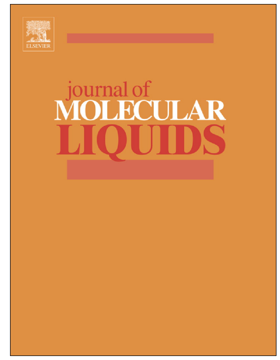
Accepted Manuscript



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PII:	S0167-7322(17)35036-5
DOI:	doi:10.1016/j.molliq.2017.11.170
Reference:	MOLLIQ 8286
To appear in:	*Journal of Molecular Liquids*
Received date:	22 October 2017
Revised date:	25 November 2017
Accepted date:	28 November 2017

Please cite this article as: Ehsan Pooryousefy, Quan Xie, Yongqiang Chen, Ahmad Sari, Ali Saeedi , Drivers of low salinity effect in sandstone reservoirs. The address for the corresponding author was captured as affiliation for all authors. Please check if appropriate. Molliq(2017), doi:10.1016/j.molliq.2017.11.170

Drivers of low Salinity Effect in Sandstone Reservoirs

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Abstract

Wettability of oil/brine/rock system is a fundamental petro-physical parameter, governing the subsurface multiphase flow behaviour, thus affecting hydrocarbon recovery. However, understanding the controlling factor(s) which drives the process is incomplete. Therefore, a detailed examination and characterization of reservoir surface forces as well as pore-surface chemistry are of vital importance. We combined contact angle, zeta potential and surface complexation modelling to demonstrate that DLVO theory and surface complexation modelling predict the same wettability trends. Moreover, we introduced Z* parameter ($Z^* = |Z_{oil/brine} + Z_{brine/rock}|$) to manage low salinity water flooding, thus mitigate the uncertainty of low salinity effect.

Keywords: Low salinity water flooding, Wettability, Contact angle, Zeta potential, Surface complexation modelling

Introduction

Wettability of oil/brine/rock system governs subsurface multiphase flow behaviour and saturation distribution of the fluids, thus affecting oil recovery from hydrocarbon reservoirs[1, 2]. Water-flooding technique has been widely used to maintain reservoir pressure, thereby improving oil recovery[3]. Recent studies [4-6] proposed a novel means to enhance oil recovery by manipulating the composition of injected water chemistries, in a process called *LoSal* flooding by BP [7, 8], *Smart Water* flooding by its originators, Austad and co-workers at the University of Stavanger, Saudi Aramco,[9] and *Designer Water flooding* by Shell[10, 11].

Several mechanisms was proposed to decipher what factors control the low salinity effect: fines mobilization,[12] limited release of mixed-wet particles,[12] increased pH and reduced IFT similar to the alkaline flooding,[13] multi-component ion exchange (MIE) ,[8, 14-16] expansion of the electrical double layer,[17] salt-in effect,[18] salting-out effect[19] and osmotic pressure [20].

However, the main mechanism behind low salinity water flooding is thought to be wettability alteration [21, 22]. Yet, knowing what specific factors govern the reservoir wettability in the presence of crude oil and formation brine has long been a goal of reservoir engineers. To understand the factors controlling the interplay between fluid-fluid and fluid-rock interfaces, atomic force microscopy (AFM)[23, 24] and quartz crystal microbalance with dissipation (QCM-D)[25] were used to investigate the effect of water chemistry on adhesion force at nano-scale. In addition, surface complexation modelling (SCM) was also applied to understand the wettability of reservoir rocks to relate the surface chemistry to measured zeta potential [26, 27]. However, the factors controlling the wettability in oil/brine/rock system is yet to be clearly explained, thus limiting the implementation of low salinity water flooding in oil fields. For instance, while most reports suggest that the presence of divalent cations, clays, and acidic compounds from crude oils, are of vital importance to yield wettability transition towards more water-wet [8, 16], Hassenkam et al. [28] found the opposite, arguing that a reduction in adhesion force of the oil/brine/rock system can be