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Preserving Uncertainty Across Disciplines: Rapid Identification of Fracture-scenarios Inconsistent with Production Data

A. Jung* (Stanford University, now Shell Global Solutions), D. Fenwick (Streamsim Technologies) & J. Caers (Stanford University)

SUMMARY

Fractures have crucial impact on the flow in reservoirs. In naturally fractured reservoirs the fracture network alone can be the dominant factor in fluid transport. Fractures as geological discontinuities introduce a high level of complexity into the entire reservoir modeling workflow. In current practice, the geological modeling of fractures and flow simulation are considerably disconnected. A lack of accurate geology in flow models results in low prediction power. Prediction of flow performance should ideally be based on realistic geology, and the associated uncertainties of conceptual models. However, in practice the range of uncertainty might be unrealistically reduced when handing over only a small number of models from the geologist to the engineer. While discrete fracture network models are considered to be a realistic reflection of the subsurface geology, the huge uncertainty in the input parameters requires a large number of models to be generated and flow simulated. We demonstrate a workflow to reduce complexity and rapidly identify geological fracture-scenarios which are inconsistent with actual production data, and inform the geologist of the probability of the remaining ones.

Introduction

The geological characterization of naturally fractured reservoirs can be subject to a significant degree of uncertainty, notably in multiple geological interpretations resulting in different fracture network models. Rapid, accurate quantification of the uncertainty in fractured reservoirs is crucial for making good decisions on potentially costly development or clean-up plans. While accuracy in modelling is desirable, in practice uncertainty modelling based on conventional flow simulators is considerably disconnected from the geological modelling of naturally fractured reservoirs. On the one hand, discrete fracture networks (DFN) are built by geologists to provide a geologically consistent way of modelling fractures in reservoirs. On the other hand, engineers run history matching and uncertainty quantification in conventional flow simulators following the dual-medium paradigm, because flow simulation of DFN models is currently infeasible at the field scale. Upscaling DFNs to such effective dual-media continuum models can be a difficult and time-consuming process. To provide a seamless integration of DFN and dual-medium models, we propose a geostatistical approach based on patterns that translates DFN models to dual-media descriptions efficiently and fast, while maintaining the important flow properties of the DFN models.

Methods

The first step of the workflow is the creation of multiple DFN models based on an experimental design to capture the conceptual and parametric uncertainties in the geological fracture descriptions. The DFN models are then upscaled to equivalent dual-medium models in the geo-cellular domain. The patterns of the dual-medium grid cells derived from each model are reduced to a manageable set of scenarios through pattern-analysis and clustering techniques. Subsequently this set of patterns delivers the training images for multiple-point statistics (MPS). The reduction of a large number of fracture scenarios to a manageable set of training images reduces redundancy while preserving the full extent of uncertainty present in the geological descriptions (Jung et al., 2013). Once the set of training images is obtained, they allow for fast generation of dual-porosity descriptions with MPS directly – while circumventing the time-consuming process of DFN modelling and upscaling (Figure 1). These training images can then be used to generate earth models of fractured reservoirs for uncertainty quantification and history matching. To identify scenarios – represented through training images – inconsistent with production data, we apply statistical techniques to estimate the posterior probability of each fracture scenario instantly. Fracture scenarios with low probabilities can be eliminated from history matching and prediction (Park et al., 2013). The likelihood of the remaining scenarios is updated according to Bayes' rule. Thereby we can demonstrate a rapid geomodelling and uncertainty workflow which we will illustrate on a synthetic model derived from a Middle Eastern fractured reservoir.

Conclusions

The demonstrated workflow can be readily implemented into reservoir modelling software to provide geo-modellers with an efficient tool for uncertainty quantification spanning across the disciplines.

References

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Figure 1 Pattern analysis and metric space modelling allow selecting a manageable and representative set of dual-medium patterns without running any flow simulation. The identified dual-medium patterns are used as training images to generate stochastic realizations with MPS.