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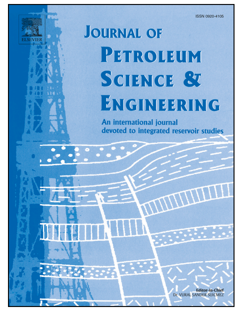

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Analyzing the Impact of Reaction Models on the Production of Hydrocarbons from Thermally Upgraded Oil Shales

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Abstract

Reaction parameters significantly affect oil production from shales by means of heating and in-situ upgrading. In this study, we perform numerical simulations of two chemical reaction models, which are mainly used in the research of kerogen pyrolysis and subsequent hydrocarbon decomposition in organic-rich porous media. They are the Braun and Burnham model and Wellington model. In these forward numerical simulations, we present the influence of the two reaction models on hydrocarbon production. The Braun and Burnham reaction model shows more vigorous kerogen and subsequent decomposition reactions and more hydrocarbon production than the Wellington model. A local sensitivity analysis identifies the reaction parameters with the highest influence on productivity, and the most sensitive outputs. A data-worth analysis identifies the most valuable observation data to be measured for the best prediction of total hydrocarbon production. We find that the most valuable observation data is the cumulative production of heavy oil in the Braun and Burnham model and of light oil in the Wellington model, respectively. Once we determine the maximum allowable prediction uncertainty and the expected measurement uncertainty, the observation data to be measured for the minimization of prediction uncertainty can be obtained.

Keywords: In-situ upgrading, Oil shale, Numerical simulation, Sensitivity analysis, Uncertainty prediction, Data-worth analysis

1. Introduction

Oil shale is a valuable source of fossil fuel with significant known resources of 8 trillion barrels in 27 countries worldwide (Ogunsola et al., 2010). Six trillion barrels of resources are concentrated in the US, and two trillion barrels among them are estimated to have a commercial value. However, hydrocarbon production of commercial scale from oil shale has not been accomplished because of the technical and economic challenges associated with the thermal upgrading process. The challenges are caused by diverse factors, including uncertainty of the reservoir properties and of the kinetic parameters of the reactions occurring during the thermal upgrading of oil shale.

Sensitivity analyses of system responses to the reservoir properties and the reaction parameters have been conducted in several previous studies. The sensitivity of hydrocarbon production to the initial fluid porosity, the initial content of organic matter, the spacing of the fracture network, and the initial saturation of the various fluid phases was quantified (Lee et al., 2016; Lee et al., 2017). In the study of parameter space reduction, a statistical methodology involving designed factorial experiments was developed to analyze the effects of the molecular weight of kerogen and of the activation energies of reactions, and to estimate the uncertainty of the hydrocarbon recovery (Bauman and Deo, 2010). In that study, the dynamic system changes were ignored, including the permeability evolution, the rock expansion, and the pore-plugging by solid cokes generated from the reactions of thermal upgrading. In the study of inverse modeling of reactivity using temperature transient data, the effects of reaction parameters and oil shale grade on the electrical heater temperature were quantified (Lee et al., 2018).

Uncertainty of reservoir properties is a persistent problem not only in oil shale reservoirs but also in many conventional and unconventional hydrocarbon