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A Comprehensive Simulation Model of Kerogen Pyrolysis for the In-situ Upgrading of Oil Shales

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Summary

Oil shale, which is composed of abundant organic matter called kerogen, is a vast energy source. Pyrolysis of kerogen in oil shales releases recoverable hydrocarbons. Here, we describe the pyrolysis of kerogen with an in-situ upgrading process, which is applicable to the majority of oil shales. The pyrolysis is represented by six kinetic reactions resulting in 10 components and four phases. Expanding the Texas A&M Flow and Transport Simulator (FTSim), which is a variant of the TOUGH+simulator (Moridis 2014), we develop a fully functional capability that describes kerogen pyrolysis and accompanying system changes.

The simulator describes the coupled process of mass transport and heat flow through porous and fractured media and includes physical and chemical phenomena of reservoir systems. The simulator involves a total of 15 thermophysical states and all transitions between them and computes a simultaneous solution of 11 mass- and energy-balance equations per element. The simulator solves the equations in a fully implicit manner by solving Jacobian matrix equations with the Newton-Raphson iteration method. To conduct a realistic simulation, we account for geological structure of oil-shale reservoirs and physical properties of bulk-oil shale rocks by considering phases and components in the pores. In addition, we involve interaction between fluids and porous media, diverse equations of state (EOSs) for computation of fluid properties, and numerical modeling of fractured media.

We intensively reproduce the field-production data of Shell In-situ Conversion Process (ICP) implemented in the Green River formation by conducting sensitivity analyses for the diverse reservoir parameters, such as initial effective porosity of the matrix, oil-shale grade, and the spacing of the natural-fracture network. We analyze the effect of each reservoir parameter on the hydrocarbon productivity and product selectivity. The simulator provides a powerful tool to quantitatively evaluate production behavior and dynamic-system changes during in-situ upgrading of oil shales and subsequent fluid production by thoroughly describing a reservoir model, phases and components, phase behavior, phase properties, and evolution of porosity and permeability.

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