A systematic methodology for increasing recovery from petroleum reservoir by wettability alteration

Geoffrey Thyne

Turning Brown Fields to Gold Fields

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Acknowledgements

- Pat Brady
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- Haifeng Jiang
- Paulina Mwangi
- Mao Romero
- Adeel Sohal

Outline

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

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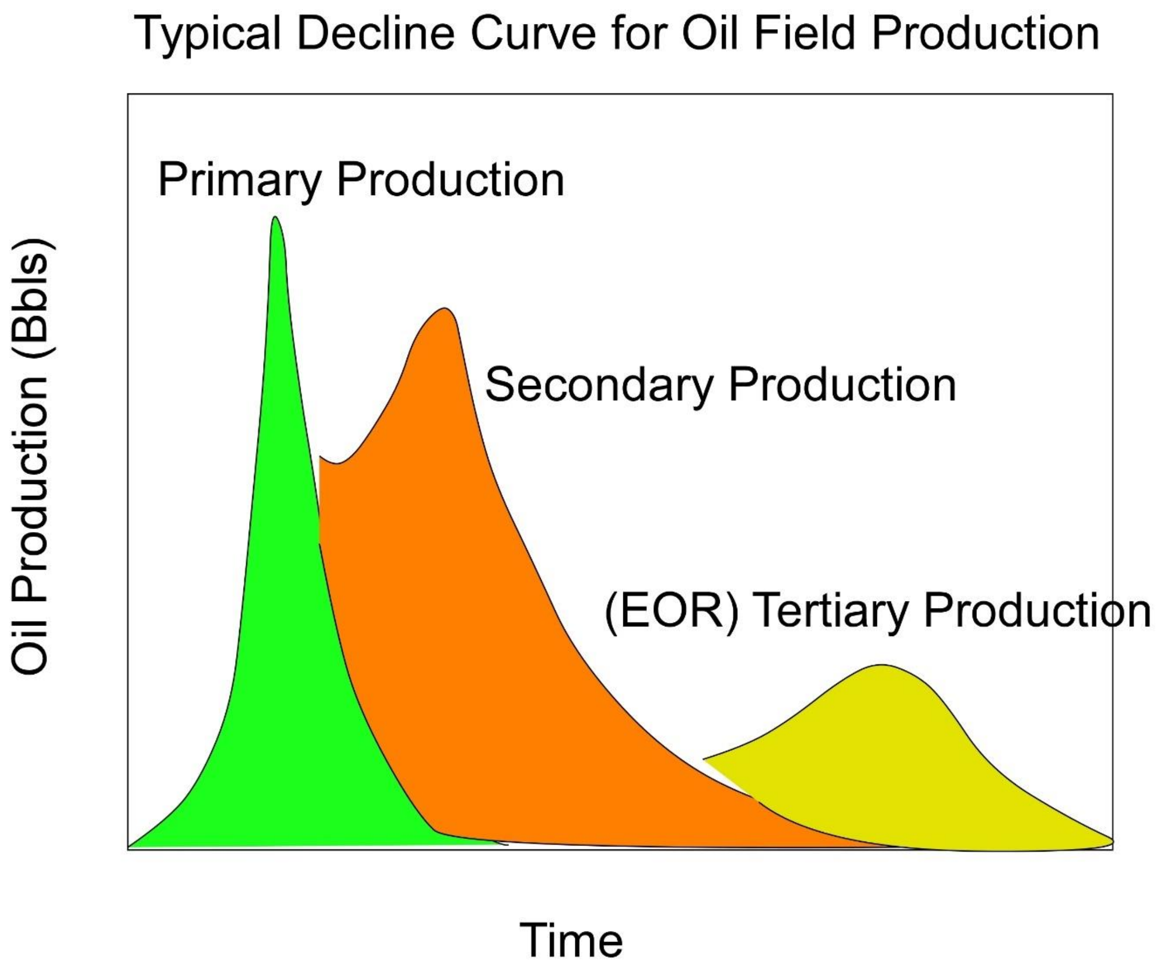
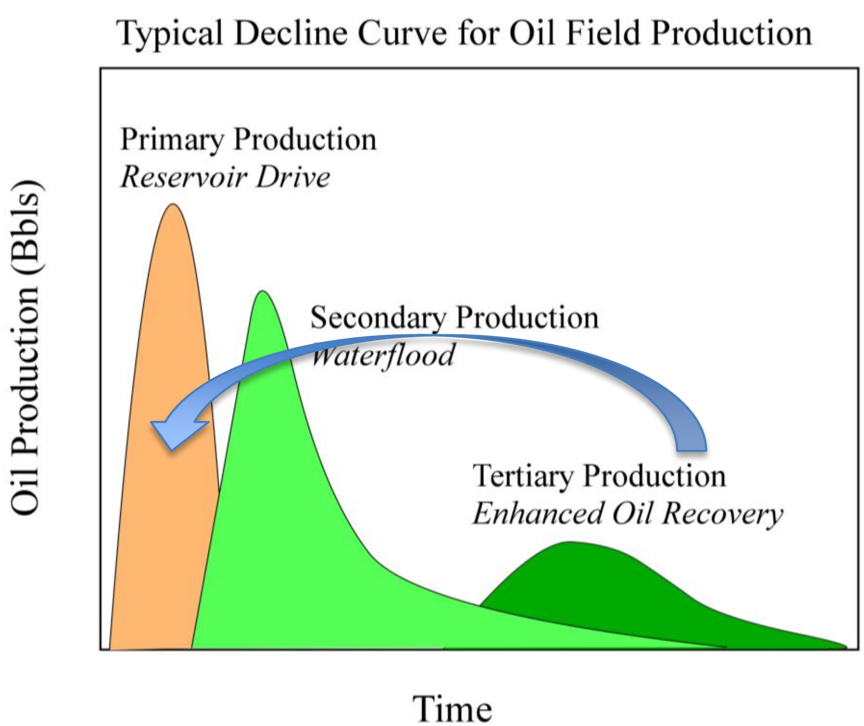
Oil Production



Take Home Message

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



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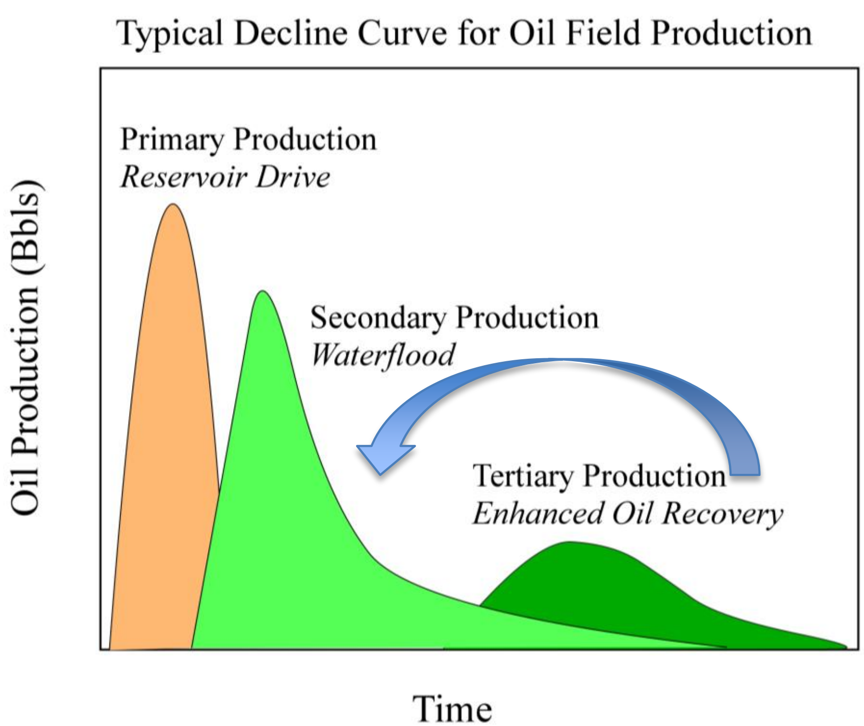
Take Home Message

- Wettability Alteration can be employed at any stage.
- Can be applied during regular waterfloods.



Conclusions

- The LSE is due to wettability change.
- Reservoir potential can be evaluated by screening.
- Reservoir wettability can be quantified using standard geochemical surface modeling.
- Experimental programs can provide reservoir-specific data for waterflood design to optimize recovery.

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Why use this technique?

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- No Change in Normal Operations
- Potential Increase in Recovery is High.
- Cost is Low.
- Works in Clastics and Carbonates.
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Why use this technique?

- North slope pilot test increased recovery by 15% OOIP.
- Shell waterflood in Syria increased recovery by 10-15% OOIP.
- Ekofisk waterflood increased recovery by 30% OOIP.

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Why use this technique?

- Evidence from Bakken, Milk River and Wolfcamp that fresh water does not optimize recovery.
- Instead of fresh water formulations, brackish water formulations may improve production.
  - Water source costs are lower.

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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

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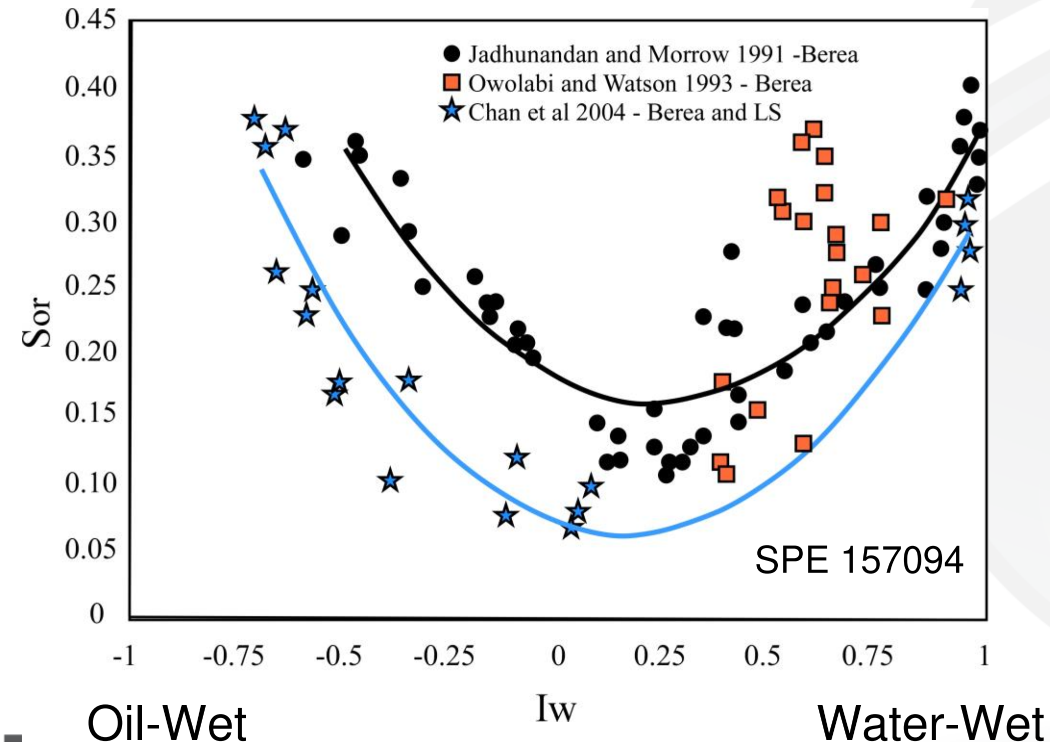
Why do we care about wettability?

- Wettability is the tendency of oil or water to adhere to the reservoir rock surfaces.
- Wettability is recognized as a major control on oil mobility and amount of recovery.
- The macroscopic fluid behavior is controlled by microscopic interactions between oil, water and rock surfaces.
- Normally, we try to improve wettability by adding surfactants (lower interfacial tension) to increase recovery.

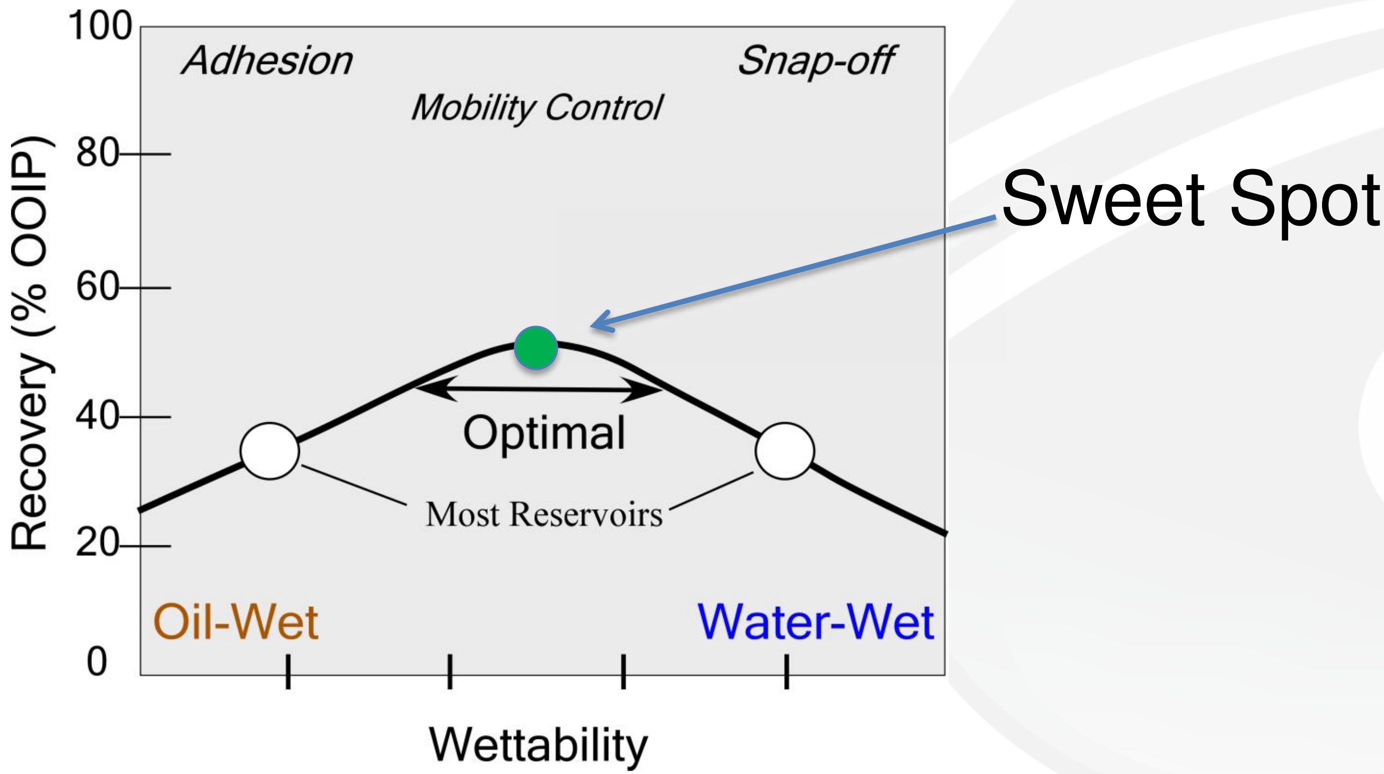
Wettability

- 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.”



Wettability

Recovery = Oil Release + Oil Mobility



How do we link wettability to salinity?

- Wettability is directly linked to recovery.
- Wettability is the chemical equilibrium between water, rock and oil.
- Wettability is the balance of forces between the oil-water and water-rock interfaces.
- Change in water chemistry changes the forces (interfacial tension) between surface and oil:
  - 1 – electrostatic (attractive or repulsive), and
  - 2 – van der Waals (attractive).

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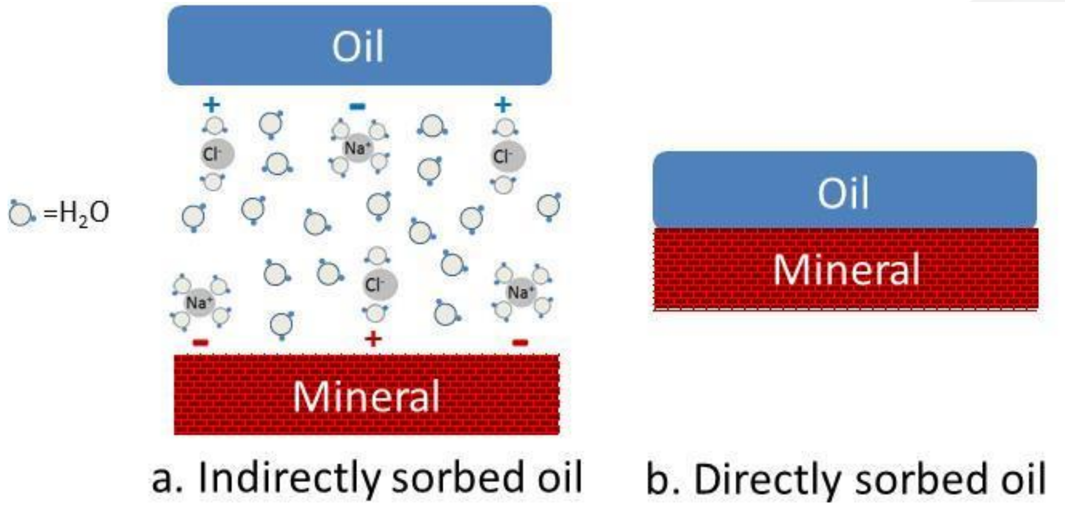
Wettability Models

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



From Brady and Thyne, 2017

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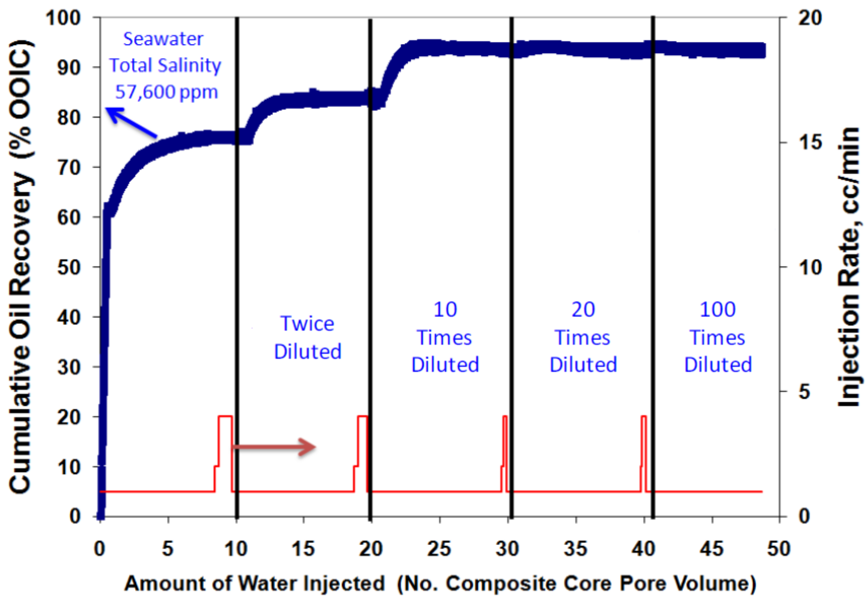
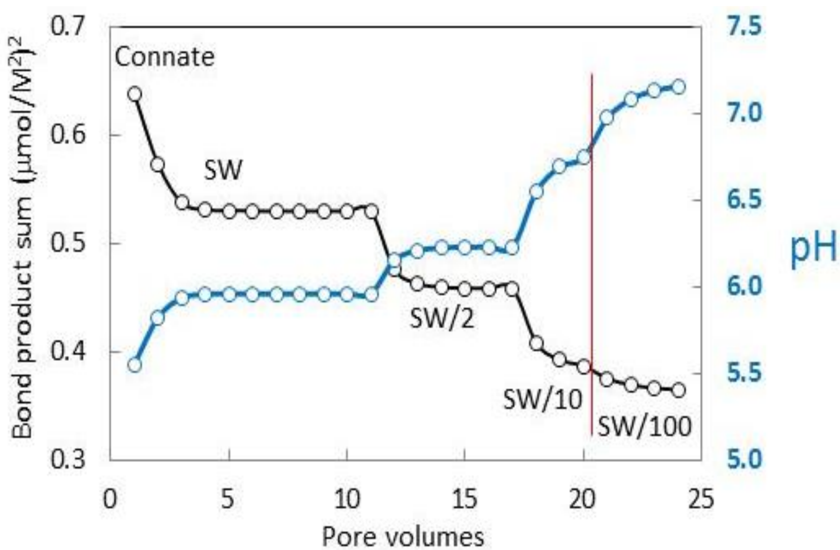
Wettability Models





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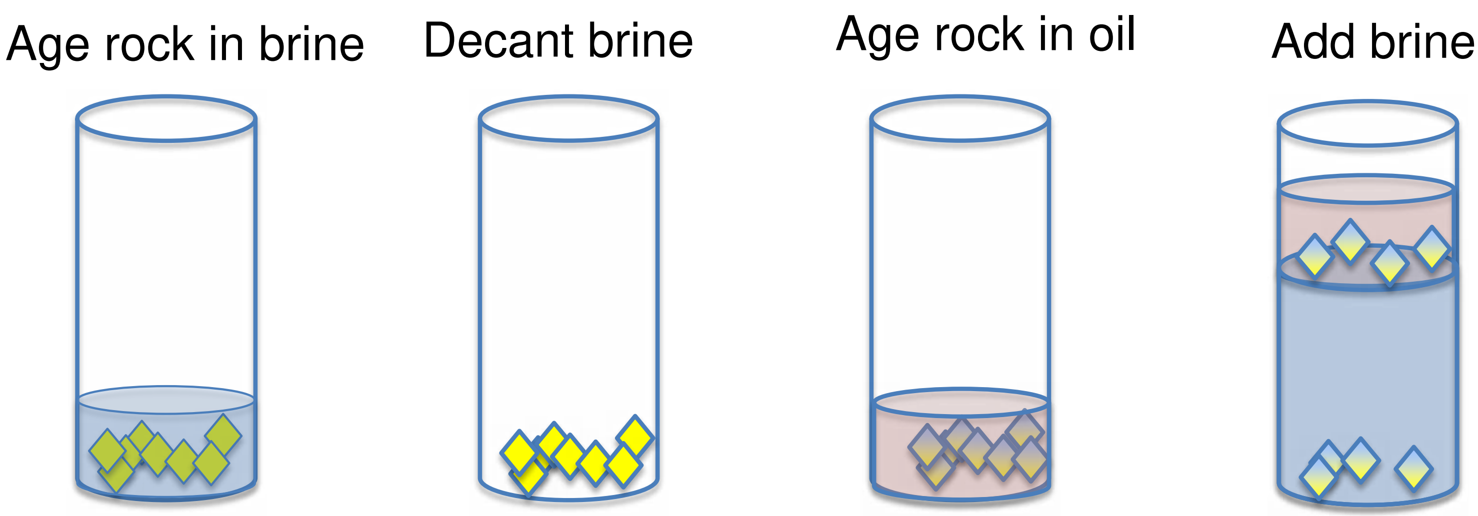
Laboratory Method

- Modified Flotation Test (Mwangi et al. 2013)
- 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.



Lab Tests - Modified Flotation

Initial separation

Rock powder floats in oleic phase

After 24 hours

Courtesy of Paulina Mwangi, PhD candidate, LSU

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Key Observations

Ove
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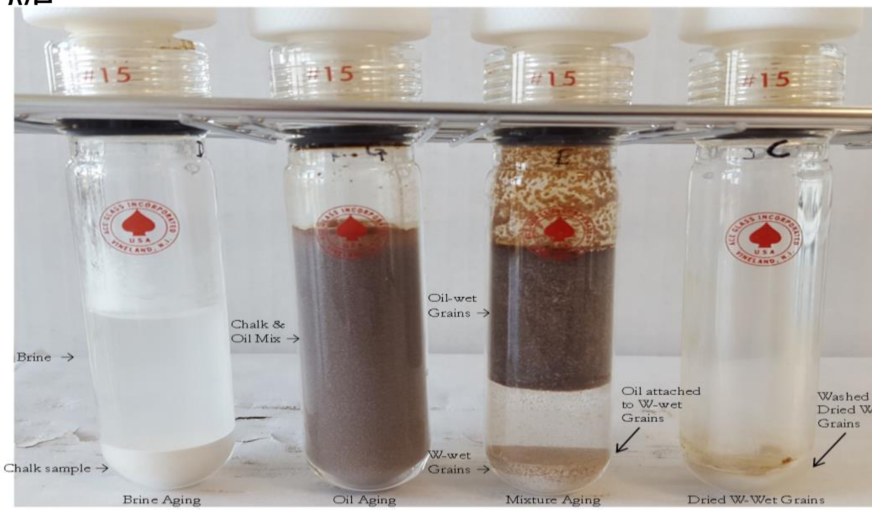
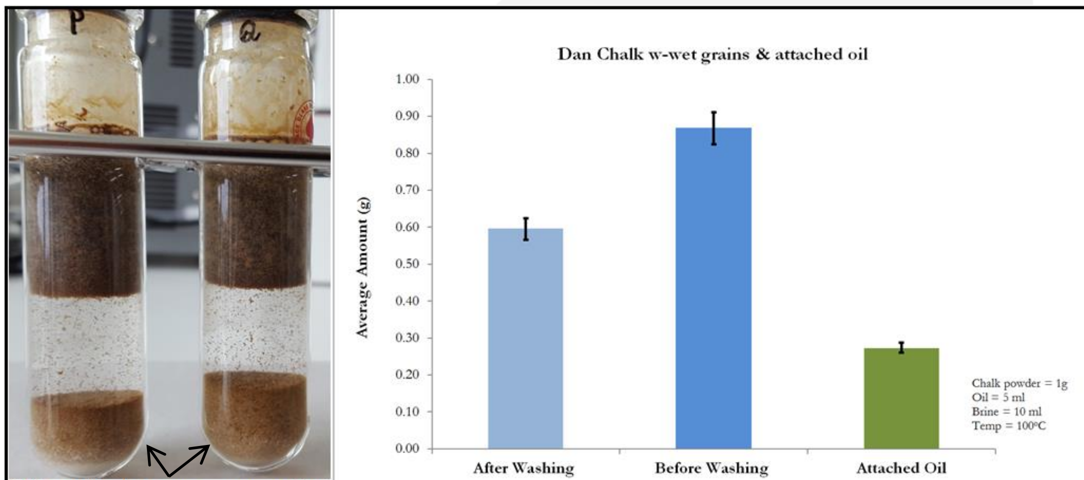


Experiments show some oil is mobile and some is retained.

Sohal et al. – 2017



Oil attached to water-wet grains

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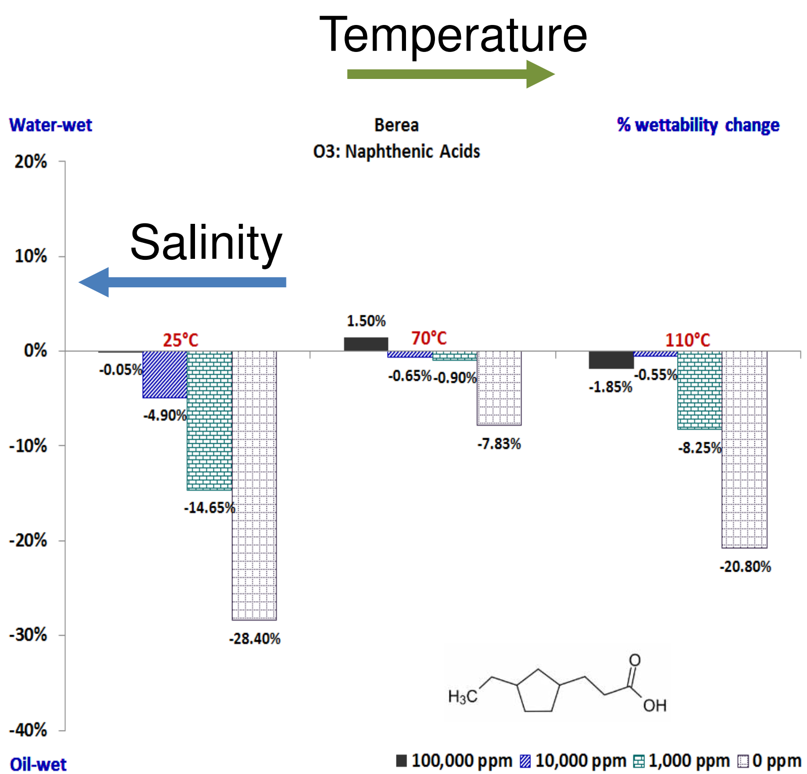
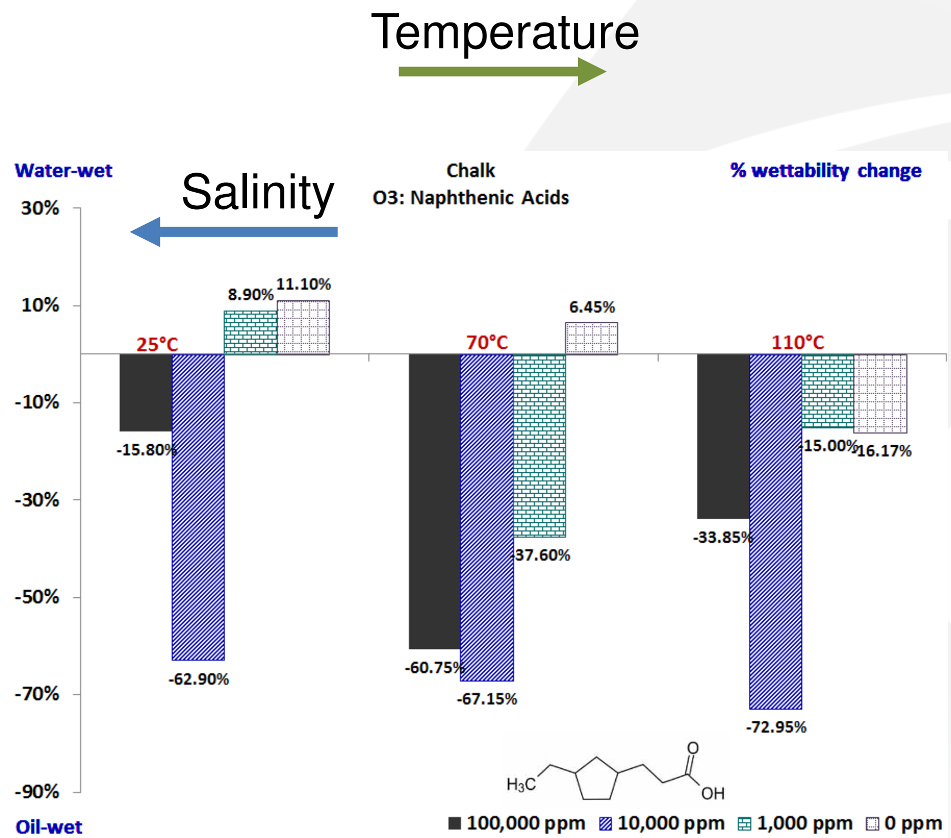
Berea Sandstone vs. Chalk (limestone)

Naphthenic Acid





Change in wettability is normalized relative to pure decane

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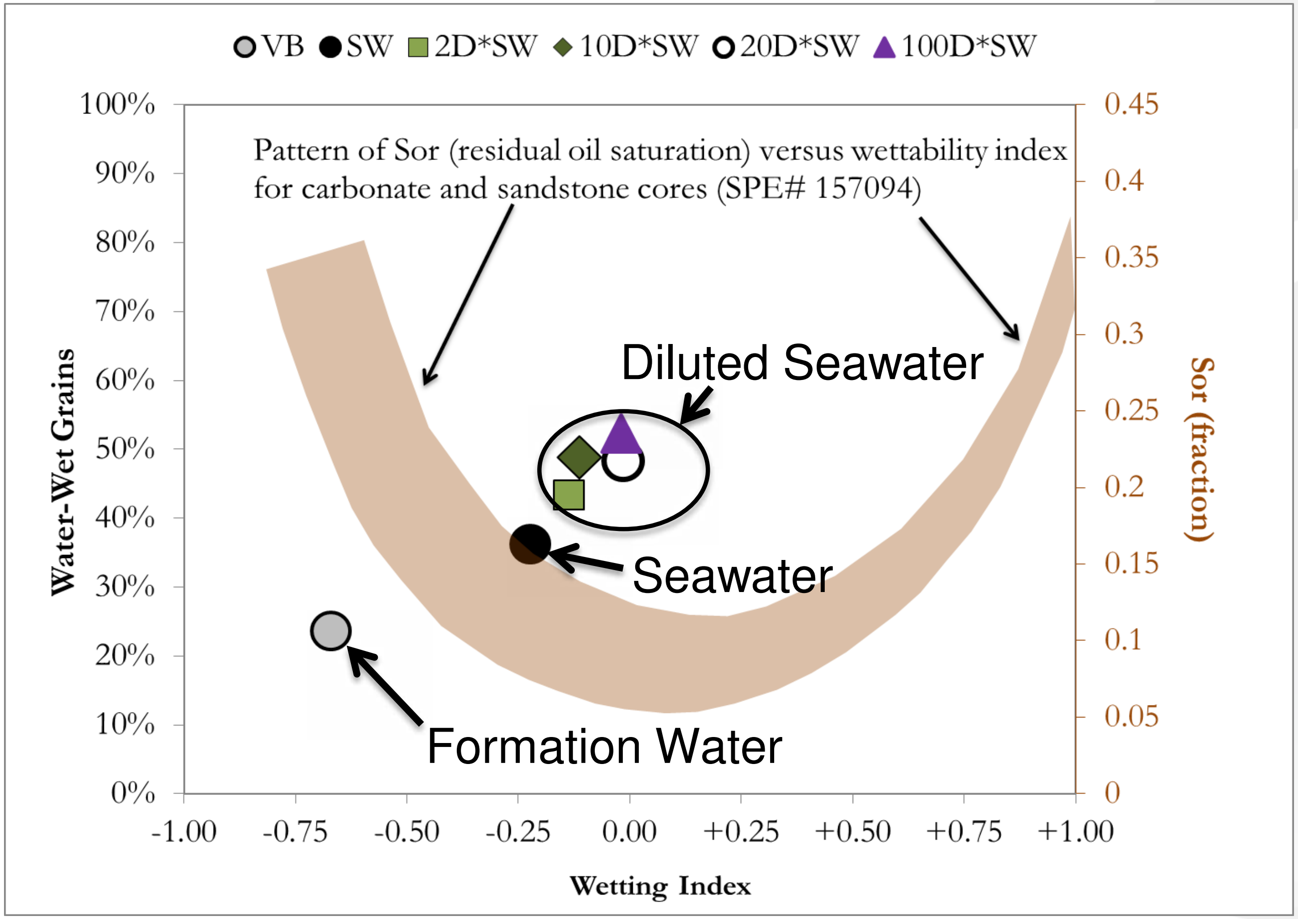
Data courtesy of Paulina Mwangi, PhD candidate, LSU, Petroleum Engineering

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



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ESal™ Work Flow

- Screening and Scoping
  - Screening – evaluate field for compatibility with process
    - Empirical model generates quantitative score based on field's 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
- Lab Tests
  - Wettability Measurements
    - Determine initial wettability and optimum chemistry
- Deployment
  - Model to assess other fluid-fluid-rock interactions
  - Design injection fluid chemistry for optimum wettability
  - Select water source
  - Generate water treatment specifications
  - Install equipment

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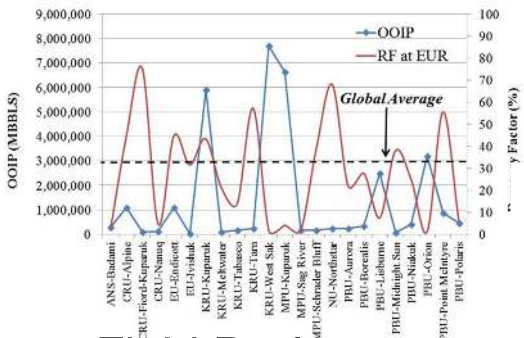
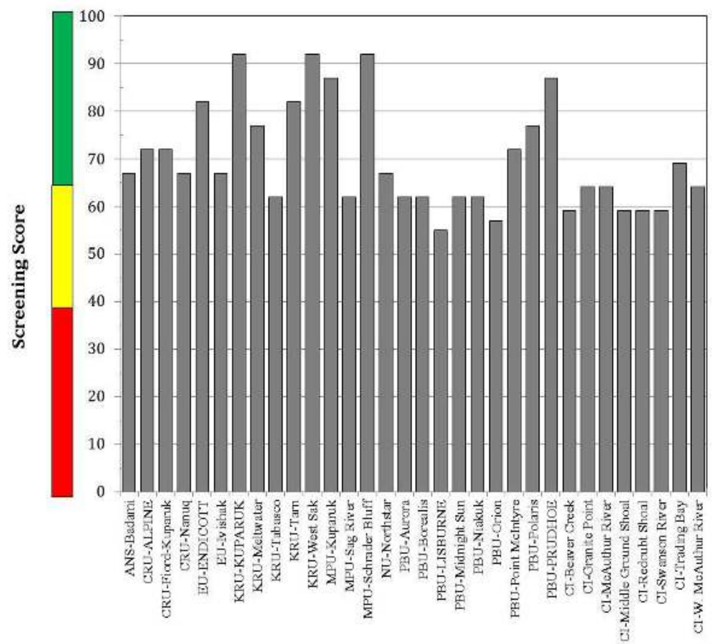
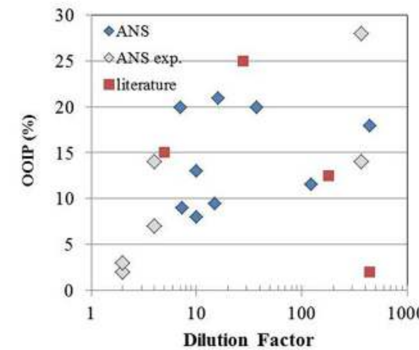
Screening for Good Candidates

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

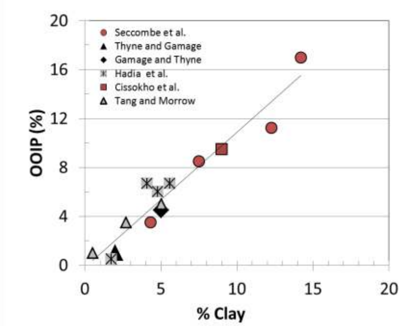


Field Performance

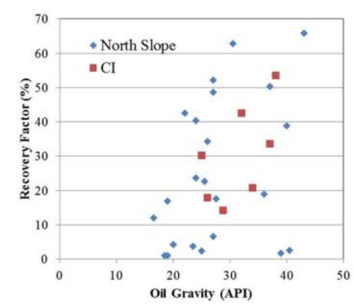




Water



Rock



Oil Properties

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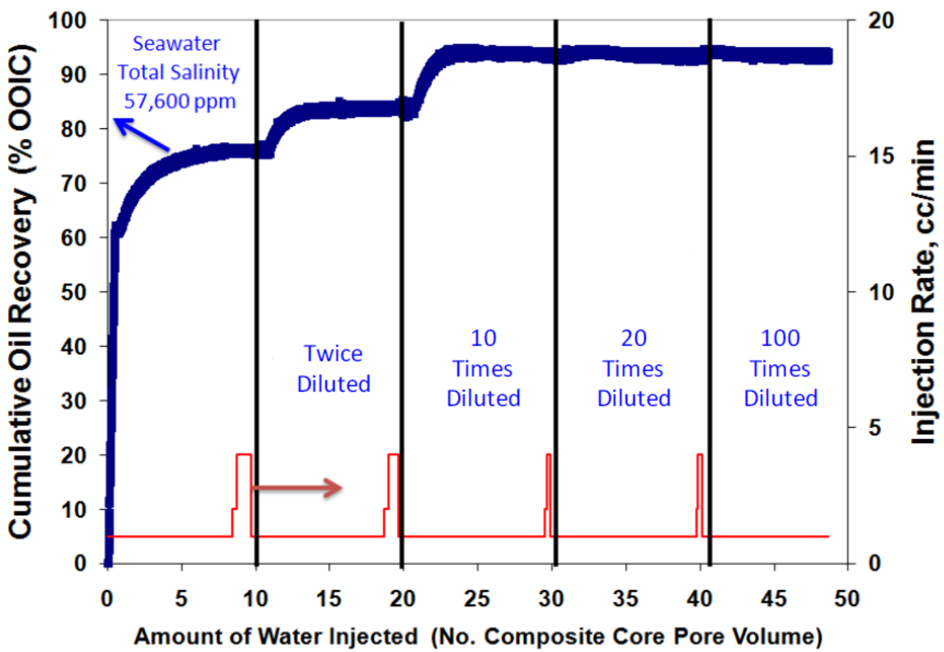
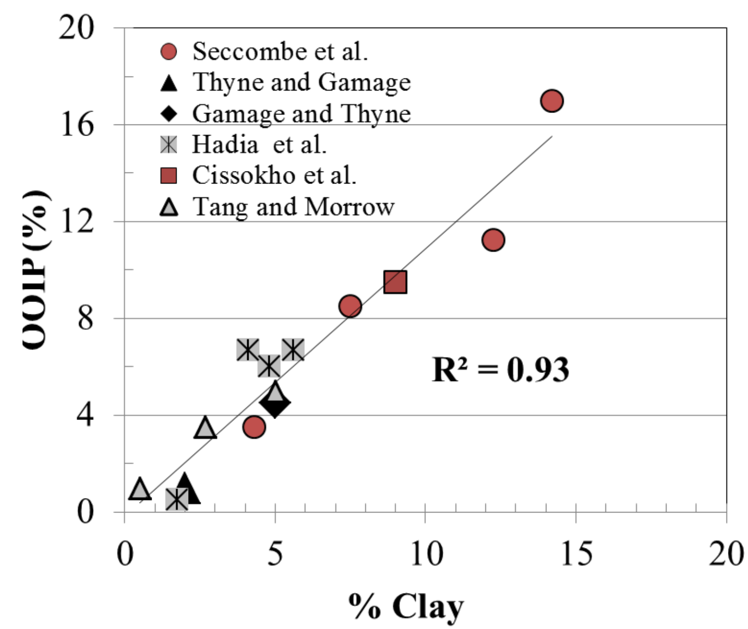
Questions?


WYOMING WIND SOCK
STRENGTH OF WIND FROM CHAIN ANGLE
0° BROKEN—NOTIFY METEOROLOGIST
30° FRESH BREEZE
45° GENTLE ZEPHYR
60° HURRICANE IN AREA
75° BEWARE OF LOW FLYING TRAINS
90° WELCOME TO BIG WONDERFUL WYOMING

Dilution benefit plateau
clay control in SS





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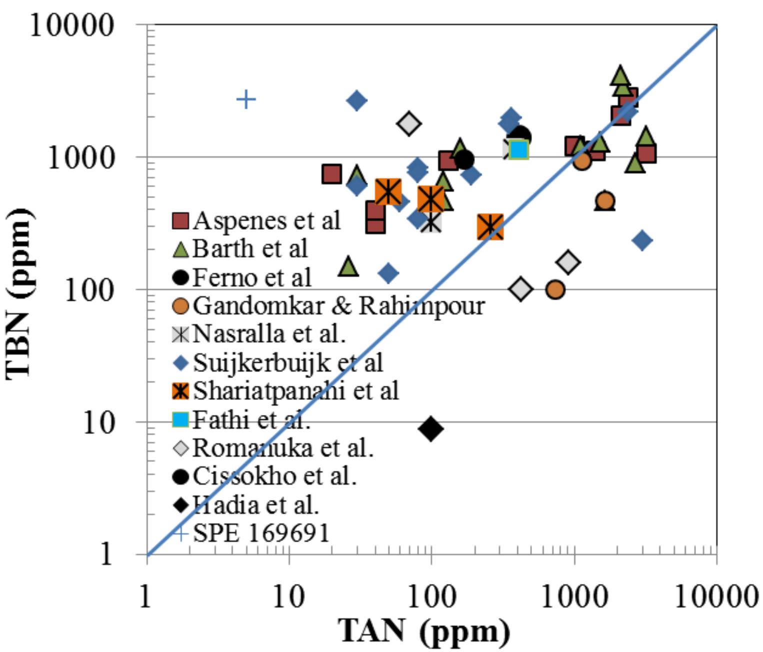
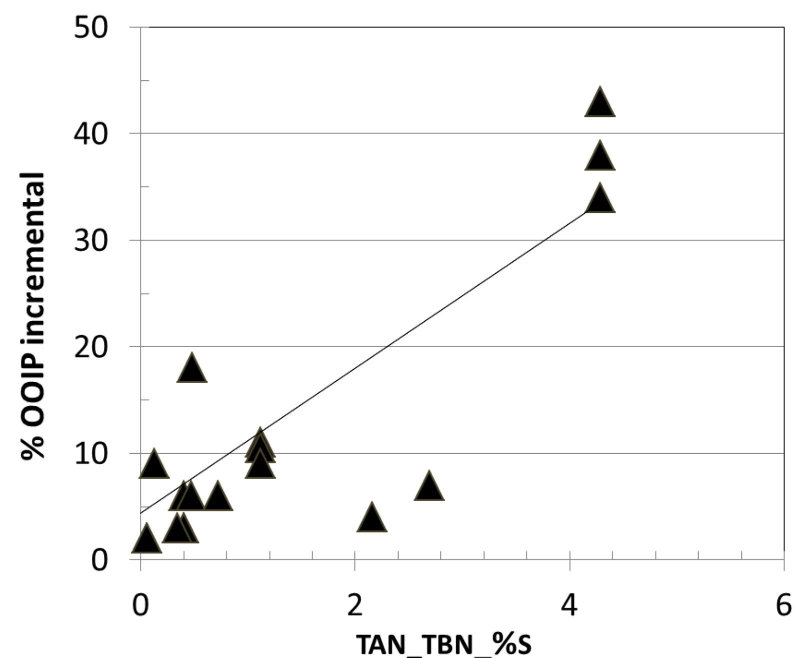
Oil must have polar components





Technique Validation

- Approach: compare the trends between Dual Drop Dual Crystal (DDDC) and MFT results
- Test 1: wettability effects due to sulfate concentration
  - Materials: dolomite rock, yates oil, and yates brine
  - DDDC results from a study by Kasmaei and Rao (2014)

Sulfate Concentration (g/l)	MFT Wettability Result
0 g/l	Oil-wet
1.1g/l (1x)	Oil-wet
2.2g/l (2x)	Fractional
4.4 g/l (4x)	Wet
10.8 g/l (10x)