Turning Brown Fields into Gold Fields with Wettability Alteration*

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Abstract

The new normal in oil prices means we need significant changes in how we do business to stay competitive. Capital investment in exploration and drilling is difficult at current prices. However, we can still find profits by returning to our brown fields and re-invigorating production through wettability alteration. Wettability alteration through salinity manipulation offers a method to substantially improve recovery in many fields. Examples from carbonate and clastic fields show recovery can be increased by as much as 30% original oil in place, even in low permeability reservoirs. This low-cost technique can improve well performance and increase reserves for little investment. The technique has several advantages compared to current methodologies for wettability alteration including substantially lower costs, no environmental impacts and ease of application. This talk details the practical approach to determine if your field is a good candidate.

The successful approach requires several key steps: screening the formation to evaluate the applicability of the technique; laboratory tests to determine current reservoir wettability and optimal water chemistry; and deployment, which includes economic evaluations, geochemical modeling, and selection of the best water treatment methodology and design of the surface facilities. Over five hundred laboratory and field examples were compiled to create an empirical basis for screening. A new laboratory methodology for wettability determination was developed for rapid and inexpensive testing. Standard geochemical models with suitable modifications are then used to design injection water chemistry that eliminates reservoir damage. The result is the ability to optimize reservoir wettability with simple and inexpensive changes that radically alter the value of your existing brown fields and identify new investment opportunities.

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Turning Brown Fields to Gold Fields.

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Engineered Salinity

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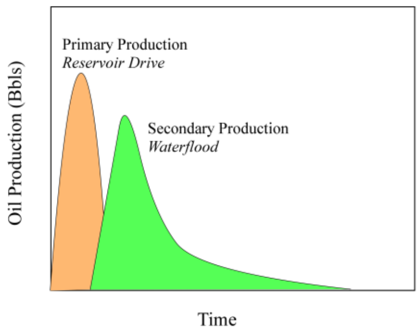
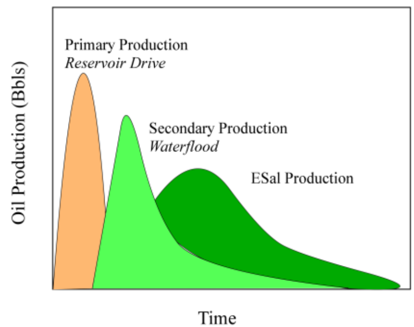
Oil Production

- Primary and Secondary Recovery is about 35%.
- Get more recovery with wettability alteration





Presenter's notes: This oil is typically the oil molecules free floating in the pores spaces. This averages only about 30% of the original oil in place. The remaining 70% of the oil is left in the reservoir and it primarily is clinging to the rock. This is known as wettability. Secondary and tertiary recovery methods are used to extract this remaining oil including include surfactants, chemical floods and waterfloods. Through engineering the salinity of waterfloods, ESal is able to get a lot of the oil stuck to the rock to release – in fact, we are able to get 5 – 30% more of the OOIP out of the reservoir.

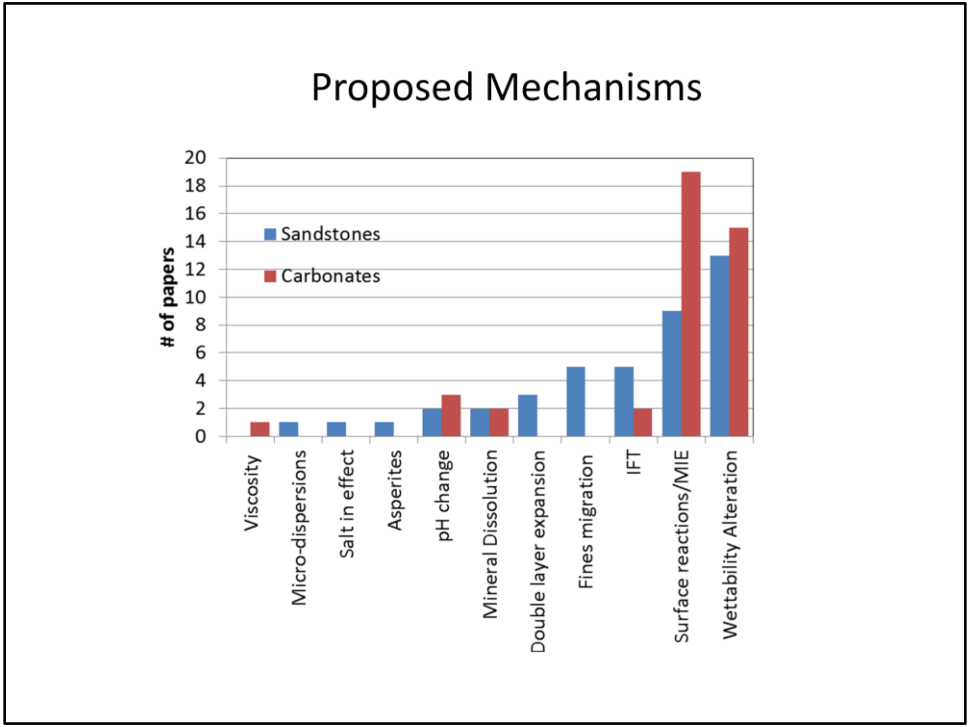
Why Alter Wettability by Salinity?

- No Change in Normal Operations.
- Increase in Recovery is High (5-25% OOIP).
- Increase Booked Reserves with successful pilot.
- Cost is Low.
- Works in Clastics and Carbonates.
- Response is Rapid (3-9 months).
- No Surfactants ($$).
- No Environmental Impact.

Presenter's notes: Wettability alteration on the reservoir scale requires injection of a solution that can spread through the reservoir and alter wettability in-situ. Instead of costly surfactants, using the inorganic chemistry (salinity and composition) to alter wettability has several advantages. These include no change in normal operations, low cost, no formation damage and no environmental impact. The process will work in carbonate and clastic (sandstone) reservoirs. The response is rapid and once proven to work during a pilot project, the producer can apply to the SEC to increase reserves across the field by the amount shown in the pilot.

Started with Low Salinity Waterflooding

- In 1990's Morrow et al. observed lowering the salinity of waterfloods increased oil production in the lab
- Then BP and Shell observed this in the field
- Everyone wants to know how it works
- Low salinity aka. "LoSal™" – BP, "Advanced Ion Management" – Exxon, Norwegians – "Smart Water", Saudi – "Designer Waterflood" Stavanger – "Smart Water", Aalborg – "Advanced Water", ESal ™ – "Engineered Salinity"



Presenter's notes: Over the past twenty years, there have been a number of mechanisms proposed to explain the observations of increased recovery. However, over the past five years, the mechanisms have centered on either wettability alteration or some form of mineral surface reaction. The only mechanisms that are proposed for both carbonate and clastic rocks are surface reaction, wettability alteration and pH change.

Successes and Failures

Successes (conventional)

BP - North Slope – SWTT and pilot for SS field (15% OOIP).

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

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

Saudi Aramco – Carbonate field, 2 SWTT's, 10-20% OOIP

Failures (conventional)

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

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

Zichebashskoe Field, Russia, SS – 4% OOIP

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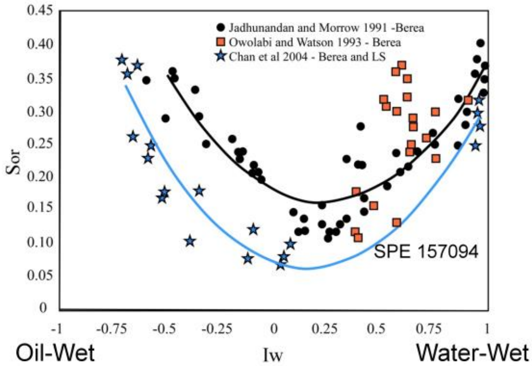
What do you need?

- Water chemistry favorable to change
- Rock with required surface sites
- Oil with sufficient polar components
- Favorable reservoir conditions
  - Temperature
  - Good waterflood

Wettability

- Reservoir wettability is the equilibrium between water, rock and oil.
- Wettability is major control on recovery.
- *Dogma - "Hydrocarbon-wet systems lower recovery and water-wet systems promote recovery".*
- *Best recovery is at neutral wettability.*

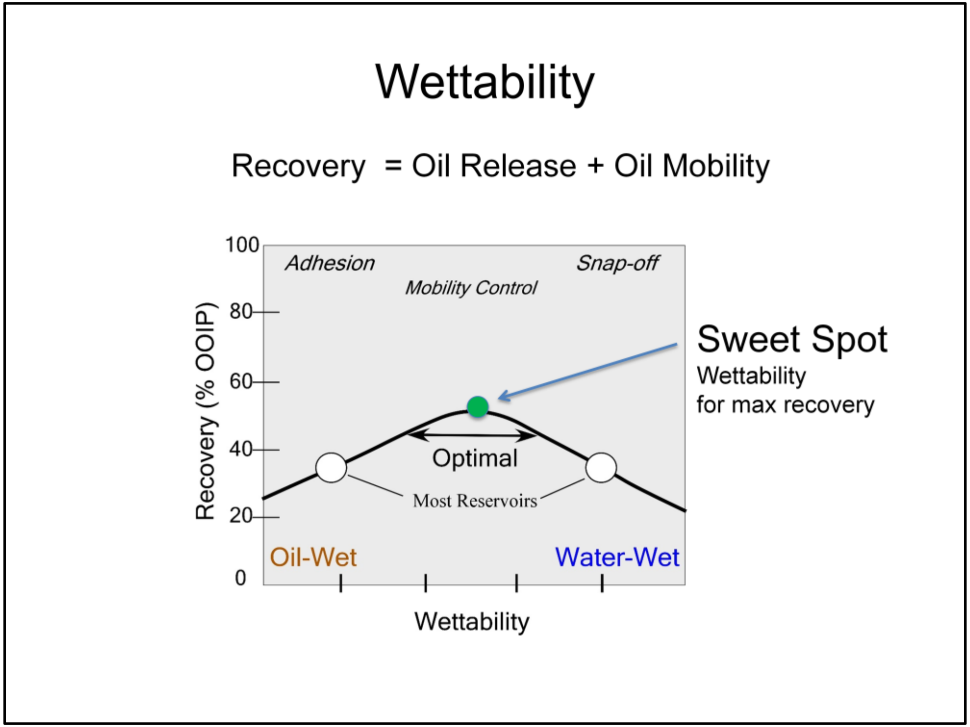


Presenter's notes: Evidence from Bakken, Milk River and Wolfcamp indicate that current fluids do not optimize wettability. Instead of fresh water formulations, brackish water formulations may improve production.

- Water source costs are lower.
- Reuse flowback

The reservoir wettability is a result of chemical equilibrium between the rock surfaces, formation water and hydrocarbon phases. During oil accumulation in a reservoir, oil displaces the water as the reservoir fills. As the oil fills the pore space it will displace bulk water, but a thin film of water remains on the mineral surface. The polar portions of the oil may be sufficiently attracted through electrostatic interactions and effectively adhere the oil to the surface. This adhesion may be strong enough to prevent the oil from moving during waterflooding. This has a direct impact on recovery.

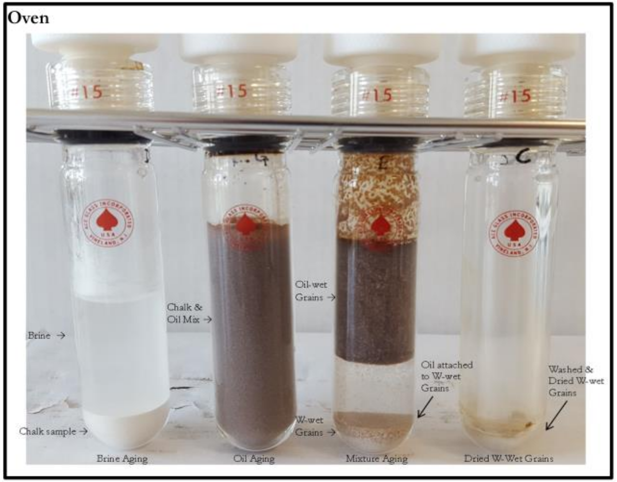
We see that if the reservoir is too oil-wet, the oil adheres to the rock, while if the reservoir is too water-wet the oil phase can snap off while moving through narrow pore throats that are coated with water. The optimum wettability is that which allows the most efficient movement of the hydrocarbon phase and maximizes recovery. This optimum wettability is a function of the pore throat distribution, mineral surfaces, and oil and water chemistry, thus unique to each reservoir. The initial wettability of the reservoir may be optimum, or may be more water-wet or oil-wet than optimal. We cannot change the rock surfaces or oil chemistry during waterflooding, but we do change the water chemistry. Water chemistry has a direct effect on the wettability and changing water chemistry can change the reservoir wettability.



Presenter's notes: To simplify the idea, there is a sweet spot that maximizes recovery. We see that if the reservoir is too oil-wet, the oil adheres to the rock, while if the reservoir is too water-wet the oil phase can snap off while moving through narrow pore throats that are coated with water. The optimum wettability is that which allows the most efficient movement of the hydrocarbon phase and maximizes recovery. This optimum wettability is a function of the pore throat distribution, mineral surfaces, and oil and water chemistry, thus unique to each reservoir. The initial wettability of the reservoir may be optimum, or may be more water-wet or oil-wet than optimal. We cannot change the rock surfaces or oil chemistry during waterflooding, but we do change the water chemistry. Water chemistry has a direct effect on the wettability and changing water chemistry can change the reservoir wettability.

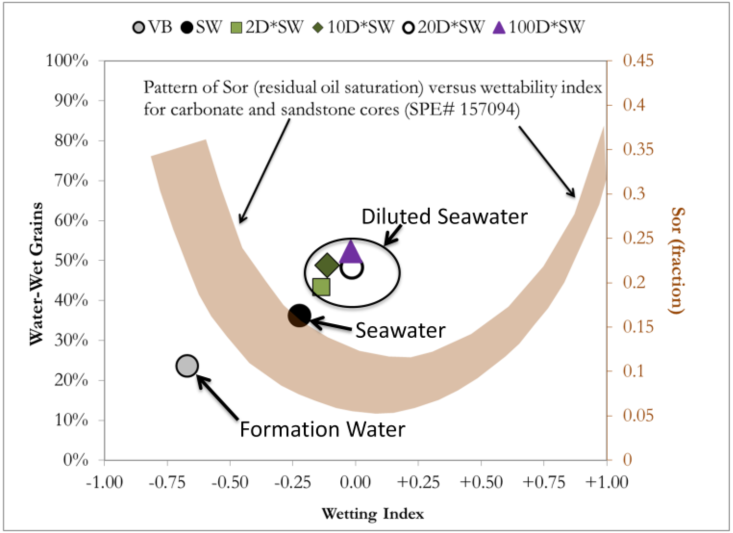
Lab Tests - Modified Flotation

Experiments to determine optimum chemistry
in the reservoir!!



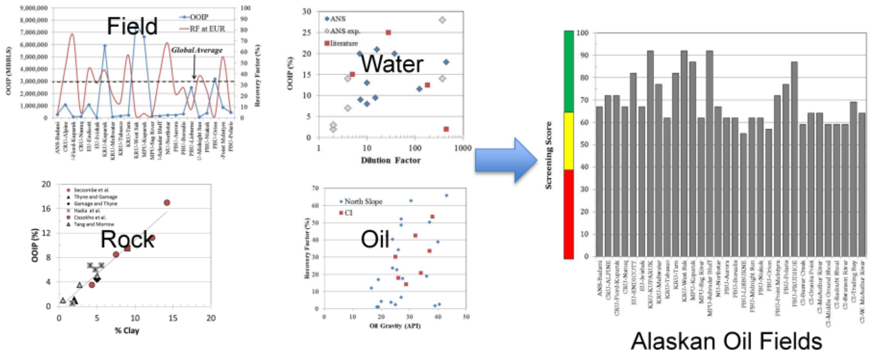
Presenter’s notes: method is simple, inexpensive and fast. Multiple experiments can be performed at temperatures up to 100°C and atmospheric pressure. Using a more complex experimental apparatus allows measurement at elevated T & P if desired. This technique is used to screen potential injection water chemistry and determine the best fluid chemistry. The results can also be used to calibrate geochemical modeling to aid in fluid design.

Example – Changes in wettability of chalk-oil-brine system for different brines



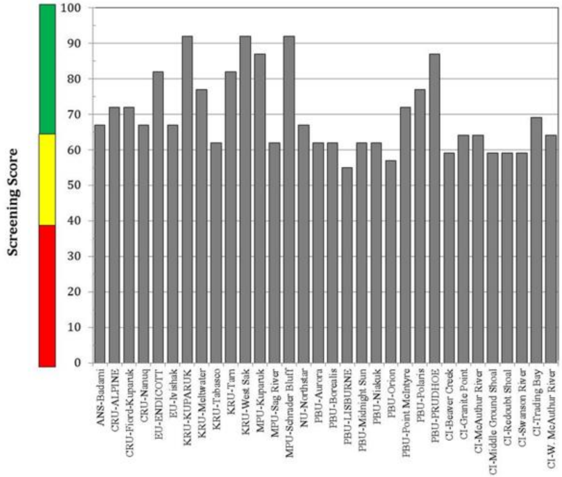
Alaskan Example - Screening for Good Candidates

- Empirical relationships used to screen candidate fields.
- Input rock, water, oil and field properties to algorithm and calculate aggregate weighted score.



Presenter's notes: Another practical application is in screening reservoirs to determine if wettability alteration is practical. In this case, we are using lab and field data from many cases to construct empirical relationships between increased recovery and rock, water and oil properties. Then we can use properties of target reservoirs to calculate an index (0-100) that predicts the likelihood that we can change wettability by changing water chemistry. If the target reservoir is a good candidate, our models can help design the water chemistry that will optimize wettability and increase recovery. The water chemistry (EOR fluid) is designed to avoid any formation damage, if the produced water salinity is lowered, may be able to remove existing scale.

Screening Results



Best Candidates

- The best candidates were fields with good WF recovery and high OOIP.
- Prudhoe, KRU-Kuparuk, CRU-Alpine, EU-Endicott and PBU-Lisburne on the North Slope
- All the fields in the Cook Inlet appear to be attractive candidates and the potential incremental production would be 360 million barrels.
- On the North Slope the potential incremental oil recovery may exceed 3.7 billion additional barrels.

Questions?

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