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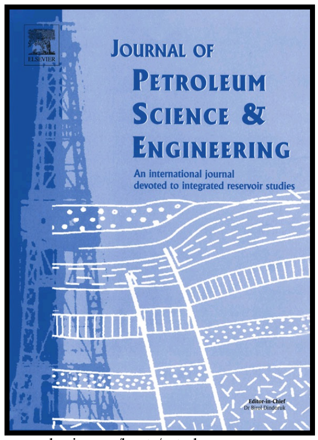

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Compositional Modeling of Fracture-to-Fracture Miscible Gas Injection in an Oil-Rich Shale

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Abstract
The ultra-low permeability of shale makes injection from a well to other wells difficult. A novel scheme was proposed in a recent patent (Dombrowski et al., 2015) where gas is injected into a hydraulic fracture along a horizontal well and production occurs from an adjacent fracture, intersecting the same well. Compositional reservoir modeling was performed to investigate the effectiveness of the proposed gas injection scheme. The computational domain consists of two hydrofrac half-stages along a horizontal well. The results show 15.7% and 12.5% OOIP incremental recovery over 5000 days of CO_2 injection for the base models with the matrix permeability of 10 μD and 1 μD, respectively, demonstrating that the gas injection scheme has the potential to vastly improve oil recovery in oil-rich shale formations. The effects of reservoir properties and injection conditions on oil recovery were investigated by changing the injection pressure, reservoir heterogeneity, distribution of natural fractures, hydrofrac spacing, size of pore space, and compositions of the injection gas. Most of them affect the oil recovery significantly. Recovery by miscible hydrocarbon gas injection is comparable to CO_2; so it should be considered as an alternative.

Keyword
unconventional resources, compositional simulations, hydraulic fractures, natural fractures, shale oil, miscible gas injection, phase behavior

1. Introduction
Advancement of horizontal drilling and multistage hydraulic fracturing has made oil recovery from shale formations technically and economically viable in the last decade. As a result, shale oil is considered as an alternative to conventional crude oil resources, which is likely to peak in the next 2-3 decades (Brandt et al., 2013). Estimated global shale resources is around 340 billion bbl of technically recoverable oil, which represents 10% of all types of oil reserves (EIA, 2014). In the U.S., the estimated reserve is nearly 60 billion bbl, and the production of shale oil makes up approximately 30% of total domestic crude production (EIA, 2014).

However, the recovery factor in shale oil remains very low. A typical example is production in the Bakken three-member formation that underlies Williston Basin and overlaps with parts of North Dakota, Montana, Manitoba and Saskatchewan in the subsurface. The formation has a porosity of about 5% and permeability of 0.0001-0.04 mD (Pitman et al., 2001). The estimated oil resource is 300 billion barrels (Flannery and Kraus, 2006), but the technically recoverable oil, as reported by the U.S. Geological Survey (Gaswirth et al., 2013), is only about 7 billion barrels. It includes the Bakken Formation in the U.S. region and the Three Forks Formation underneath. Daily production for a new well can reach close to 1,000 barrels, but decline in half in the first year (North Dakota Department of Mineral Resoursecs, 2012), which is a typical phenomenon of shale reservoirs due to their low permeability.

The vast amount of unrecoverable shale oil suggests a large potential for improved recovery methods. Even a small percentage of improvement in the field is equivalent to billions of barrels of oil.