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Reservoir facies modeling using stochastic inversion and probability perturbation method

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Extended Abstract

Summary

One of the basic steps in determination of the characteristics of a reservoir is modeling its various facies. In this paper, a geostatistical inversion method is presented for facies modeling using well logs and angle stack data. First, the conditional probability of occurrence of facies conditioned to well logs in each cell has been calculated using the sequential indicator simulation method. Then, petrophysical and elastic properties of reservoir facies have been obtained using the Gaussian sequential simulation method and rock physics relations. In order to generate and update the facies model consistent with seismic data, the probability perturbation optimization algorithm has been used. This method tries to create a model of facies and other properties of the reservoir that have a good consistency with seismic data by successively changing the facies probability conditioned to seismic data in each cell. To obtain the total probability distribution of facies occurrence from the probability of facies conditioned to seismic data and the probability of facies conditioned to well logs, Tau model has been used. At each stage, after obtaining different properties, a geophysical forward model is constructed and compared with seismic data. Finally, all these steps are used for different possible models obtained from the sequential indicator simulation method. This method is applied to synthetic data sets with different signal-to-noise ratios. In the case of seismic data with a signal-to-noise ratio of 9, a high-resolution model for the facies has been obtained that is 81.83% consistent with the reference facies model and has improved the initial facies model by 19.97%. In order to further investigate this method, it has also been applied to seismic data with the signal-to-noise ratios of 4 and 2. The results have shown that this method has a good ability to detect facies and other petrophysical and elastic properties of the layers in the reservoir.

Introduction

Reservoir modeling is the process of creating a three-dimensional numerical model to show the spatial distribution of geological or petrophysical properties of the reservoir. The process of obtaining elastic properties from seismic data is called seismic inversion. There are different methods for seismic inversion, which are classified into two main groups: deterministic methods and stochastic methods. Understanding the differences between these two methods and their restrictions is important for their correct application and interpretation. Due to the band-limited nature of the seismic data, the results of deterministic methods are smooth maps of acoustic impedance and may be far from the reservoir facts. In contrast, stochastic inversion produces high-resolution maps of the acoustic impedance because the spatial continuity models (variograms) control the frequency content of stochastic inversion results. A well-known challenge of stochastic inversion is that it is often extremely expensive from computational point of view. In this study, a stochastic method has been used to obtain the facies and other properties of the reservoir.

Methodology and Approaches

In this study, to show the ability of the introduced method in modeling reservoir facies, a two-dimensional artificial model has been used. The formation in the reference model of this study consists of sandstone facies with high porosity (reservoir interval) and dense shale facies (non-reservoir interval). The formation is located at a depth of 2000 to 2200 m. At the top and bottom of the formation, a 50-m layer of shale with constant properties is considered. In order to model the facies of the reservoir, variogram parameters for different facies have been calculated from the well logs of the reference model. In the next step, the conditional probability of occurrence of the facies in each cell has been calculated using the sequential indicator simulation method with different random seeds. Then, the probability perturbation optimization algorithm has been applied to update each facies model until the model become consistent with the seismic data. At each step, a geophysical forward model is constructed and compared with seismic data.

Results and Conclusions

After implementing the stochastic inversion method to the seismic data with a signal-to-noise ratio of 9 in the reference model, it was found that the optimized facies had an 81.83% correlation with the reference facies and was improved the initial facies model by 19.97%. The correlation values decreased to 77.67% and 72.38% when the seismic data with the signal-to-noise ratios of 4 and 2 were respectively used. When the seismic data with the signal-to-noise ratio of 4 was used, the initial model was improved by 15.81%, and when the seismic data with the signal-to-noise ratio of 2 was used, the correlation decreased to 10.52%.