Wettability Alteration in the Eagle Ford: How to Design Drilling Fluids to Improve Recovery in Shale Plays*

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Abstract

The current economic conditions have challenged producers to find methods to lower costs and improve production. While incremental improvements in efficiency are possible, the current 50% reduction in oil prices means we need significant changes to stay competitive. Wettability has a significant effect on hydrocarbon recovery and offers a basis to substantially improve well performance. Each reservoir has a wettability state that leads to maximum recovery, but the initial wettability of a reservoir is usually not optimal. Traditionally, we have used surfactants and chemical agents to try to optimize wettability and recovery, but this process is expensive and does not always produce the desired results. This talk will outline recent advances in the science of wettability, as well as a practical methodology to realize the goal of increasing well recovery in Eagle Ford reservoirs.

In unconventional reservoirs, the opportunity to increase initial flow rates and extend decline curves is an attractive goal. We can optimize wettability by changing the water chemistry of well fluids during hydraulic fracturing and completions in unconventional targets. The technique has several advantages including substantially lower costs, ease of application and lower probability of negative outcomes. Recent studies have shown that rather than fresh water formulations, brackish water generates better well recovery. Not only does the use of the correct brackish water increase recovery but also the costs associated with fresh water use can be avoided.

A successful approach to wettability alteration requires several key steps: screening the formation to identify current wettability, simple laboratory tests to evaluate the in-creased recovery potential, economic evaluations to estimate costs and benefits, and finally, well-constrained geochemical models to help correctly design the wettability-modifying fluids. While some current assumptions will be refined as we become more knowledgeable, the basic idea, that we can alter wettability with water chemistry to optimize recovery seems well justified.

References Cited

Ayirala, S.C., and A.A. Yousef, 2014, Injection water chemistry requirement guidelines for IOR/EOR: in SPE, Improved Oil Recovery Symposium, 12-16 April, 2014, Tulsa, Oklahoma, Society of petroleum Engineers.

Brady, P., J. Krumhansl, and S. Laboratories, 2013, Surface Complexation Modeling for Waterflooding of Sandstones: SPE Journal (April) SPE 163053.

Chen, J., G.J. Hirasaki, and M. Flaum, 2004, Study of Wettability Alteration from NMR: Effect of OBM on Wettability and NMR Responses: 8th International Symposium on Reservoir Wettability, Houston, TX, May 16-18-2004

Dang, C.T.Q, L.X. Nghiem, Z. Chen, and Q.P. Nguyen, 2013, Modeling Low Salinity Waterflooding: Ion Exchange, Geochemistry and Wettability Alteration: SPE 166447, Web Accessed April 22, 2015, http://www.spe.org/atce/2013/pages/schedule/tech_program/documents/spe166447-page1.pdf.

Hirasaki, G.J.S., 1991, Wettability: Fundamentals and surface forces: SPE Form. Eval., 6, p. 217-226.

Jadhunandan, P.P., and N.R. Morrow, 1991, Effect of Wettability on Waterflood Recovery for Crude-Oil/Brine/Rock Systems: SPE 22597.

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.

Mahani, H. A.L. Keya, S. Berg, W.-B. Bartels, R. Nasralla, and W.R. Rossen, 2015, Insights into the Mechanism of Wettability Alteration by Low-Salinity Flooding (LSF) in Carbonates: Energy Fuels, v. 29/3, p. 1352–1367, DOI: 10.1021/ef5023847.

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

Owolabi, O.O., and R.W. Watson, 1993, Effects of Rock-Pore Characteristics on Oil Recovery at Breakthrough and Ultimate Oil Recovery in Water-Wet Sandstones: SPE 26935.

Wettability alteration in the Eagle Ford: how to design drilling fluids to improve recovery in shale plays.

Geoffrey Thyne

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What I learned so far

- The Eagle Ford is a technological play at this point.
- It will not be a very active play at $50.
- Only $30% or less of frack fluid comes back.
- Marl is the source and storage unit.
- Limestone/marl geometry is important.
- We are talking about refinements to improve recovery (better locations, spacing, completions, etc).
- The Alamo is smaller than in the movie.

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Outline

- Take Home.
- Why use this technique?
- What is this technique?
- Science and Engineering.
- Practical Aspects.

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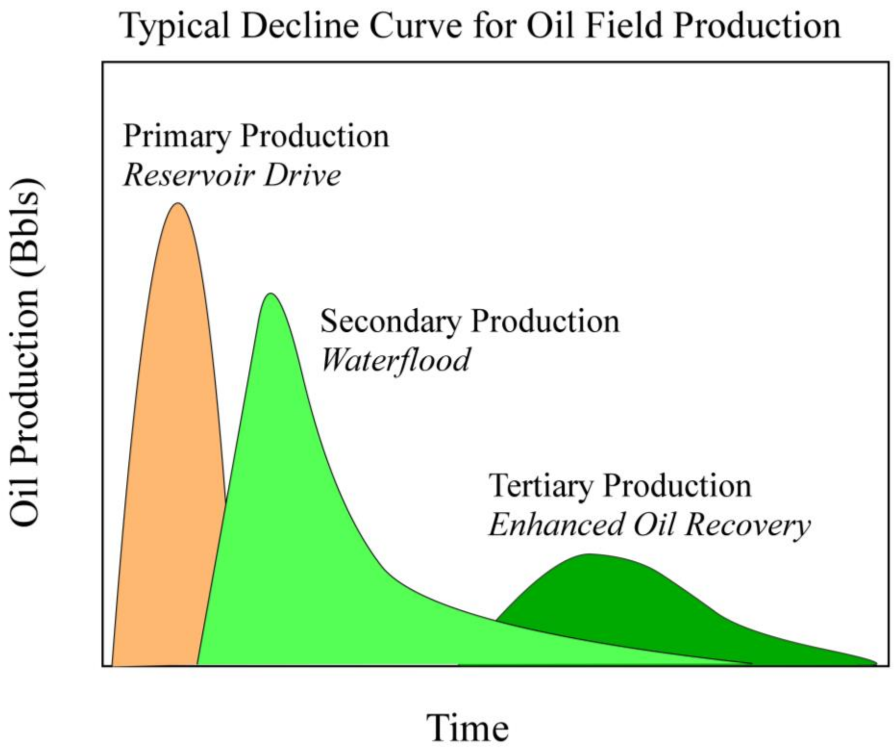
Take Home Message

- Typical Oilfield Production



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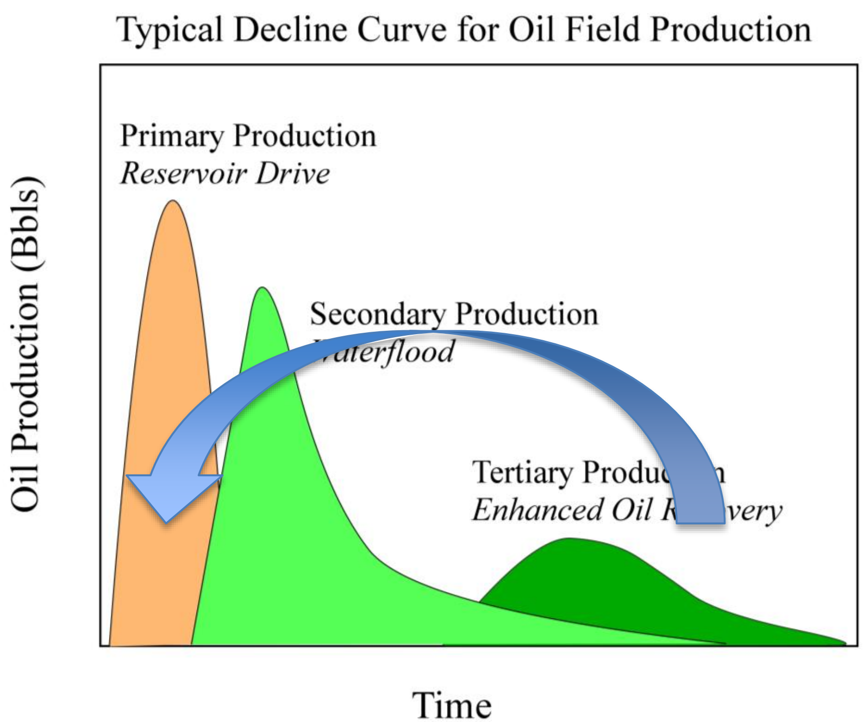
Take Home Message

- Wettability Alteration can be employed at any stage.
- Can be deployed during D&C (unconventional).



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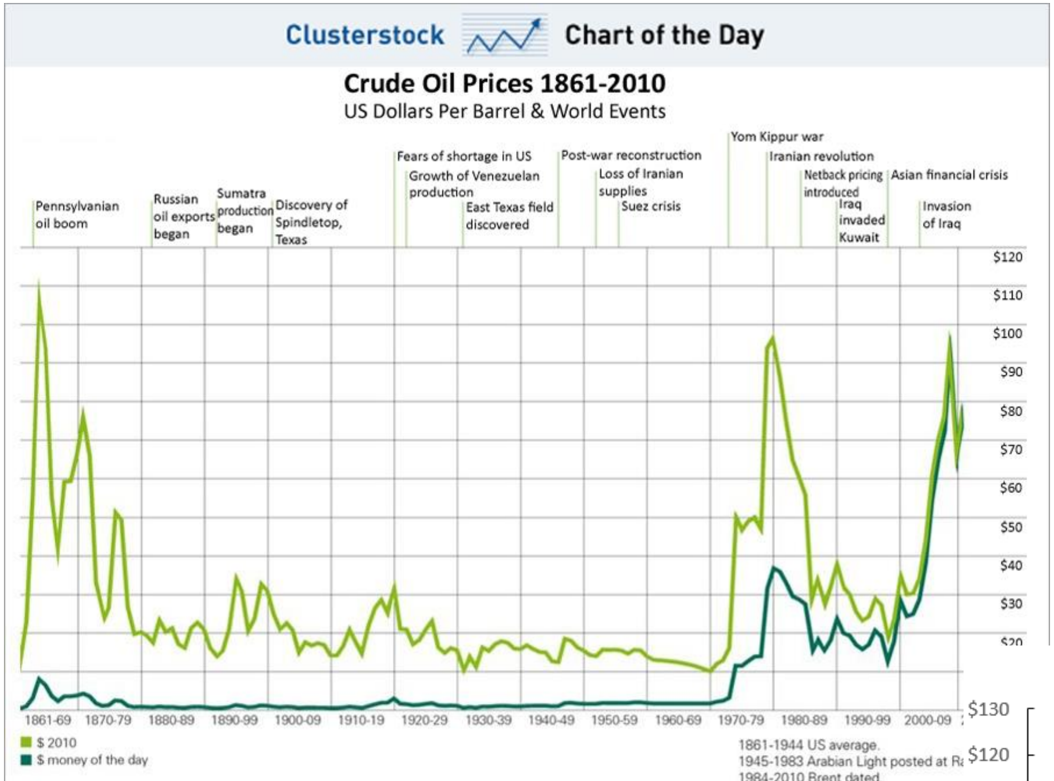
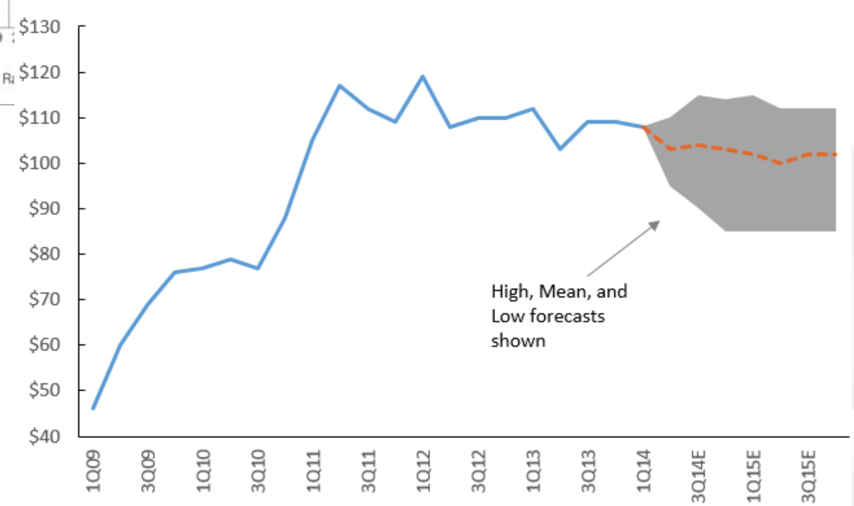
Context



Brent Crude Oil Price & Forecast



Source: Bloomberg, Oilpro

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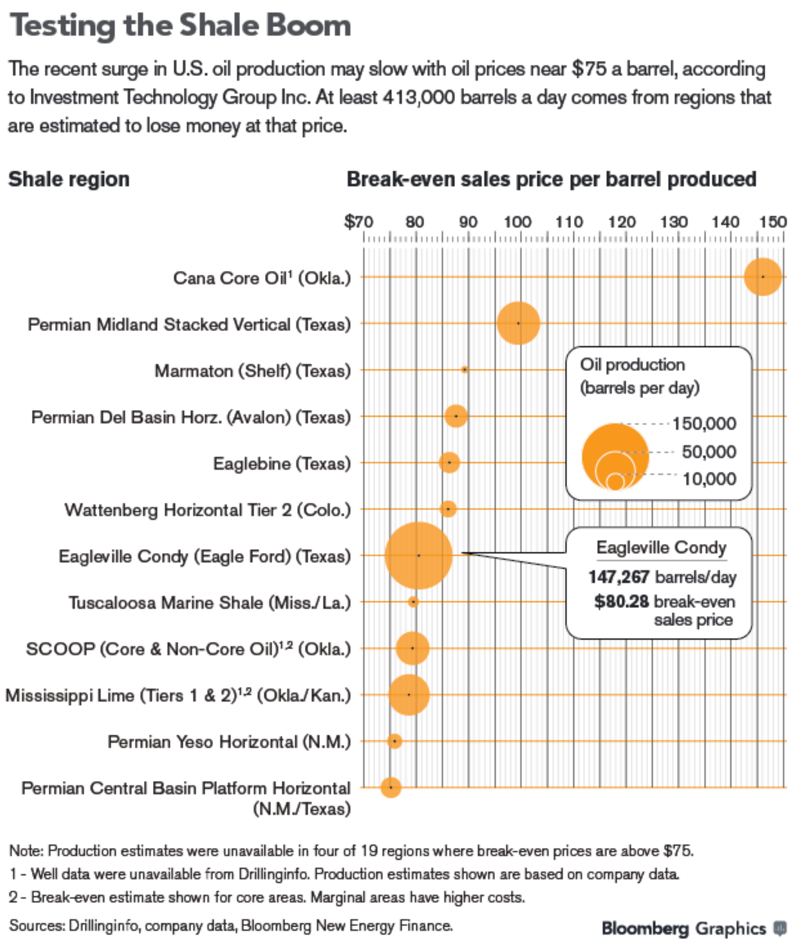

$50 is not going to work at current costs

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Why do we care about wettability?

- In petroleum reservoirs wettability is the tendency of oil to adhere to the reservoir rock surfaces limiting oil movement and recovery.
- Wettability is recognized as a major control on oil mobility and amount of recovery.
- Normally we try to improve wettability by adding surfactants (lower interfacial tension) to increase recovery.

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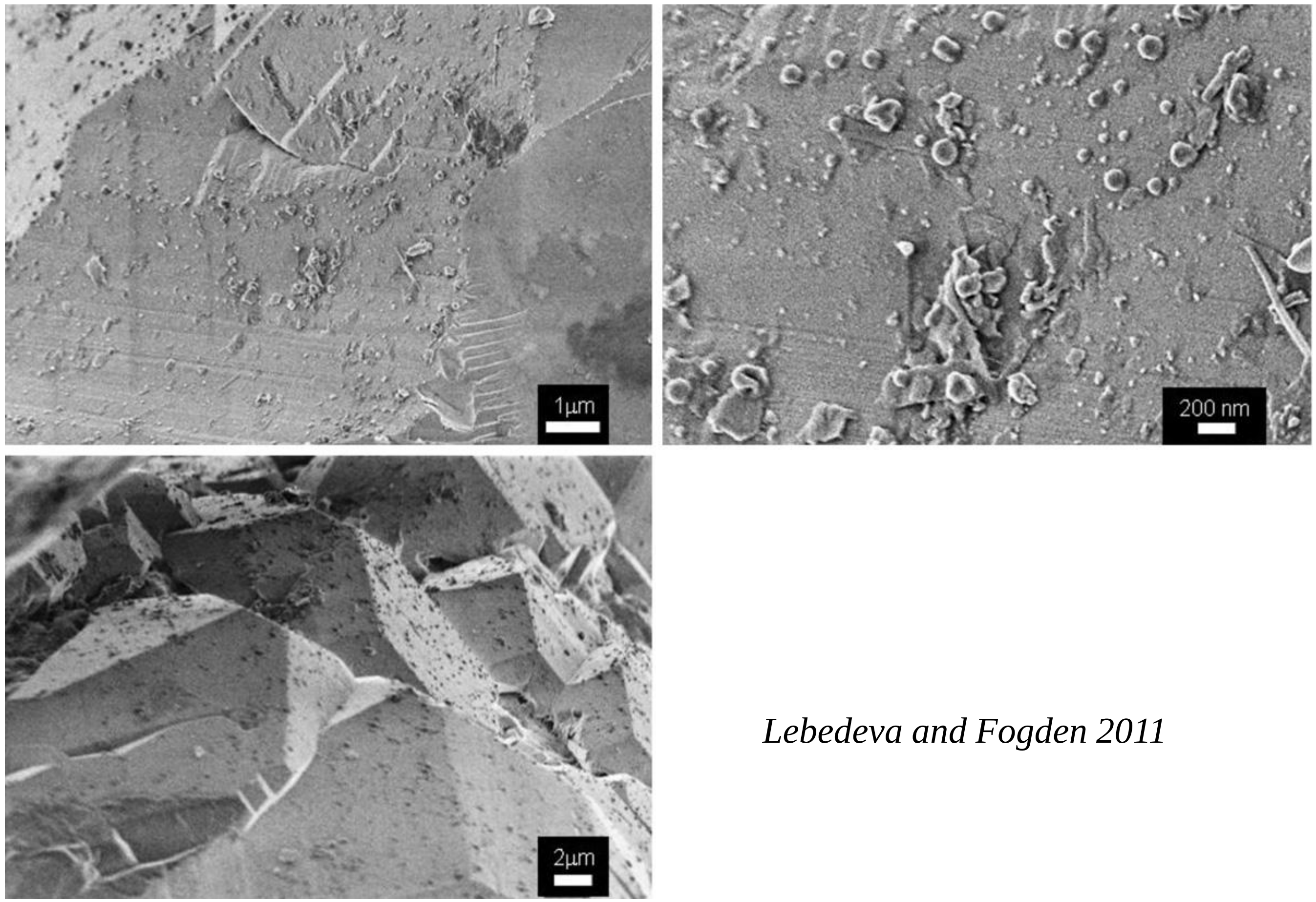
Observations of Wettability

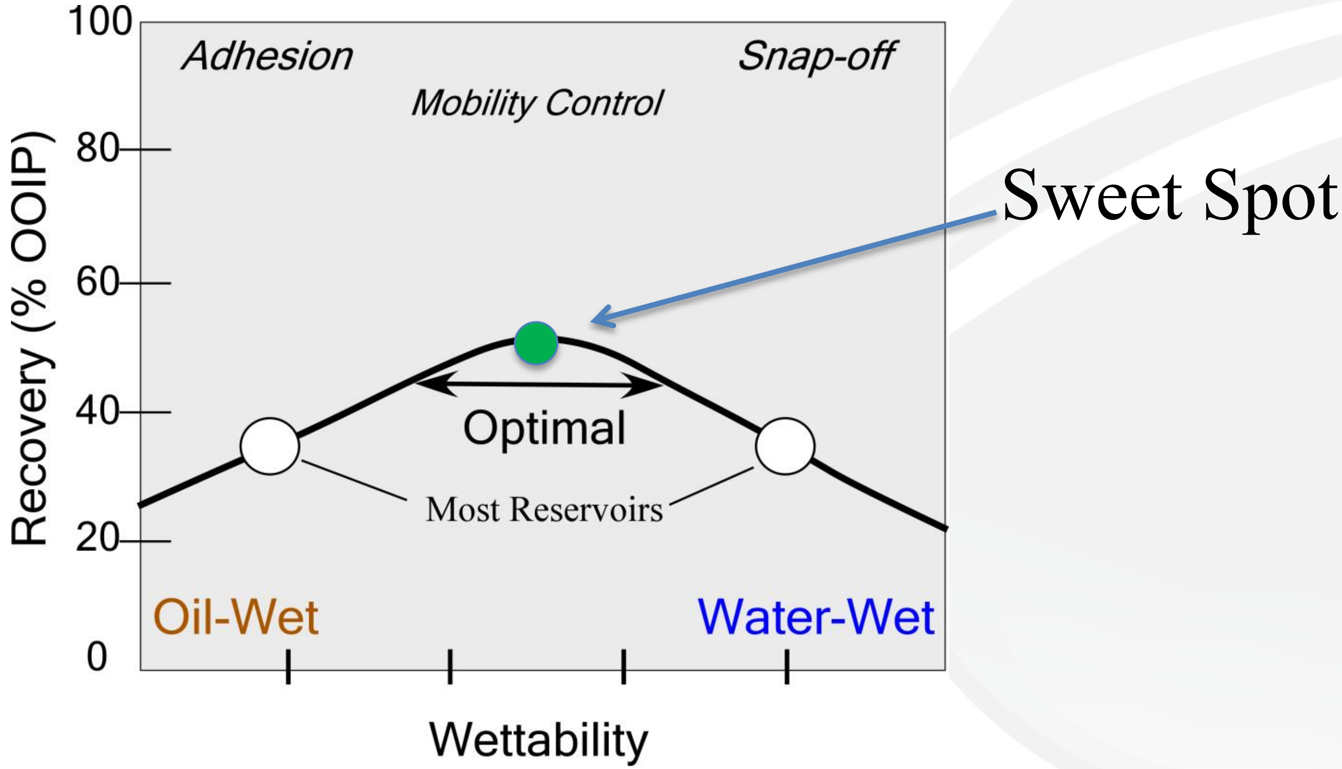
FESEM images - Sandstone surface coated with oil, at pH of 4 in 0.01 M NaCl



Lebedeva and Fogden 2011

Wettability

Recovery = Oil Release + Oil Mobility



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Wettability Modification in Conventional Reservoirs

- BP – Clare Ridge project
- Recent Papers:
  - Mahani et al. 2015 (Shell) – carbonate mechanism, field results.
  - Ayirala and Yousef 2014 (Aramco)– review of performance and guidelines for projects.
  - Brady et al. 2013 (Sandia) – mechanisms and modeling.
  - Mwangi et al. 2013 (LSU)– methods and experiments.
  - Dang et al. 2013 (SPE 166447) – modeling low sal.

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Why Alter Wettability by Salinity?

- No Change in Normal Operations.
- Potential Increase in Recovery is High.
- Cost is Low.
- Works in Clastic and Carbonate.
- Increase Reserves.
- No Environmental Impact.

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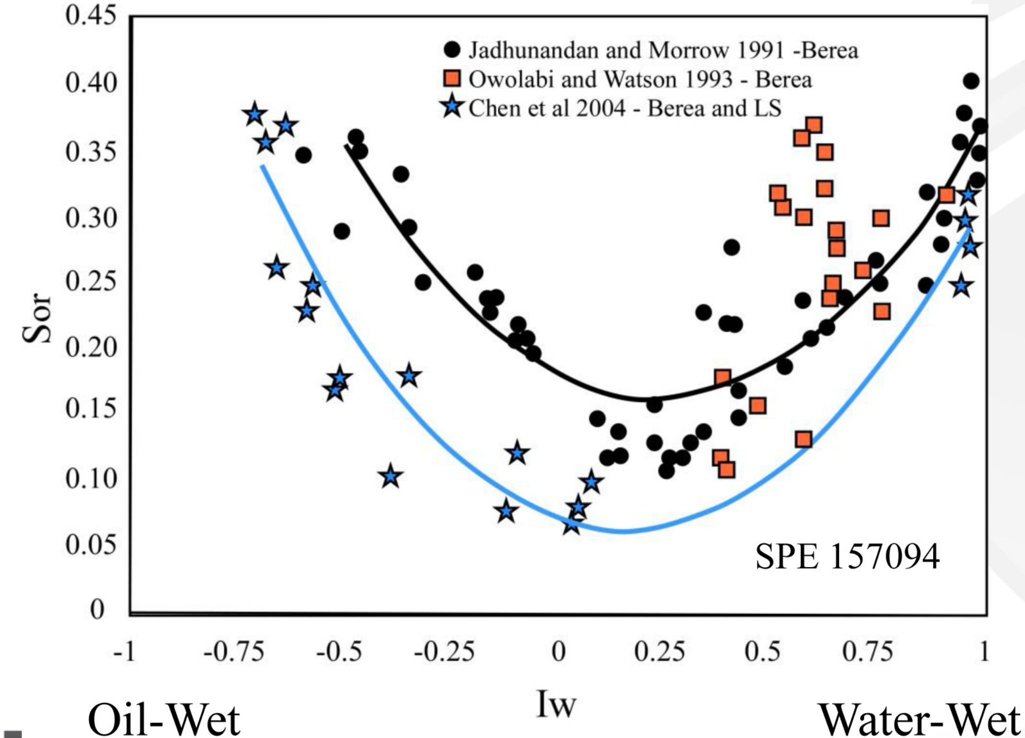
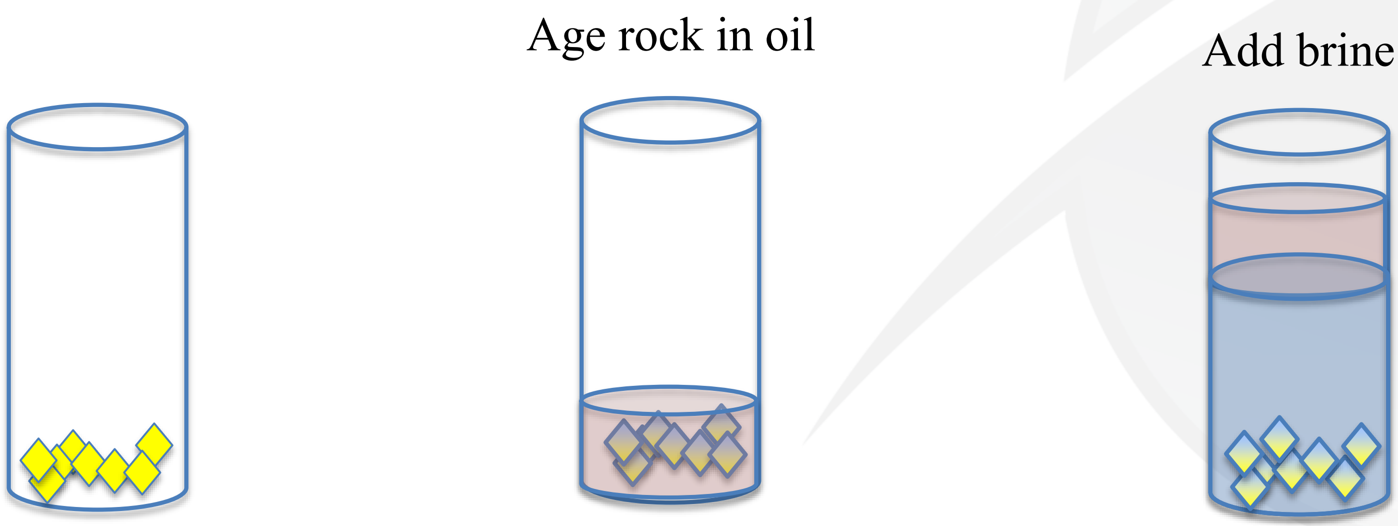
Wettability

- Reservoir wettability is the equilibrium between water, rock and oil.
- Wettability is major control on recovery.
- *“Hydrocarbon-wet systems retard hydrocarbon mobility”.*
- *“Water-wet systems promote hydrocarbon mobility”.*



Water Films?

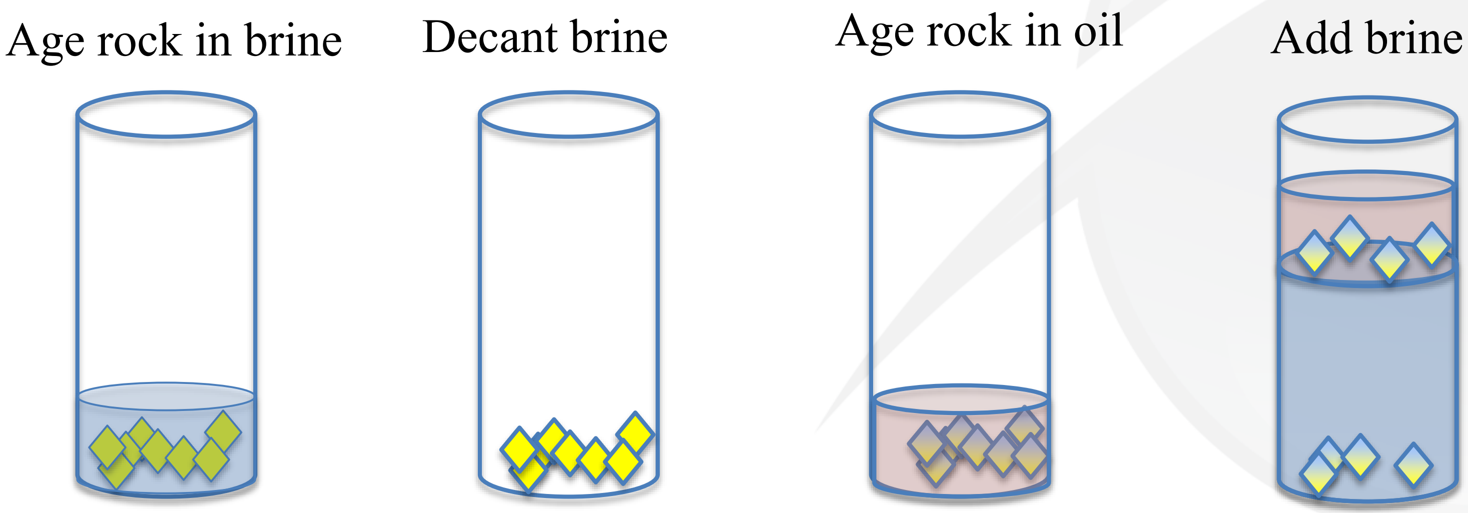
- Modified Flotation Test shows importance of water films
  - Age rock in 3ml of oil (decane) for 48 hours, stir every 12 hours.
  - Add brine to oil-rock mixture.
  - Stir and allow 24 hours.
  - Decant, dry, and weight fractions.



From Mwangi and others, 2013

Water Films?

- Modified Flotation Test
- Allows rapid investigations in wide range of rock types
  - 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 et al. 2013

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Lab Tests - Modified Floatation

Rock powder floats in oleic phase

Initial separation

After 24 hours

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How do we link wettability to salinity?

- Wettability is the equilibrium between water, rock and oil.
- Wettability is dependent on the balance of forces between the oil-water and water-rock interfaces.
- Change in water chemistry changes the balance.
- Forces (pressure) between surface with a water film and oil are composed of
  - 1 – electrostatic (attractive or repulsive),
  - 2 – van der Waals (attractive),
  - 3 – structural or hydration (repulsive below 3-4 nm).

Hirasaki, 1991

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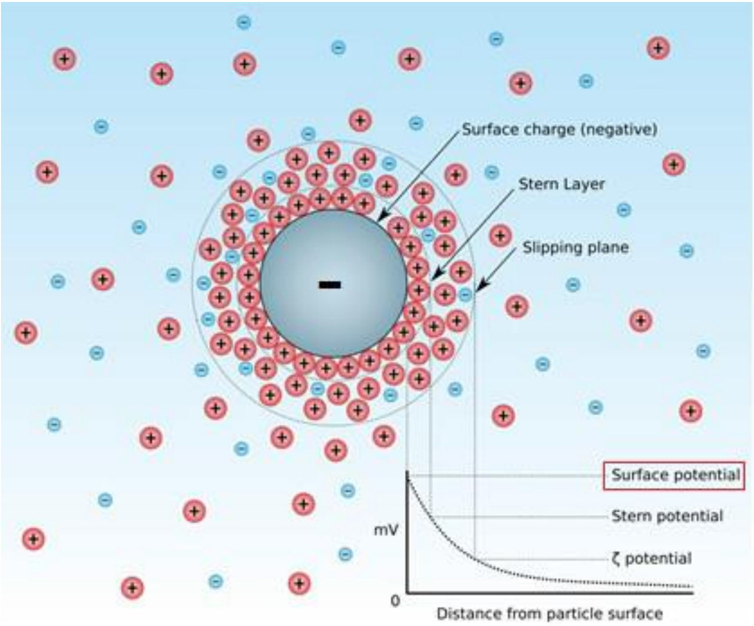
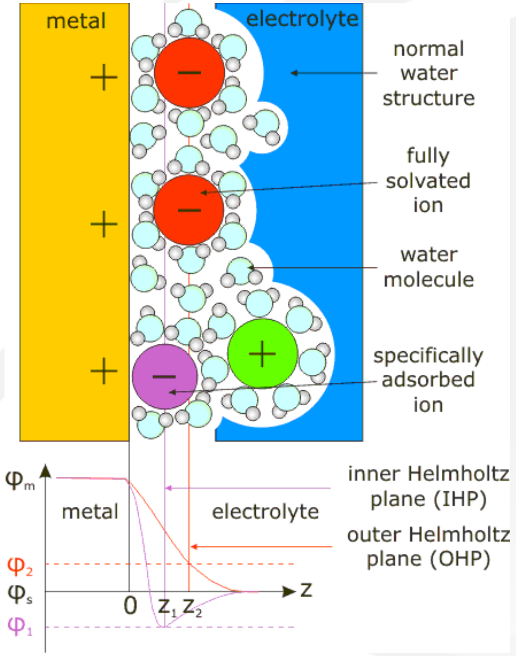
Wettability Models

- Model of aqueous, oil and surface reactions.
- Double layer models assume surfaces are coated with water and electrostatic forces are dominant.





What scale are we talking about?

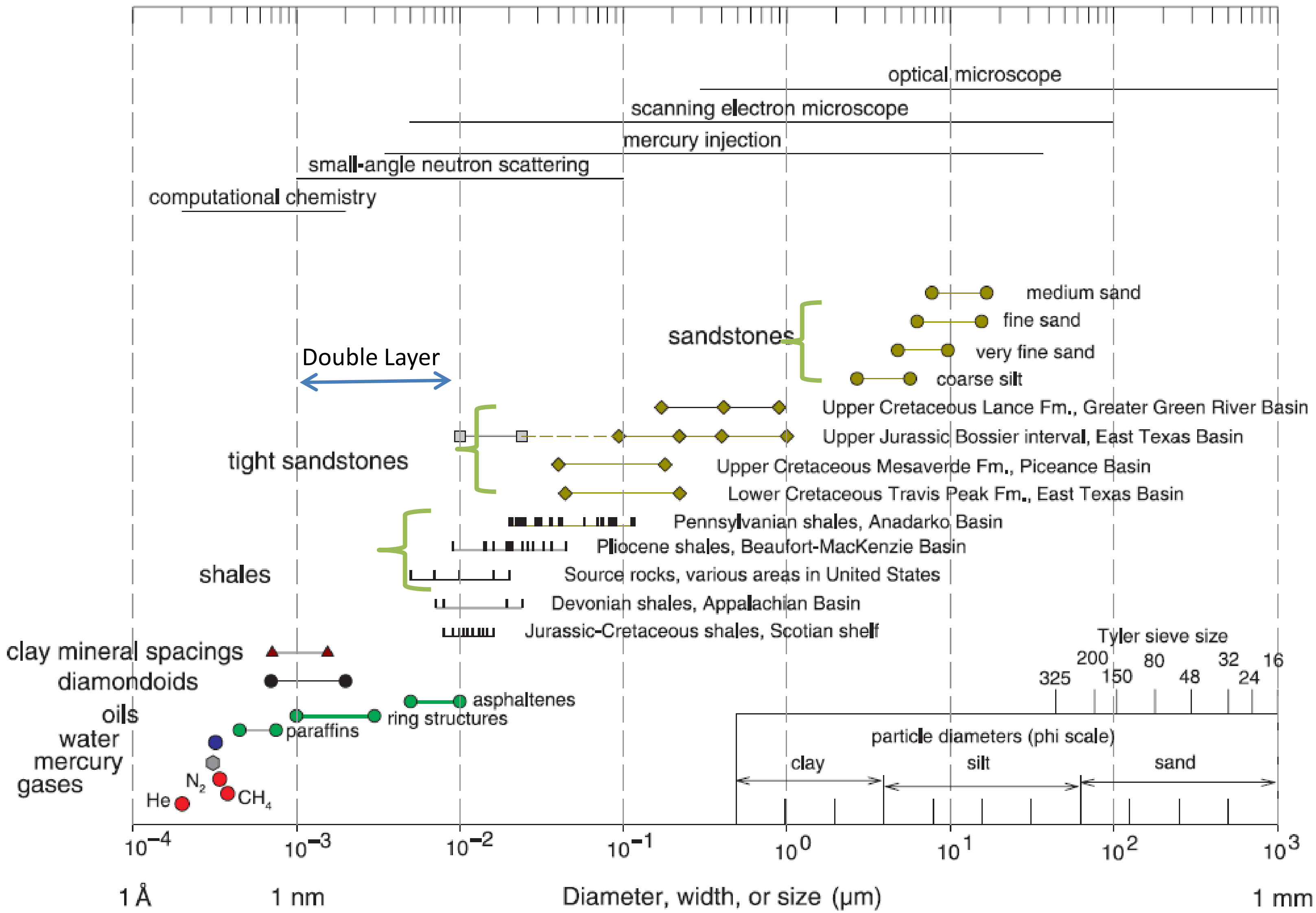


Figure 2. Sizes of molecules and pore throats in siliciclastic rocks on a logarithmic scale covering seven orders of magnitude. Measurement methods are shown at the top of the graph, and scales used for solid particles are shown at the lower right. The symbols show pore-throat sizes for four sandstones, 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

Application to Eagle Ford

- Evidence from Bakken, Milk River and Wolfcamp that current fluids are not formulated to optimize wettability.
- Instead of fresh water formulations, brackish water formulations may improve production.
  - Water source costs are lower
- May be able to use geophysical logs (FMI) to determine in-situ wettability.

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ESal™ Work Flow

- Evaluation (is my field a good candidate?)
  - Screening – Generate Field Score
    - empirical model generates quantitative score based on field, oil, water and rock properties
    - preliminary water source assessment
  - Scoping – Economic Assessment of Projects
    - expense/profit modeling (modified Kinder-Morgan)
    - multiple economic evaluations and scenarios
- Experiments and Models
  - Wettability Measurements
    - rapid scan to find optimum chemistry
  - Modeling to assess other fluid-fluid-rock interactions
  - Design injection fluid chemistry for optimum wettability
- Deployment
  - Select water source
  - Generate water treatment specifications
  - Install equipment

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Questions?

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