The Economics of Wettability Alteration for Renewed Production from Old Fields in the Permian Basin: Evaluations of Spraberry, Avalon and Bone Springs Reservoirs*

Geoffrey Thyne[1], Sharon Yacob[2], and Teresa Nealon[3]

Search and Discovery Article #41379 (2014)**
Posted June 30, 2014

*Adapted from oral presentation given at AAPG 2014 Southwest Section Annual Convention, Midland, Texas, May 11-14, 2014

[1]ESAL LLC, Laramie, WY (geoffthyne@gmail.com)
[2]ESAL LLC, Midland, TX
[3]University of Wyoming, Laramie, WY

Abstract

Changing reservoir wettability by changing injected water chemistry has been the subject of intensive research for the last fifteen years. The promise of taking old fields and recovering additional oil during normal waterflood operations is always attractive. However, while many hypotheses have been advanced to account for the observations, the lack of confidence in predicting response has limited application of this technique. This paper presents a review of field and lab performance focused on establishing reasonable empirical bounds for the factors leading to increased production. Using this basis, we developed a quantitative screening tool to identify fields with high probabilities for favorable outcomes. Representative screened fields were used to perform economic evaluations to assess potential profitability.

We screened a range of sandstone and carbonate fields in the Spraberry, Avalon and Bone Springs using public-domain data. More than 60% of fields passed the criteria. Those fields were then evaluated to determine the potential costs and benefits using an analog model based on the Kinder Morgan CO_2 economic scoping tool with suitable modifications. We can account for taxes, royalties, etc, and assume a worst-case operational cost model, that all the produced water is treated before re-injection. We did not include peripheral benefits such as lower maintenance costs, reduced scaling and souring and improvement in injectivity making the calculations even more conservative in nature.

Assuming incremental recoveries similar to known field cases (5 to 15% OOIP, the relatively low CAPEX and OPEX compared to other surfactant flooding mean that many fields will be profitable. We varied water treatment costs, oil prices and recovery factors to evaluate the likely economic return only smaller fields are marginal. The major sensitivities are the amount of remaining oil and the rate of water injection. In cases where water treatment is required, costs are modest assuming reverse osmosis technology. Other cases where target injection chemistry can be achieved by blending produced water with other resources are even more profitable. While some assumptions used in this evaluation may need to be refined as we become more knowledgeable, the basic idea, that waterflooding to alter reservoir wettability will be profitable seems well justified from technical and economic perspectives.

Selected References

Lebedeva, E., and A. Fogden, 2011, Wettability alteration of kaolinite exposed to crude oil in salt solutions', Colloids and Surfaces A: Physicochemical and Engineering Aspects, v. 377/1-3, p. 115-122.

Mwangi, P., G. Thyne, and D. Rao, 2013, Extensive Experimental Wettability Study in Sandstone and Carbonate-Oil-Brine Systems: Part 1 – Screening Tool Development: International Symposium of the Society of Core Analysts held in Napa Valley, California, USA, 16-19 September 2013. Web Accessed June 26, 2014. http://www.scaweb.org/assets/papers/2013_papers/SCA2013-084.pdf.

Nelson, Philip H., 2009, Pore-throat sizes in sandstones, tight sandstones, and shales: AAPG Bulletin, v. 93/3, p. 329-340.

The economics of wettability alteration for renewed production from old fields in the Permian basin: Evaluations of Spraberry and Bone Springs reservoirs.

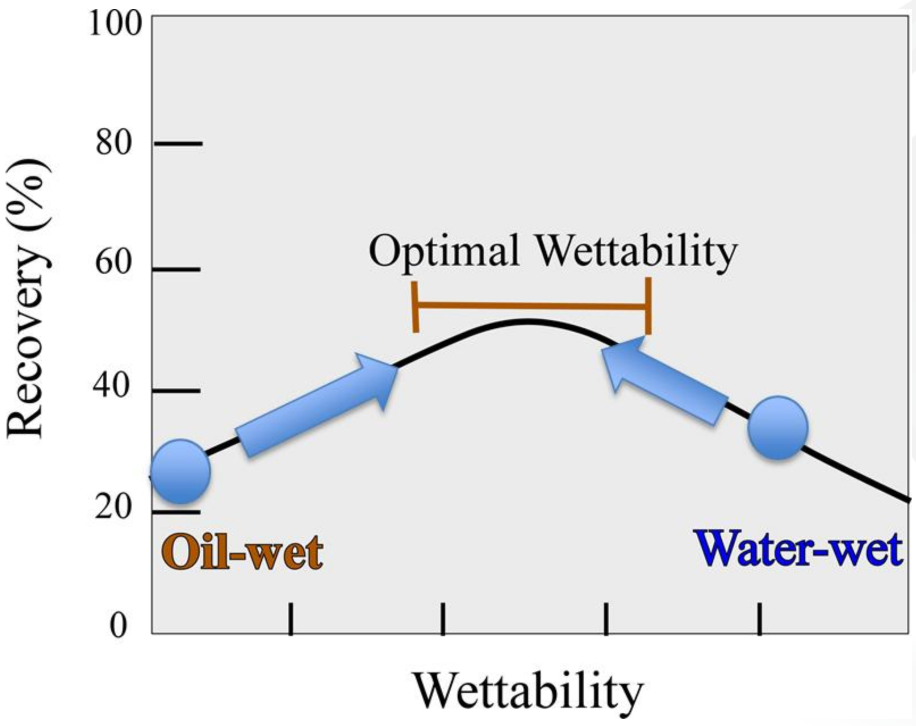
Geoffrey Thyne[1], Sharon Yacob[2] and Teresa Nealon[3]

1 –Esal – Laramie, WY
2 – Esal – Midland, TX
3 – University of Wyoming

ESal Engineered Salinity

Conclusion

- Reservoir wettability is the equilibrium between rock, water and oil.
- Wettability is a function of salinity.
- We can optimize reservoir wettability by changing salinity.



Who is using this technique?

Successes

BP - North Slope –flooding shallow SS field (15% OOIP).

Conoco-Phillips - North Sea –flooding deep chalk field (30% OOIP).

Shell - Syria –flooded SS field (10-15% OOIP).

Pioneer - Spraberry SS (lab) – 10% OOIP

Failures

Independents - Wyoming –Minnelusa SS – no increase in recovery.

Stat Oil - North Sea –Stratfjord SS - minimal response (<2% OOIP).

ESal Engineered Salinity

Presentation Structure

- Science
  - Wettability Alteration
- Applications
  - Screening Candidates
- Conclusions

ESal
Engineered Salinity

Wettability

- the quality or state of being wettable : the degree to which something can be wet
  - Merriam-Webster Dictionary
- Wettability or wetting is the actual process when a liquid spreads on a solid substrate or material.
  - Biolin Scentific
- Wettability describes the preference of a solid to be in contact with one fluid rather than another based on the balance of surface and interfacial forces.
  - Aldallah et al. 2007
- A type of damage in which the formation wettability is modified, generating a change in relative permeability that eventually affects well productivity.
  - Schlumberger Oilfield Glossary

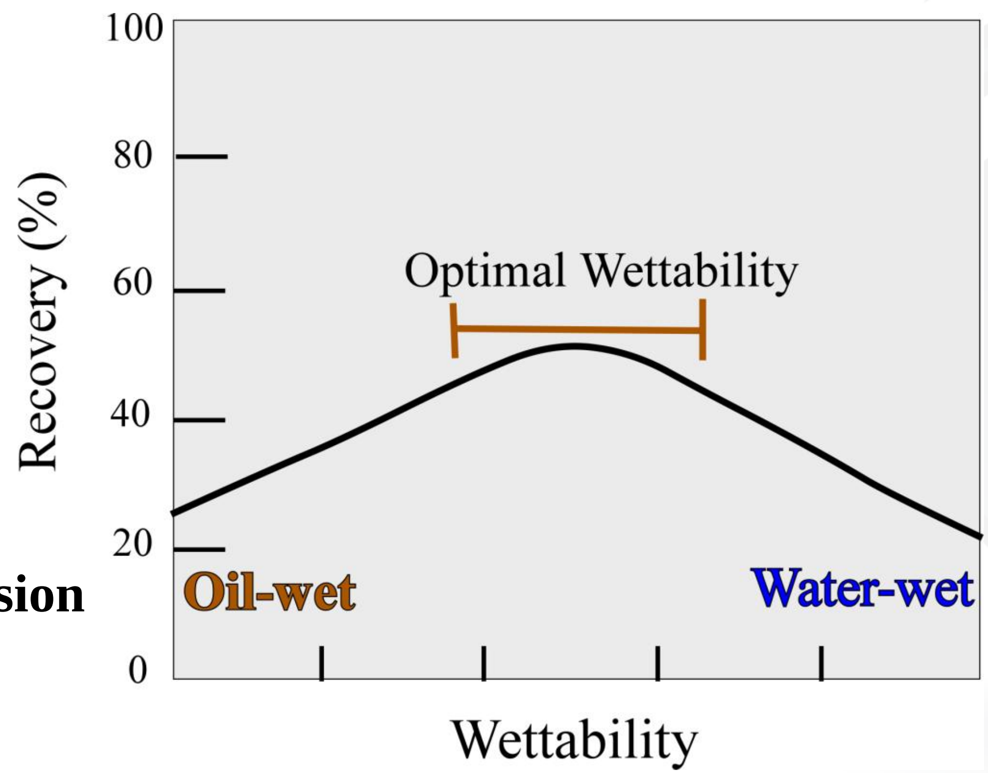
ESal Engineered Salinity

Wettability

"If your car is waxed, water runs off"

Applied Aspect

- There is an optimal wettability for a reservoir that minimizes snap off and adhesion.

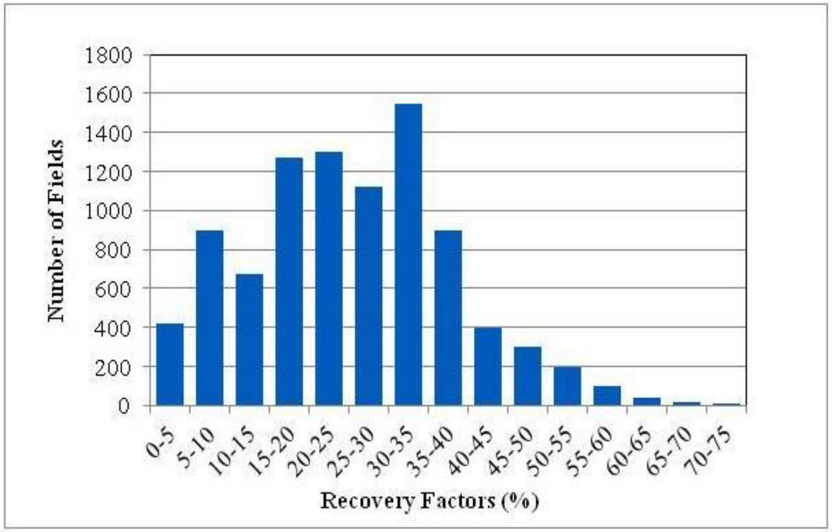


Oil adhesion

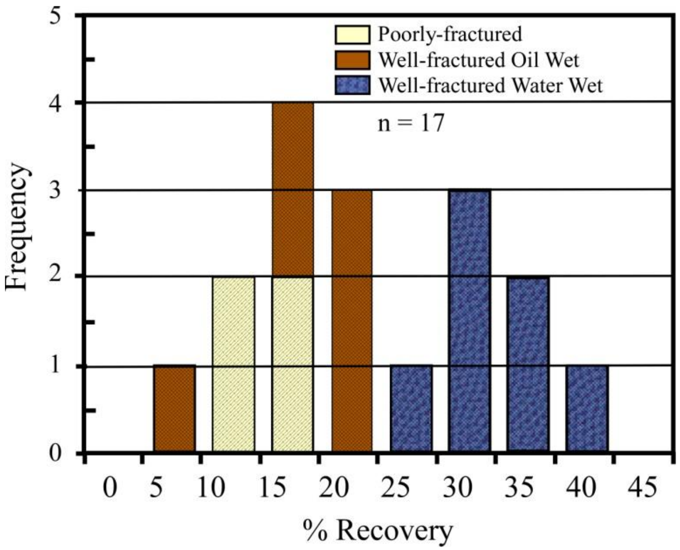
Oil snap off

Applied Aspect

- Current world average recovery is 32% of OOIP.
- Wettability is major control on oil mobility during waterflood.
- Initial wettability is result of equilibrium between rock, water and oil.
- We can change water chemistry on the reservoir scale (lab and field data).



Modified from Harper, 2004, BP Energy Institute
data from IHS Energy, approximately 9000 fields worldwide



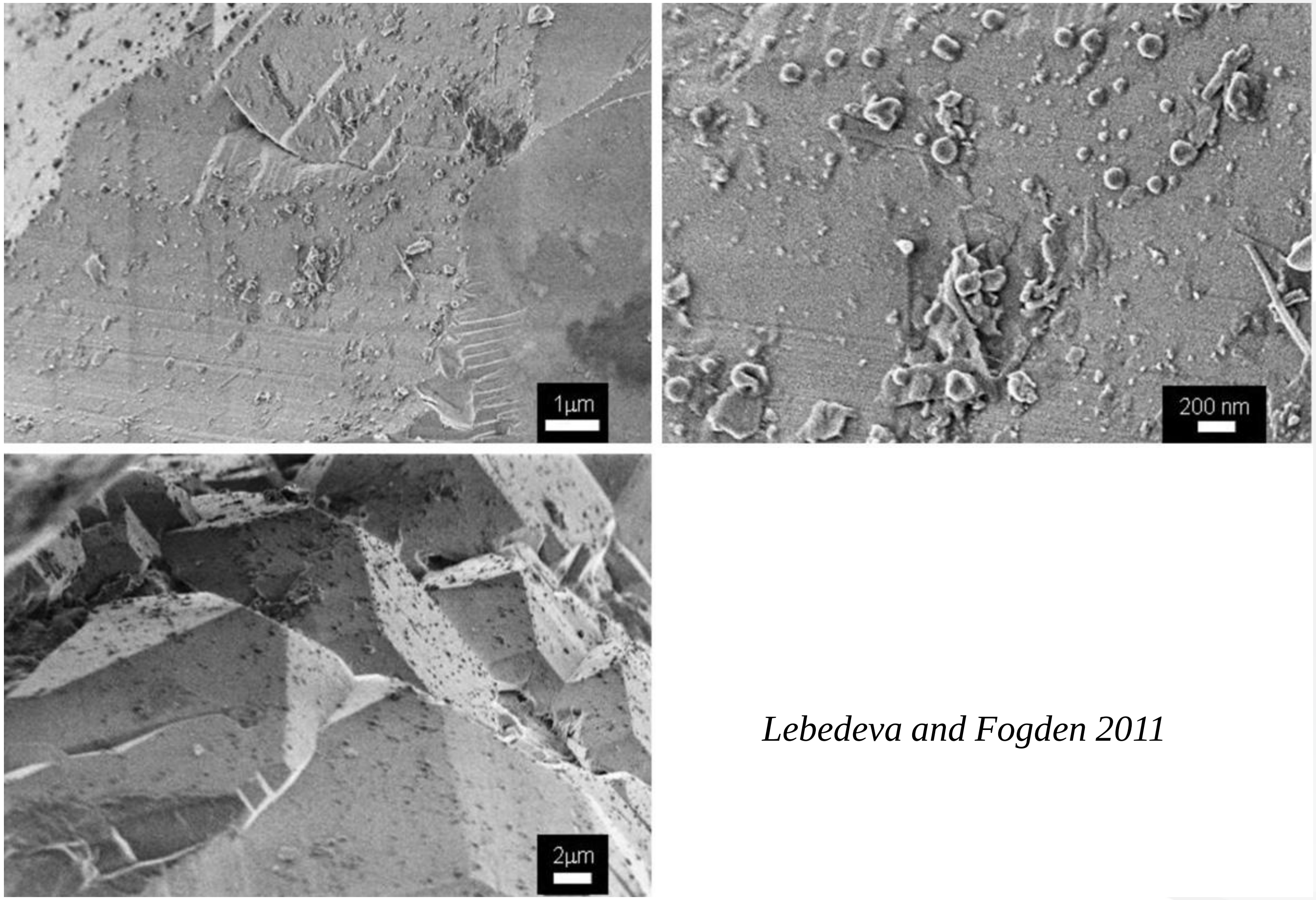
Modified from SPE 84459

Standard Wettability Formulation

Oil displaces water from the mineral surface and then wets the mineral (surface binding) – leads to calculation of disjointing pressure, capillary force measurements, IFT, etc.

Observations of Wettability

FESEM images - Sandstone surface coated with oil, at pH of 4 in 0.01 M NaCl



Lebedeva and Fogden 2011

What scale are we talking about?

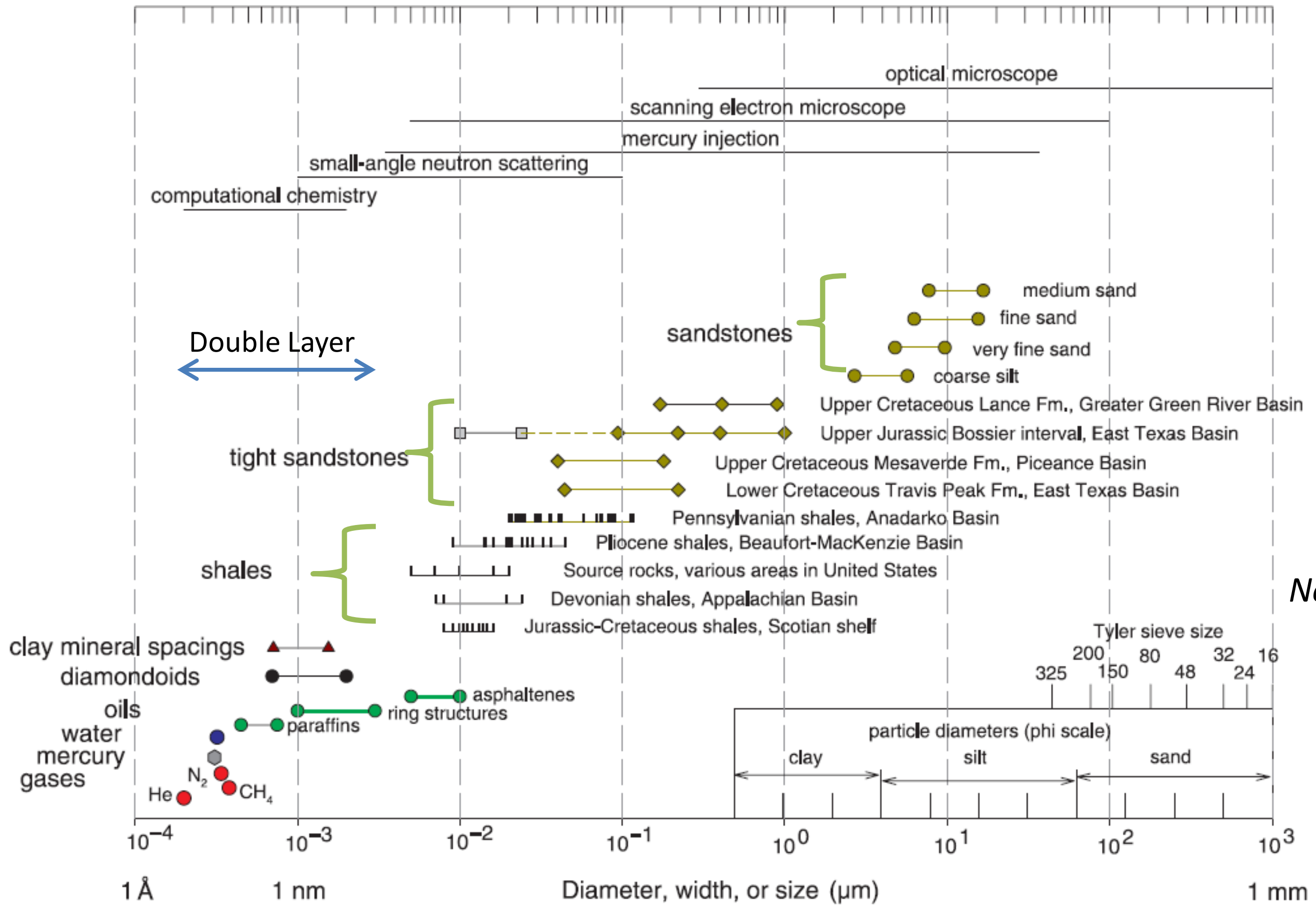


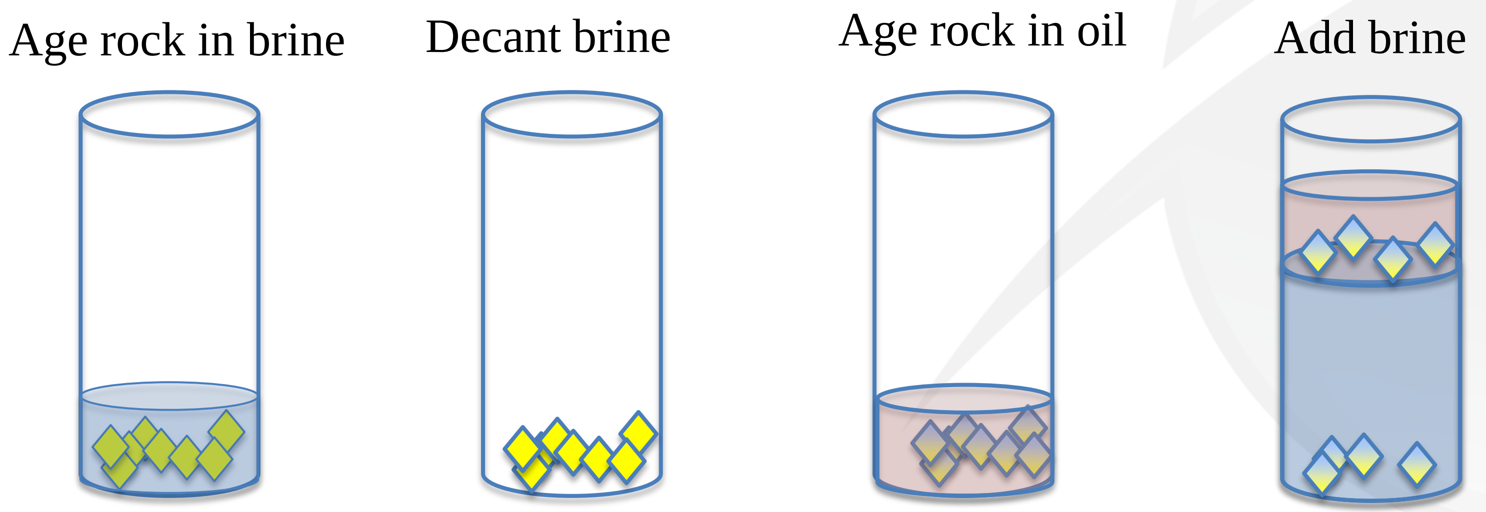
Figure 2. Sizes of molecules and pore throats in siliciclastic rocks on a logarithmic scale covering seven orders of magnitude. Measurement methods are shown at the top of the graph, and scales used for solid particles are shown at the lower right. The symbols show pore-throat sizes for four sandstones, four tight sandstones, and five shales. Ranges of clay mineral spacings, diamondoids, and three oils, and molecular diameters of water, mercury, and three gases are also shown. The sources of data and measurement methods for each sample set are discussed in the text.

Nelson 2009

ESal Engineered Salinity

Modified Floatation Test

- Modified Flotation Test
  - Age 0.2 grams of rock in brine for 48 hours.
  - Decant brine.
  - Age rock in 3ml of oil (decane) for 48 hours, stir every 12 hours.
  - Add brine to oil-rock mixture.
  - Stir and allow 24 hours.
  - Decant, dry, and weight fractions.

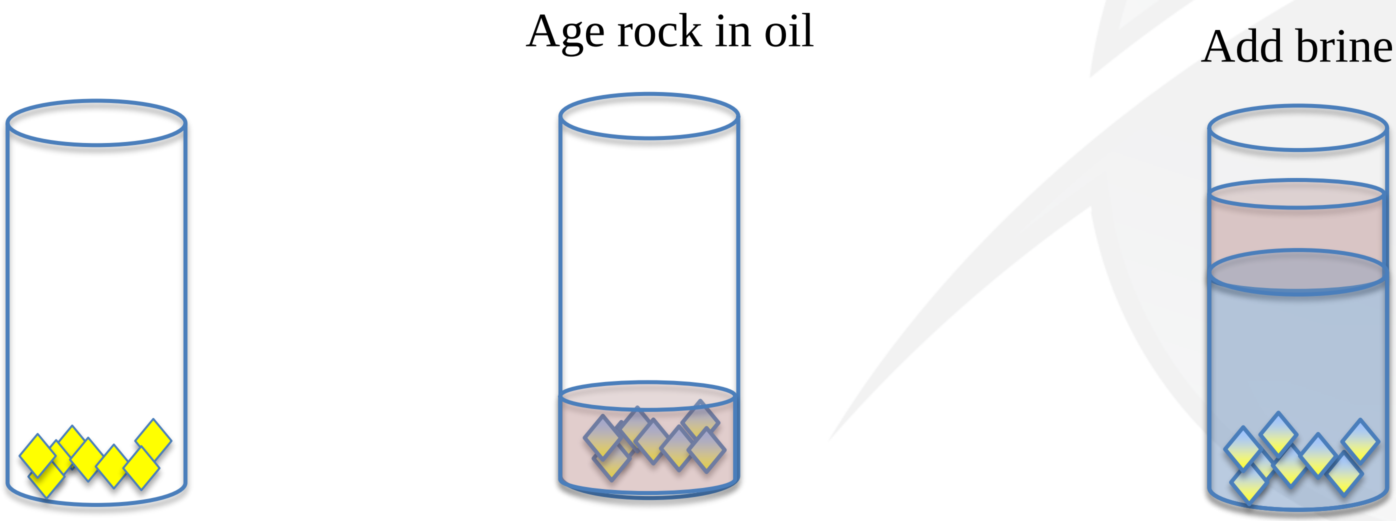


From Mwangi and others, 2013

ESal Engineered Salinity

Modified Floatation Test

- Modified Flotation Test
  - Age rock in 3ml of oil (decane) for 48 hours, stir every 12 hours.
  - Add brine to oil-rock mixture.
  - Stir and allow 24 hours.
  - Decant, dry, and weight fractions.



From Mwangi and others, 2013

Modified Floatation Test

Rock powder floats in oleic phase

Observations

- Grains are carried up in the hydrocarbon phase by the adhesion (wettability).
- When rock is mixed with oil only, no grains “float”.
- When rock is mixed with water first, grains “float”.

ESal Engineered Salinity

Implications of Experiments

- Oil does not break the water film during oil-wetting.
- Instead electrostatic interaction between mineral surfaces and oil through the water film causes oil to adhere to surfaces.
- This interaction is predictable using chemical models calibrated to experiments.

We can engineer optimal wettability.

ESal Engineered Salinity

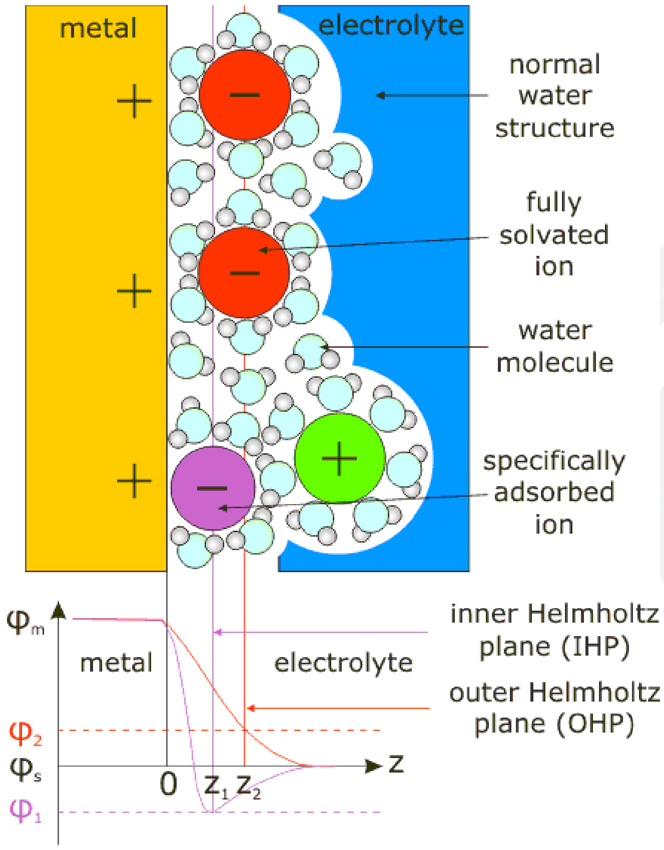
Alternative Wettability Formulation

The electrostatic attraction between surfaces and oil cause the surface to become "oil-wet", however there is still a very thin water film. The scale of interaction is that of the double layer, 1 to 10 nm.

ESal Engineered Salinity

How do we model wettability?

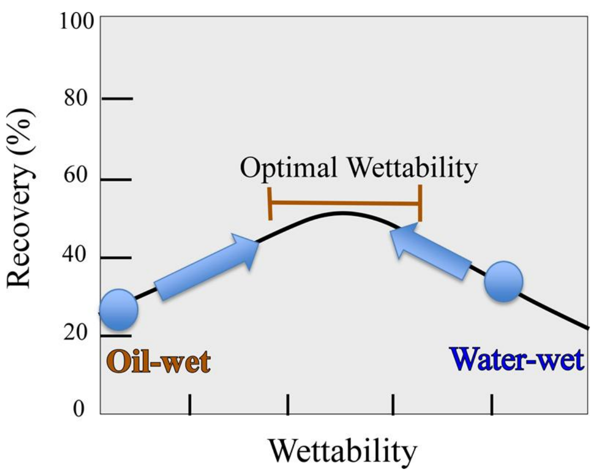
- Appropriately modified double-layer models.

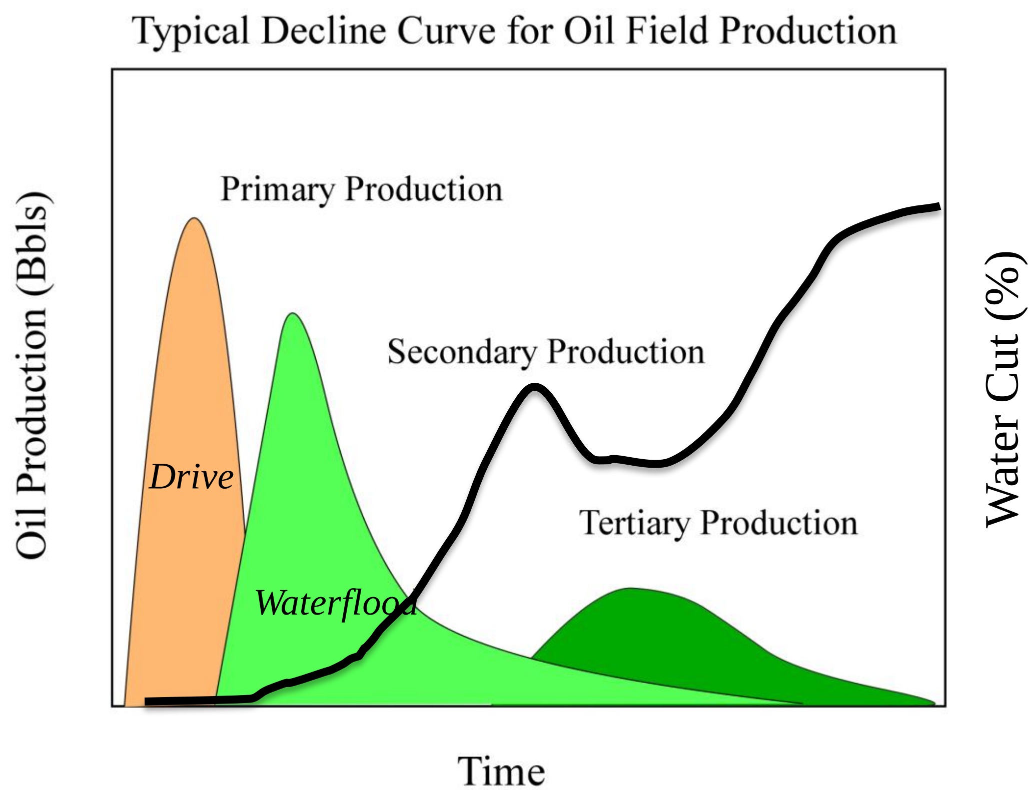


ESal Engineered Salinity

Applied Aspect

- We may have already changed the wettability during fracking or waterflooding.

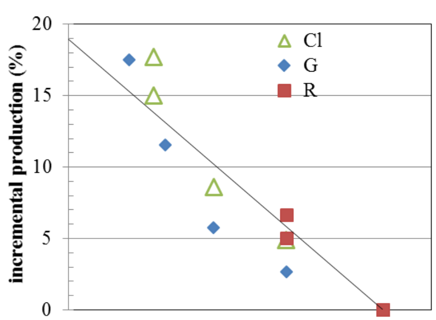


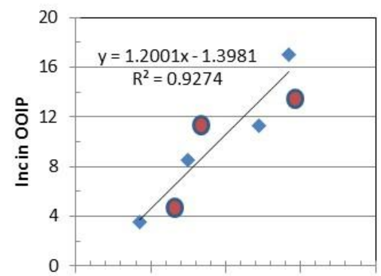


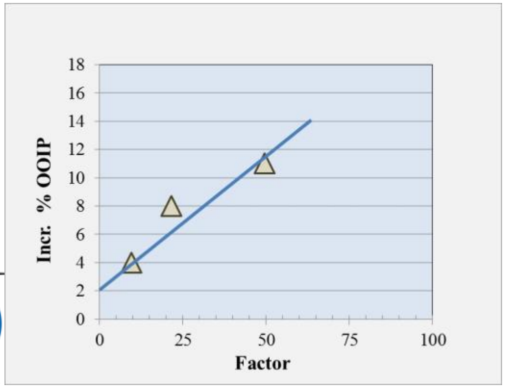
Screening for good candidates

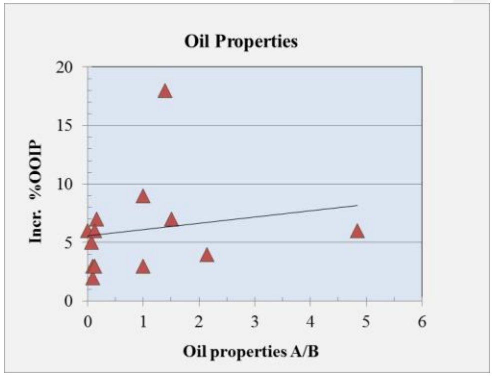
Use lab and field to determine empirical relationships.

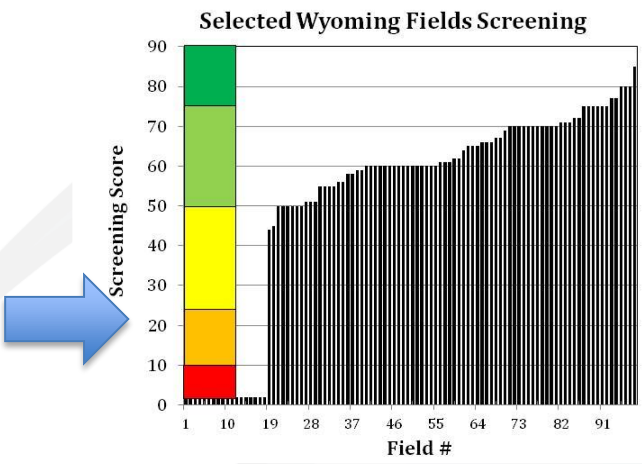
Input rock, water, oil and field properties to algorithm and calculate aggregate weighted score.





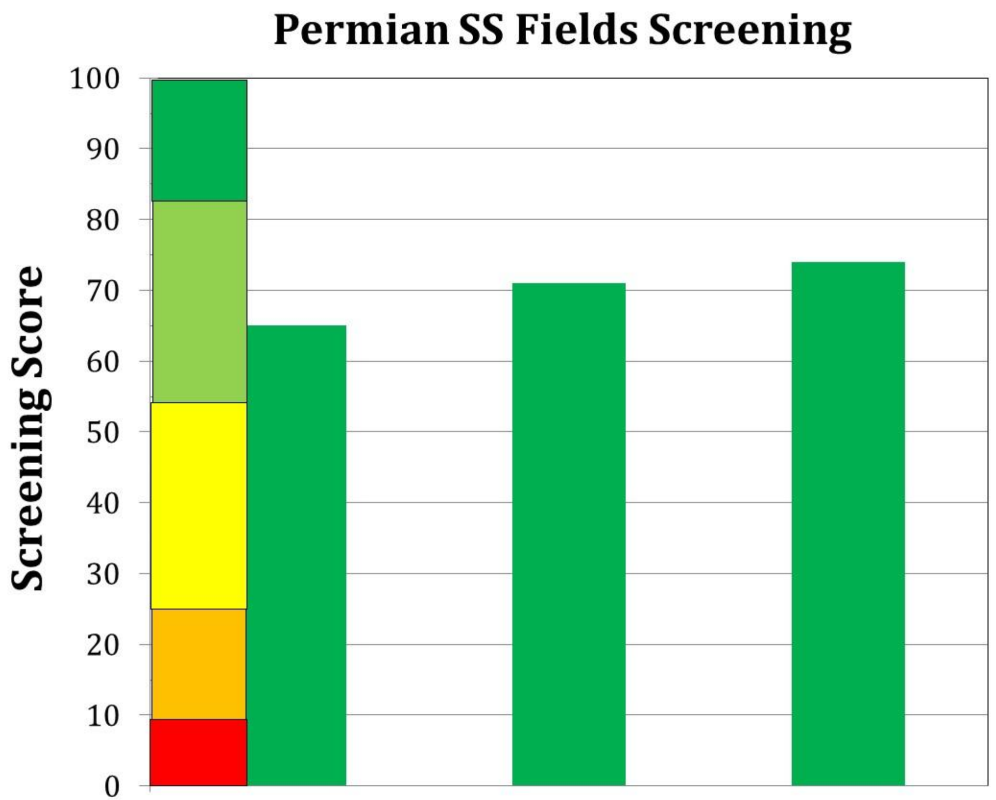






Screening the Permian Sandstones

Avalon, Bone Spring and Spraberry Sandstones.



Screening the Permian Sandstones

Bone Spring and Spraberry = good targets.

Targets for Consortium Research (Screening and Design)

- Delaware Basin - Delaware group, Bone Spring
- Midland Basin – Spraberry (Jo Mill)

Engineered Salinity - Advantages

- Incremental Production (5-15% OOIP) is similar to other techniques (Thermal, Chemical, CO_2, Microbial).
- Response is rapid (3-9 months).
- Cost of field test is low.
- Works in both clastic and carbonate reservoirs.
- CAPEX is low compared to typical EOR.
  - No steam plant or recycling plant.
  - No replacement of tubing and pipe.
- OPEX is low
  - No expensive chemicals.
  - No change in operations.
  - Water treatment can be designed to remove scale and improve injectivity in addition to changing wettability.

ESal Engineered Salinity

Questions?

www.esalinity.com