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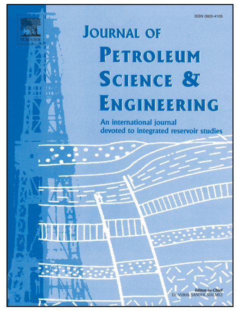

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Integration of Artificial Intelligence and Production Data Analysis for Shale Heterogeneity Characterization in Steam-Assisted Gravity-Drainage Reservoirs

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Abstract

Steam-Assisted Gravity Drainage (SAGD) recovery is strongly impacted by distributions of heterogeneous shale barriers, which impede the vertical growth and lateral spread of a steam chamber and potentially reduce oil production. Conventional reservoir heterogeneities characterization workflows that entail updating static reservoir models with dynamic flow data are quite time-consuming. Furthermore, certain assumptions are often needed to approximate the complex physical processes. This study proposes a workflow integrating artificial intelligence (AI) in a model selection framework that aims to identify associated shale heterogeneities in SAGD reservoir based on extracted features from production time-series data.

A series of SAGD models based on typical Athabasca oil reservoir properties and operating conditions is constructed. After constructing the base homogeneous model, the shale barriers are assigned randomly by sampling their location, lateral extent, and thickness from several probability distributions, which are inferred from field data assembled from the public domain. Sensitivity analysis is carried out to identify and analyze features in the production response that are related to shale characteristics: whenever the steam chamber encounters a shale barrier, a drop in the production is observed; this drop continues until the steam chamber has advanced past the shale barrier, and the production would rise again. Several types of input feature extraction methods are introduced in this work: piecewise linear approximation (PLA), cubic spline interpolation (CSI), and discrete wavelet transform (DWT). Next, artificial neural network (ANN) is constructed to calibrate a relationship between the retrieved production pattern parameters (inputs) and the corresponding geologic parameters describing shale heterogeneities (outputs), which include some variables capturing the location, orientation or size of a particular shale barrier encountered by the steam chamber. The final model is implemented in a novel characterization workflow to infer shale heterogeneities from production profiles. A number of realistic applications are presented to illustrate its utility.

The ANN models are validated using numerous synthetic models, where the exact shale distributions are known. The trained ANN models can reliably estimate the relevant shale parameters and the associated uncertainties, while accurately predicting the corresponding production responses. It is intended to extend the proposed method to construct the ANN models directly from well logs and production data.

This work presents a preliminary attempt in correlating stochastic shale parameters with observable features in production time-series data using AI techniques. The proposed method facilitates the selection of an ensemble of reservoir models that are consistent with the production history; these models can be subjected to further history-matching for a precise final match. The proposed methodology does not intend to replace traditional simulation and history-matching workflows, but it rather offers a complementary tool for extracting additional information from field data and incorporating AI-based models into practical reservoir modeling workflows.

1 Introduction

Steam-assisted gravity drainage (SAGD) is one of the proven thermal recovery techniques for bitumen production in Canada. Since its inception (Butler et al., 1981), the SAGD process has been widely employed for commercial heavy oil production. A pair of parallel horizontal wells, consisting of an injector and a producer that is located a few meters beneath the former, is placed near the bottom of the target formation. Steam with high temperature and pressure is injected continuously to form a steam chamber. As the temperature of the bitumen increases, its viscosity decreases. The heated crude oil would drain along the edge of the steam chamber to the producer due to gravitational force.

In a typical SAGD operation, the steam chamber would rise vertically and expand laterally away from the horizontal wellbore in a homogeneous reservoir. A primary challenge with SAGD process is that steam chamber development is highly sensitive to the underlying reservoir heterogeneities. Shale barriers with ultra-low permeability and high water saturation would often impede the steam chamber development, hindering proper