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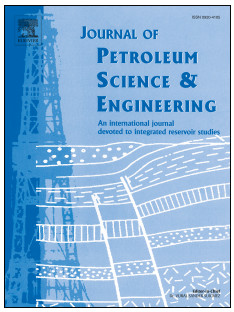

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Low Salinity Waterflooding for a Carbonate Reservoir: Experimental Evaluation and Numerical Interpretation

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Abstract

Several laboratory studies and some field trials have already demonstrated the potential of lowering the injected brine salinity and/or manipulating composition to improve oil recovery in carbonate reservoirs. Laboratory SCAL tests such as coreflooding and imbibition are key steps to screen low salinity waterflood (LSF) for a particular field to (i) ensure that there is LSF response in the studied rock/oil/brine system, (ii) find the optimal brine salinity, (iii) extract relative permeability curves to be used in the reservoir simulation model and quantify the benefit of LSF and (iv) examine the compatibility of injected brine with formation brine and rock to de-risk any potential scaling or formation damage caused by fines mobilization.

This paper presents an extensive LSF SCAL study for a carbonate reservoir and the numerical interpretation of the tests. The SCAL experiments were performed at reservoir conditions using reservoir core plugs, dead crude oil and synthetic brines. The rock was characterized using porosity-permeability measurement semi-quantitative X-ray diffraction (XRD), scanning electron microscopy (SEM), and mercury intrusion capillary pressure (MICP) techniques. The characterization work showed that the plugs can be classified into two groups (uni-modal and bi-modal) based on pore throat size distribution which correlated with porosity-permeability cross-plots.

The SCAL experiments were divided in two categories. Firstly, spontaneous imbibition and qualitative unsteady-state (USS) experiments were performed to demonstrate the effect of low salinity brines. In addition, these experiments helped to screen different brines (seawater and different dilutions of seawater) in order to choose the one that showed the most promising effect. Secondly, quantitative unsteady-state (USS) experiments were conducted and interpreted using numerical simulation to extract relative permeability curves for high salinity and low salinity brines by history-matching production and pressure data.

The main conclusions of the study are: 1- The spontaneous imbibition and qualitative USS experiments showed extra oil production when switching from formation brine to seawater or diluted seawater subsequently, 2- Oil recovery by LSF can be maximized by injection of brine at a certain salinity threshold, at which lowering the brines salinity further did not lead to additional recovery improvement,