Modelling of Salt Solubilities for Smart Water flooding in Carbonate Reservoirs using Extended UNIQUAC Model - DTU Orbit (31/12/2018)

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For most oil reservoirs which were drilled with conventional methods, the expected initial recovery of available hydrocarbons may be as low as 15% – thus leaving 85% of hydrocarbons in the reservoir. Implementation of mechanical methods including pump jacks and initial gas injection or thermal recovery can increase that capture up to 25-30% of original oil in place (OOIP). But cost effective Enhanced Oil Recovery (EOR) techniques if implemented correctly can be used to produce another 10-15% of the initially available hydrocarbons.

Advanced water flooding (i.e. altering injection brine compositions by varying concentration of selected ions) is an enhanced oil recovery method which in a low cost, non-toxic manner increases oil recovery from various carbonate reservoirs. Dan and Halfdan are chalk reservoirs from the Danish North Sea, which are matured oil fields that have been flooded with water for more than a decade and are potential candidates for brine composition based EOR. Advanced water flooding through alteration in brine composition has been termed as Smart Water (SmW) Flooding, Designed Water flooding, Low salinity brine injection, LowSal™ EOR, and Advanced Water flooding in different research studies. Several spontaneous imbibition and water flooding experiments have been conducted in order to understand the fundamental mechanism behind the observed increase in oil recovery for variation in injection of brine composition. When reported in literature, this observed increase in oil recovery has been explained using the wettability alteration mechanism.

The wettability alteration mechanism reported in literature can be divided into two parts:

1. Substitution of calcium by magnesium: When Mg containing brine is injected into a core plug, the existing Ca²⁺ from the mineral surface/lattice is gradually replaced by the injected Mg²⁺. Decrease in magnesium concentration in the effluent and the corresponding increase in calcium concentration further support this phenomenon.

2. Adsorption of SO₄²⁻ ions: When SO₄²⁻ ions are injected into the core plugs along with Ca²⁺ and/or Mg²⁺ ions, then SO₄²⁻ ions get adsorbed on the mineral surface. This leads to desorption of carboxyl ions from the mineral surface and makes the oil more mobile. Thus, eventually leading to an increase in oil recovery. According to the wettability alteration mechanism, an increase in oil recovery therefore takes place when brines with high concentrations of Ca²⁺, Mg²⁺, and SO₄²⁻ ions are injected. It has been further recommended that precipitation of ions must be avoided as precipitation can choke the pore throats and thus have an adverse effect on the sweep efficiency of the flooded water. Several questions have been raised to the wettability alteration mechanism due to fundamental contradictions with experiments. It has been observed that Stevns Klint chalk from Denmark shows consistent increase in oil recovery for an increase in injection brine SO₄²⁻ concentration. But similar increases in oil recovery are not observed for Niobrara or Rørdal outcrop chalk core plugs.

Observed increases in oil recovery for completely water wet core plugs are also contradictory to the proposed wettability alteration mechanism. No increase in oil recovery observed when injecting brines with high concentrations of SO₄²⁻ ions is also contradictory to the proposed wettability alteration mechanism. Therefore, understanding the fundamental mechanism behind SmW-EOR is quite important. In this study it is attempted to conduct geochemical modeling of salt solubility at reservoir conditions to explore the possible correlation between different brine properties and the corresponding increase in oil recovery (as reported in literature).

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