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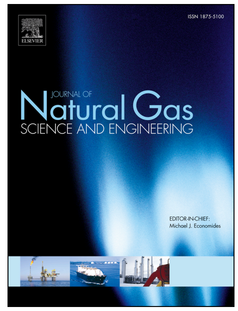

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Investigating the Effects of Gas Type and Operation Mode in Enhanced Gas Recovery in Unconventional Reservoirs

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Abstract

A model that combines the Dusty-Gas approach and Darcy's Law is used to investigate the dynamics of production enhancement by gas injection in unconventional reservoirs. A comparison between CH_4, N_2 and CO_2 injection in both Huff-n-Puff and Flooding operation modes is performed.

The mechanism of production enhancement for each gas is different. CO_2 can be injected to preferentially adsorb into the shale matrix, releasing hydrocarbons. In this case, the dominant mechanism is competitive adsorption. Due to stronger affinity with adsorption sites, CO_2 injection would suggest high cumulative production. In spite of that, frontal displacement is very slow in this case, resulting in poorer short-term production when compared to N_2 and CH_4.

N_2 injection induces the release of hydrocarbons solely by partial pressure reduction. Frontal velocities are fast, resulting in high short-term production. Yet, since N_2 is deemed inert, it does not replace components retained in the adsorbed phase.

CH_4 injection also prompts desorption of heavier hydrocarbons by partial pressure reduction. However, as heavier fractions are desorbed, CH_4 molecules occupy the vacant sites. In this case, combined mechanisms of partial pressure reduction and uptake by the adsorption sites results in efficient release of heavier hydrocarbons.

In this work, we demonstrate the impact of the presence of heavier hydrocarbon fractions in modeling gas transport during enhanced gas recovery processes. Multicomponent gas flow affects average reservoir pressure, produced gas composition and natural gas liquids (NGLs) yields, which is relevant for development of wet-gas and dry-gas unconventional reservoirs. Moreover, we demonstrate that injection gas composition significantly influences transport behavior of chemical species through the porous medium, and we highlight the relevant transport mechanisms during enhanced gas recovery in tight reservoirs.

Keywords: Shale Gas, Adsorption, Diffusion, Chromatographic Separation

Introduction

The potential of enhanced recovery by gas injection in shale plays has received increasing attention recently. Shale reservoirs containing heavier hydrocarbon fractions (wet-gas and liquid-rich reservoirs) are the potential candidates for enhanced recovery due to the higher added value of condensates, when compared to low price gas.

Conventional reservoir simulators have been used to evaluate enhanced recovery options in shale reservoirs (Eshkalak et al., 2014; Li et al., 2016; Zhang et al., 2016; Haghshenas et al., 2017; Phi and Schechter, 2017). Nevertheless, species transfer in porous media are characterized by complex transport mechanisms, and conventional simulators often neglect relevant physics that greatly influence displacement velocities and hydrocarbon production.

Some models have been developed to address the physics of species transfer in tight formations. Zhang et al. (2015), developed a multicomponent model including slip, transitional and free-molecular flow and multicomponent adsorption. They investigate the effect of non-Darcy flow, hydraulic fracture and initial gas composition; nonetheless, the important aspect of molecular diffusion is not taken into account. Rezaveisi et al. (2014) used an advective-diffusive flow model to evaluate chromatographic separation. They investigated effects of reservoir parameters such as absolute permeability, tortuosity and reservoir length on outlet gas composition, though adsorption and molecular diffusion were ignored.

When different chemical species are present, molecular diffusion effects are crucial in dictating produced hydrocarbons composition and natural gas liquids (NGL) yields. Usually, molecular diffusion is incorporated to reservoir models by using classical Fick's Law, Generalized Fick's Law or Maxwell-Stefan (MS) equations. Most commercial reservoir simulators use classical Fick's law; however, it has been discussed that this method is applicable under strict conditions that are not met in most reservoir applications. Krishna and Standart (1979) demonstrated that classical Fick's law for multi-component does not honor flux balance. It has also been verified that classical Fick's law fails to predict the direction of fluxes in cases involving ternary gas mixtures (Krishna, 1993), mixed ion systems (Vinograd and McBain, 1941), systems involving non-ideal liquid mixtures, multicomponent flows in microporous materials (Lauerer et al., 2015), and metal solutions. Other examples of the inadequacy of Fick's law can also be found in (Krishna, 2016a) and references therein.

Both Generalized Fick's Law and MS equations incorporate drag effects between molecules, being superior in capturing phenomena such as osmotic diffusion, uphill diffusion and diffusion barrier (Krishna, 1993; Hoteit, 2013). In this study, MS formulation is preferred. Unlike Generalized