Geologic Modeling and History Matching of Multi-Scale Flow Barriers in Deep-Water Reservoirs: Methodology and Field Application*

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Abstract

This work addresses the situation where multi-scale shale drapes are present along channel, channel belt and/or valley bounding surfaces, but the channel locations are uncertain or unknown. In order to reduce the uncertainty of shale drape location, first a realistic representation of the channel distribution must be obtained and constrained to hard data; then the channel and drape locations must be calibrated to the production data.

We propose a coupled geologic modeling and history matching method where the channelized reservoir architecture is simulated with a pre-defined stacking pattern using surface-based modeling techniques. Then the discontinuous shale drapes along multi-scale bounding surfaces are simulated using multiple-point statistical techniques. Channel geometry, location and the corresponding shale drape locations are gradually perturbed until the corresponding flow responses match the field production data. The perturbation during the history matching honors the individual channel geometry statistics and the interpreted channel stacking patterns, providing a geologically consistent perturbation.

A 3D geologic model based on a real turbidite reservoir in offshore West Africa is used to demonstrate this modeling and history matching approach. The multi-scale shale drapes along the bounding surfaces of channel, channel belt and canyon are simulated and
perturbed while the reservoir geologic concepts are preserved and the static data are honored. The final history-matched geologic models have better prediction capability than randomly selected geologic models.

References


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3.1 Proposed workflow: architecture modeling

- Identify key architecture elements (e.g., channels)
- Develop a stochastic model of architecture
- Use multi-point geostatistics for channel distribution

3.2 Proposed workflow: architecture perturbation

- Identify key perturbation parameters (e.g., migration ratio)
- Use optimization techniques to find optimal parameters
- Apply perturbations to architecture models

5. Proposed workflow: architecture perturbation

- History matching channel distribution to production data requires a perturbation method that maintains qualitative similarity (channel stacking patterns and geometrical characteristics)
- Employ a perturbation method that preserves the architecture model
- Use optimization techniques to find optimal perturbations

6. Proposed workflow: channel geometry perturbation

- Use a perturbation method that preserves the channel geometry
- Employ optimization techniques to find optimal perturbations

7. Proposed workflow: shale drapes perturbation

- Use a perturbation method that preserves the shale drapes
- Employ optimization techniques to find optimal perturbations

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<th>1. Introduction</th>
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<td>Deep water reservoirs, shale drapes may be distributed along the bases of channel belts</td>
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8.1 Application: reference model construction

- Realistic reservoir analog built after real offshore West Africa reservoir
- Valley belt-channel system
- High NTG (0.7-0.8) reservoir
- Channels/belts within valley and outside valley have different amount of shale drapes

8.2 Application: reference model construction

Multi-scale shale drapes

- Valley edges
- Belt edges
- Channel edges

8.3 Application: reference model construction

Geologic modeling parameters:

- Plan view: Amplitude 2.4 km
- Orientation: 30° (North)
- Wavelength: 2000 m
- Thickness: 1 m

Scour hole training image

Hole training image for valley proportion: 0.4
Hole training image for belt proportion: 0.25
Hole training image for channel proportion: 0.25

Well facies data and geologic regions

- Region 1 (purple-colored) has shale drape proportion 0.55/0.6/0.65 for valley/belt/channel
- Region 2 (gray colored) has shale drape proportion 0.8/0.8/0.8 for belt/channel

9. Application: region sensitivity study

- Drape proportion along channels is the most sensitive factor
- WCT and BHP are used to calculate objective function
- BHP can be used to assign producers to regions

10.1 Application: History matching

- History matching assuming one region
- History matching assuming two regions
- Water saturation distribution comparison

Summary

A methodology for modeling and history matching of multi-scale flow barriers in channelized reservoirs has been presented. With this methodology, reservoir models containing multi-scale facies architecture and associated flow barriers are constructed that match production data and consistent to geologic data such as well-log and conceptual channel stacking patterns.

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