors are modeled on the quasivertical block edges, analogous to seismic traces. Simulation at the edges preserves geometric detail in cornerpoint models.This problem fits inside a larger workflow, where this combination of the