Modified Salinity Waterflooding of the Lansing Kansas City Formation-
Relationship between SCAL Properties and Water Composition

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SUBSURFACE APPLICATION: Lansing Kansas City limestone intervals, Oread,
Foraker
STATUS: Long-term project in progress
TIMING: To be completed in the future if funded
FUNDING: Kansas Interdisciplinary Carbonate Consortium

Purpose
- To study the incremental oil recovery caused by modification of injected water for the
  Lansing-Kansas City (LKC) limestone intervals.
- To study the effect of salinity modification on relative permeability and capillary
  pressure curves.
- To study the effect of salinity modification on interfacial properties between oil and
  water for LKC.
- To study the ion exchange mechanism with salinity modification between rock and
  oil-water system.

Project Description
Effect of water salinity reduction and modification on the production of oil from
sandstone and carbonate rocks due to waterflooding is well understood. Incremental oil
recoveries of 2-10% have been reported due to modification of injected water
composition (Strand et al. 2008; Ligthelm et al. 2009; Romanuka et al. 2012). Despite all
the existing controversy regarding the modified salinity water-flooding mechanisms,
effect of such mechanism (s) on relative permeability and capillary pressure curves has
been postulated and used during the simulation of low- or modified-salinity
waterflooding processes. Even though modifying the relative permeability and capillary
pressure in order to match the displacement results (Romanuka et al. 2012) has been used
often, a complete study of the effect of low salinity and modified salinity water-floods on
carbonate rocks is necessary.

LKC reservoirs have been exposed to water-flooding for many years (Allison, 1959).
LKC has contributed significantly to the 47% oil production of the State of Kansas that
comes from Pennsylvanian formations (Evans and Newell, 2013). Incremental oil
production due to modification of injected brine will potentially bring an economically
viable option to increase the income for producers in the State of Kansas.

Three sets of LKC core plugs will be cleaned using a Dean-Stark apparatus and then
saturated with synthetic LKC brine. Primary drainage will be conducted next to establish
initial water and oil saturations. Core plugs will be aged in LKC crude oil to simulate the
initial reservoir conditions. The following experiments will be conducted.
- The first set of core plugs will be used for spontaneous imbibition tests using brines
  with different salinity and brine compositions to study the wettability state of the
cores.
• The second set of core plugs will be used to conduct oil/water relative permeability measurements using brines of different composition. Effect of brine composition on relative permeability curves will be studied.

• The third set of core plugs will be used to measure capillary pressure curves using brines with different composition.

• Core plugs flooded using brine with similar composition at the reservoir brine and at their residual oil saturation will be used to study modified salinity waterflooding as an improved oil recovery method.

• A simulation study of the lab experiments will be conducted next to extract properties for the field scale modified waterflooding simulation for LKC reservoirs.

• To investigate the effect of salinity modification on interfacial properties between oil and water for LKC, high temperature and high pressure IFT and contact angle measurements will be conducted by Pendant Drop Method. The interfacial properties will be correlated to oil-water and oil-water-rock interface properties.

• To study the effect of salinity modification on ion exchange between rock and oil-water system, the base ion exchange test will be conducted. Cores which will be saturated in synthetic brine which is analogue to LKC formation will be flooded with various salinity and composition of brines. The brine effluents will be analyzed by Inductively Couple Plasma (ICP).

• An inverted 5-spot pattern will be selected in a LKC reservoir in order to conduct a pilot test of low salinity waterflood and analyze the production and injection data.

Deliverables
This project will deliver a designed recipe for water composition in order to increase oil production during waterflooding of LKC reservoirs. Moreover, a correlation will be sought between wettability, relative permeability and capillary pressure for different water salinity and compositions.

References
ALLISON, R.S., 1959, Case History - A Lansing-Kansas City Waterflood, Kansas Waterflood Symposium of the Society of Petroleum Engineers of AIME, 19 November, Great Bend, Kansas.


Experimental Investigation, Computer Simulation, and Field Application of CO₂ Huff-n-Puff in Unconventional Tight Carbonate Reservoirs

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SUBSURFACE APPLICATION: Mississippian limestone, Bakken, Austin Chalk, Niobrara
STATUS: Project Proposed
TIMING: To be completed in the future if funded
FUNDING: Seeking funding

Purpose
The focus of this project will be on an experimental study of miscible and near miscible continuously injected CO₂ at reservoir pressure and temperature, and huff-n-puff CO₂ injection tests in unconventional (tight) carbonate reservoir rock. The main objective of this project is to compare the results of different experimental setups and injection modes. These will be used to match the experimental results and numerical simulation models of core-flooding experiments in order to provide recommendations for approaches for enhancing recovery in unconventional formations.

Project Description
Unconventional oil basins in the United States store several hundred billion barrels of crude oil. New technologies in horizontal drilling and stimulation have assisted commercial production from unconventional oil reservoirs, but with a limited primary recovery factor of only 5-10% due to the ultra-low matrix permeability. Moreover, fast decline in production rates have been observed for most unconventional plays, especially those with ductile properties and with no natural fractures. The extra low permeability of reservoir, high capillary forces, as well as possibility of clay swelling imposes risks to water flooding of these oil-bearing plays. An alternative to water flooding is necessary.

Gas injection is a feasible method to improve recovery in oil reservoirs as it has favorable injectivity, due to the low viscosity of gas and minimal formation damage. Among all gases, CO₂ is preferred compared to other gases because of its relatively high viscosity, high density and low miscibility pressure (assuming asphaltene deposition is not a serious problem). The best choice for injection/production pattern posed the greatest challenge, however, mainly because in each well the fluid flow is restricted within the stimulated reservoir volume (SRV).

There is a growing body of evidence that suggests there is great potential for application of CO₂ to extract more oil shale reservoirs. With the relatively low primary recovery factor in unconventional reservoirs, small improvements in recovery could yield millions of barrels of incremental oil, securing long-term productivity of wells. With the great extent expected for heterogeneities in unconventional shale oil reservoirs, complexity of any development plan is likely. Improved production from these tight formations will mostly rely upon development of an efficient technique.