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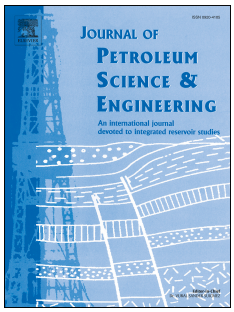

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Experimental Study of the Effect of Core Aging on Fluid Distribution in Middle Bakken Cores

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Abstract

Formation wettability is a critical parameter when designing enhanced oil recovery (EOR) for field applications both in conventional and unconventional reservoirs. In this study, we focused on one unconventional resource only—the Bakken. Specifically, we conducted laboratory experiments in five as-received Middle Bakken cores having different initial fluid saturations to determine (1) where the fluids reside within the pores, and (2) the effect of aging on wettability change.

The experimental protocol included hydrocarbon-saturation of three as-received cores with Bakken oil. The cores were aged at 180°F and 2,500 psi pressure for four weeks, and stored in crude oil for one year at ambient laboratory conditions (about 14 psi and 66°F). Next, synthetic brine was used to produce oil from the aged cores by spontaneous imbibition in Amott cell. Additional oil was produced from the cores using a high-speed centrifuge.

For the remaining two as-received cores, synthetic brine was used to saturate them, and brine was replaced with oil using a centrifuge. The cores were stored in crude oil at ambient laboratory conditions for four months; then, oil recovery from the cores was measured in Amott cell. NMR measurements were conducted on the cores after each fluid saturation/desaturation experiment to determine the effect of aging time and temperature on the core wettability and fluid distribution in the pores. Porosity and permeability of as-received cores as well as cleaned twin cores were measured at several net confining stresses.

The experimental results indicated that hydrocarbon-saturated cores become slightly more oil-wet than brine-saturated cores. NMR measurements indicated that brine resides in smaller pores and as a brine film on grains regardless of aging time, and the core fluids redistributed with time indicating a strong rock-fluid interaction. Finally, the analysis of oil production indicated the preponderance of chemical osmosis over imbibition as the mechanism of oil displacement.

Keywords: Wettability, Chemical osmosis, Capillary pressure, Centrifuge, Nuclear Magnetic Resonance, Pore size distribution

1. Introduction

Bakken Formation is located in the Williston Basin which extends in North Dakota, South Dakota, Montana, and Canada. The Formation is one of tight unconventional liquid-rich hydrocarbon resources in the United States that plays a major role in domestic oil production (Fig. 1). The original oil in place of 7.4 billion barrels and original gas in place of 6.7 trillion cubic feet (associated/dissolved gas), and 0.53 billion barrels of natural gas liquids were estimated by the United States Geological Survey (USGS 2013) for the Bakken Petroleum System (BPS). The BPS includes Lower Lodgepole, Bakken, and Upper Three Forks Formations. Bakken Formation consists of three members: Upper Bakken Shale member (source); Middle Bakken member (reservoir); and Lower Bakken Shale member (source) (Sonnenberg, 2014). The Middle Bakken lithology consists of sandstone, siltstone, dolomite, and mudstone with low porosity (<10%) and low permeability (<0.01 mD). The Middle Bakken member is the subject of this study.

Hydrocarbon production from unconventional resources became economical by drilling horizontal wells and implementing multi-stage hydraulic fracturing. Production from Bakken region reached 1.2 million barrels per day around middle of 2014. However, low oil price and dramatic decrease in rig count and activities in Bakken, caused reduction in oil production. Current oil production from Bakken is less than one million barrels per day (EIA, 2016).