Engineered Water for Improvement of Oil Recovery from Fractured Reservoirs

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Oil & Natural Gas

2020 Integrated Review Webinar

Program Overview

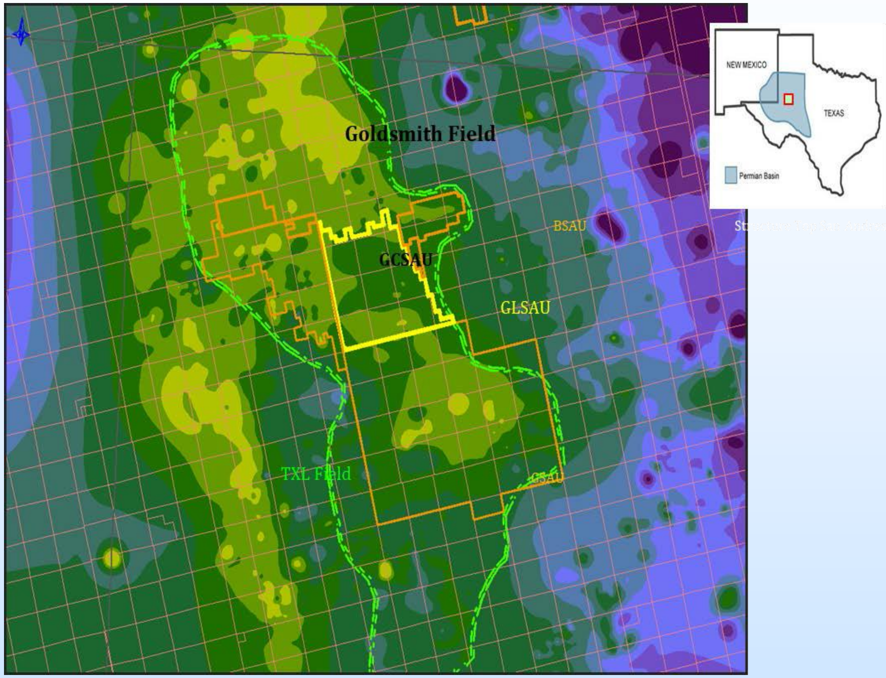
- Funding
  - DOE: $7,919,227
  - Cost Share: $1,979,808
- Overall Project Performance Dates
  - October 2019 – September 2023
- Project Participants
  - The University of Texas at Austin
  - Kinder Morgan CO2 Company
- Goal: Field test an engineered water (ionic composition, surfactant or nanoparticles) injection to improve oil recovery from a carbonate reservoir

Objectives

- To identify a modified brine composition to enhance oil recovery from Goldsmith-Landreth San Andres Unit (GLSAU) in West Texas
- To field test the novel EOR processes
- To evaluate the field test
- To develop criteria to apply these chemical processes economically in carbonate reservoirs

Background: Technology

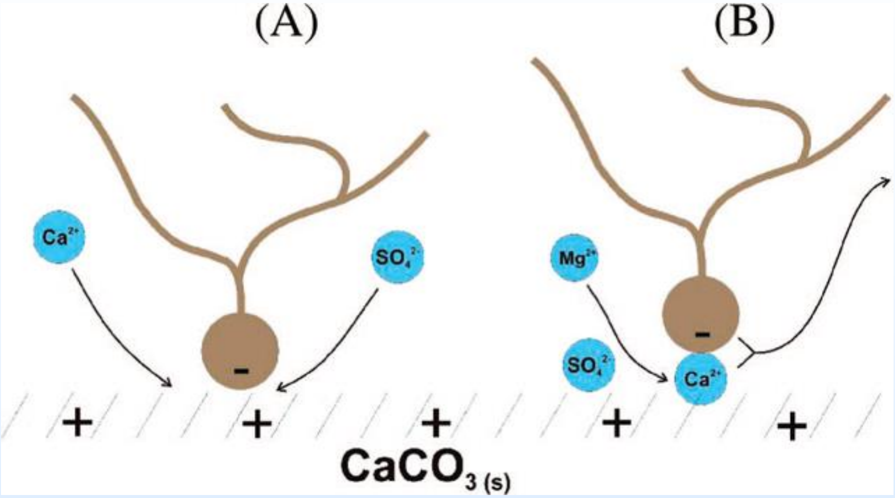
- Cumulative oil recovery < 20%
- Oil is bypassed due to
  - -heterogeneity
  - -oil-wettability
- Improve oil recovery by imbibing water into the bypassed regions
- Improve water-wettability by
  - -ions
  - -surfactants
  - -nanoparticles

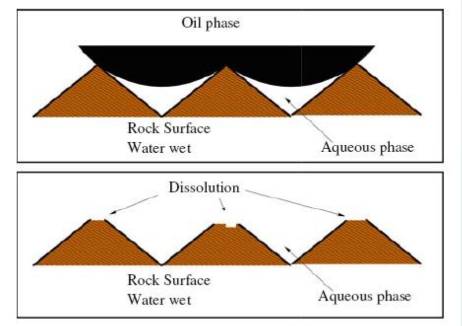


- Vuggy, slightly fractured dolomite
- Produced water salinity: 60,000 ppm
- T ~35 ºC

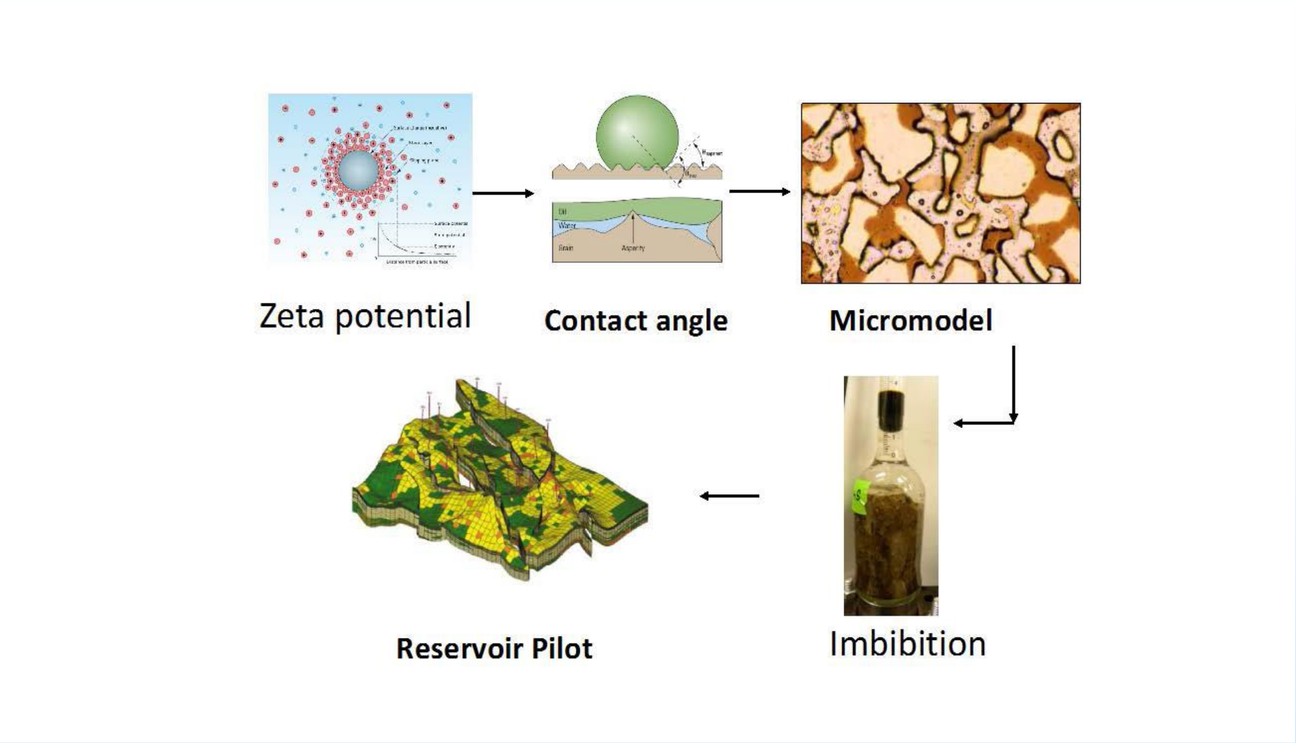
Wett. Alt. Mechanisms in Carbonates

- Austad et al. (2006), Yousef (2010): Exchange of SO_4 ions with adsorbed naphthenic acid groups, low salinity
- Austad et al. (2000): Ion-pair formation of cationic surfactants with the naphthenic acid groups
- Gupta & Mohanty (2009): Micellar solubilization of naphthenic acid groups with anionic surfactants
- Chen & Mohanty (2011): Mineral surface dissolution





Advantages & Challenges



- Advantages
  - Depleted, low permeability, oil-wet, carbonate
  - Fractured and heterogeneous reservoirs
- Challenges
  - Low temperature, high salinity, rate of oil recovery

Technical Approach

- Task 1: Project Management & Planning (Month 1)
- Task 2: Chemical Formulation Development (Month 1-12)
- Task 3: Reservoir Characterization, Design of SW Tests (Month 1-12)
- Task 4: Single-Well Field Tests (Month 13-24)
- Task 5: Multi-Well Test Design (Month 25-36)
- Task 6: Multi-Well Field Test (Month 37-48)
- Task 7: Field Deployment Strategy (Month 37-48)

Sample Analysis

- Rock Mineralogy
- Oil Properties
- Brine Compositions

Salinity Optimization

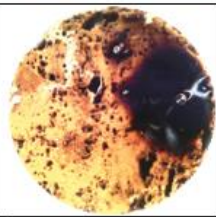
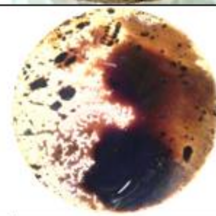
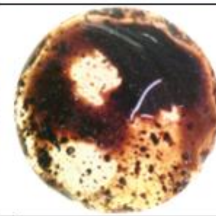
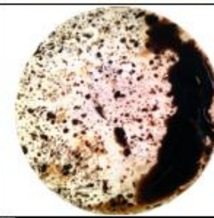
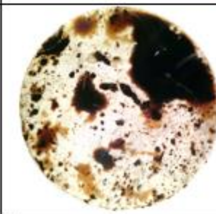
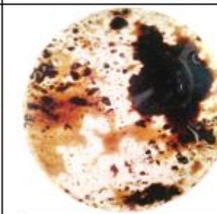
- Zeta Potential
- Contact Angle

Surfactant Screening

- Aqueous Stability
- Contact Angle
- Interfacial Tension
- Imbibition, core flood

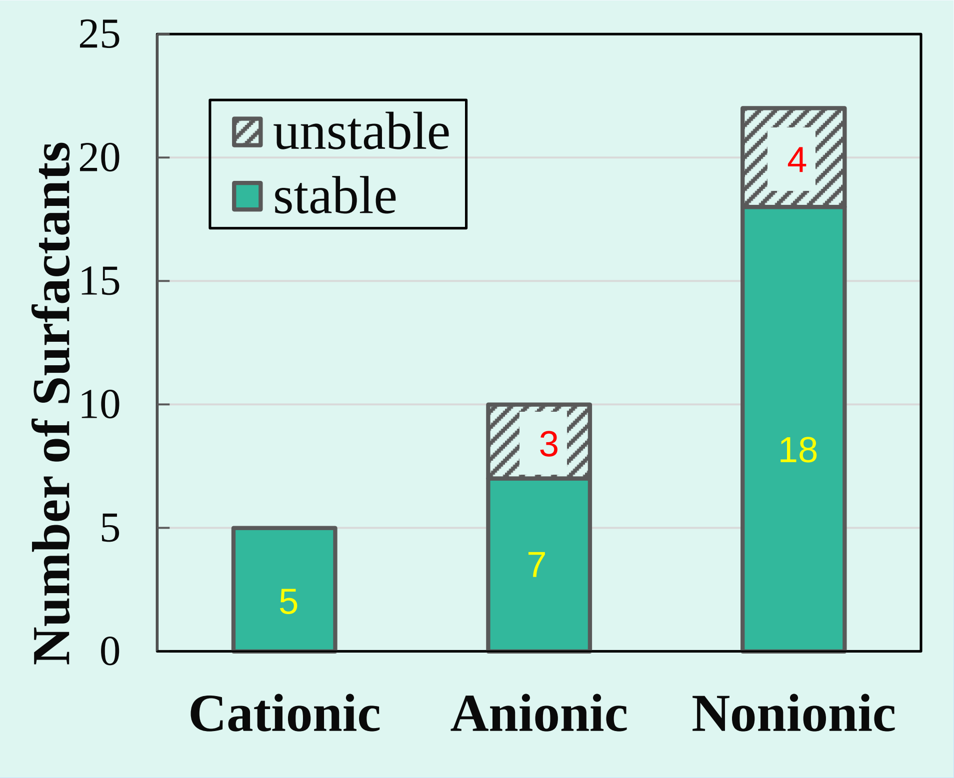
Micromodel Study

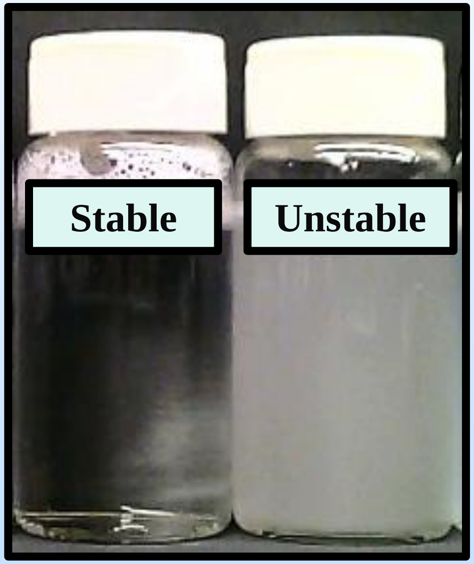
Progress: Task 2

Dilution	PW	PW/2	PW/4	PW/8	PW/16	PW/32
CA test side view						
CA test top view						
Post-CA (dark area)						
Post-CA (clean area)	N/A					

Salinity Optimization: Produced water/16

Surfactant Screening: Aqueous Stability

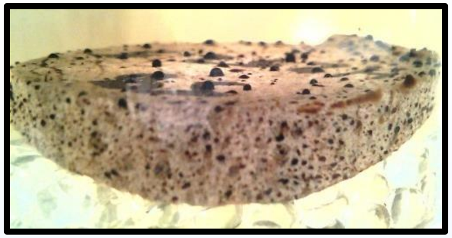


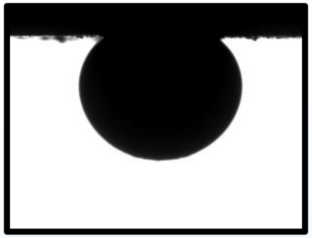


30 out of 37 surfactants are stable

Surfactant Screening: CA & IFT

Aspiro 6420

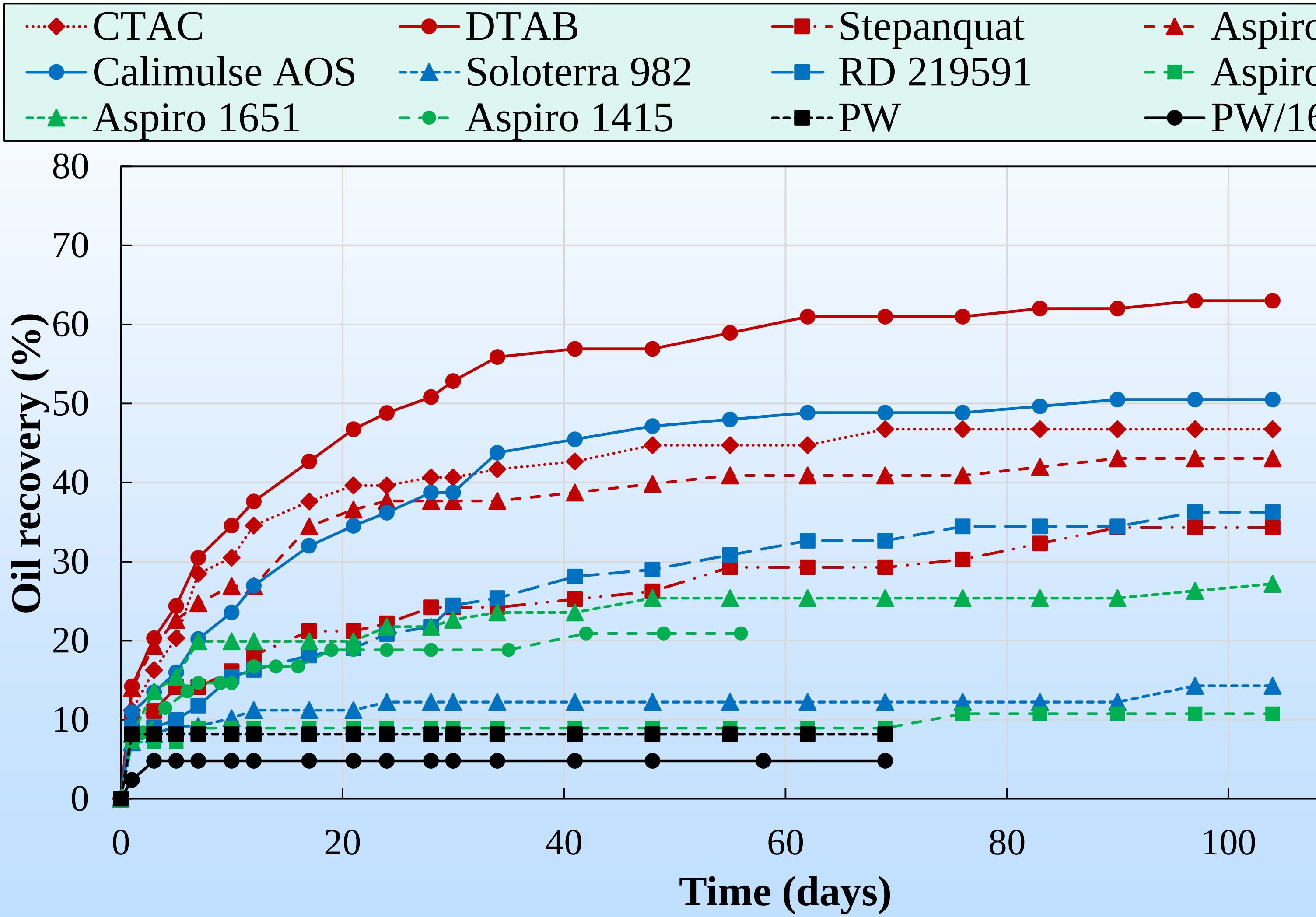




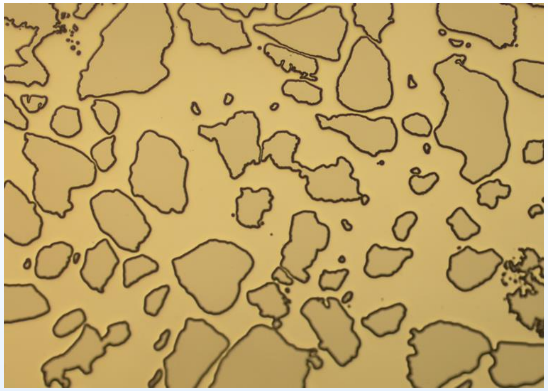
Calfax 16L-35

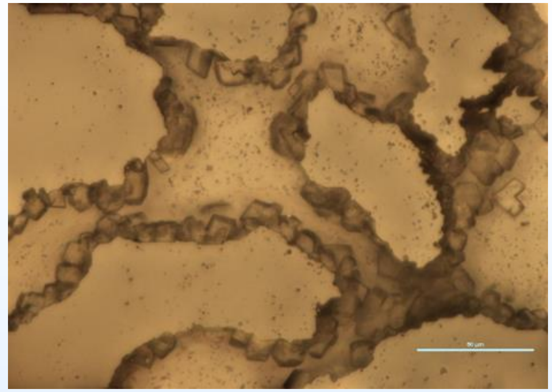
Surfactant	Type	pH	Advancing CA (°)	IFT (mN/m)	
				Mean	SD
STEPANQUAT 3712W	Cationic	7.9	95-120	1.942	0.007
CTAC	Cationic	7.93	80-115	0.861	0.039
DTAB	Cationic	8.38	85-115	1.696	0.065
Aspiro 6420	Cationic	3.92	80-110	0.210	0.042
Soloterra 982	Anionic	7.7	105-120	2.597	0.018
Calimulse AOS	Anionic	8.6	N/A	0.872	0.015
RD 219591	Anionic	7.25	N/A	0.186	0.021
Aspiro 1275X	Non-ionic	7.64	N/A	3.588	0.008
Aspiro 1415X	Non-ionic	7.56	120-130	1.720	0.020
Aspiro 1651X	Non-ionic	7.46	N/A	1.749	0.004

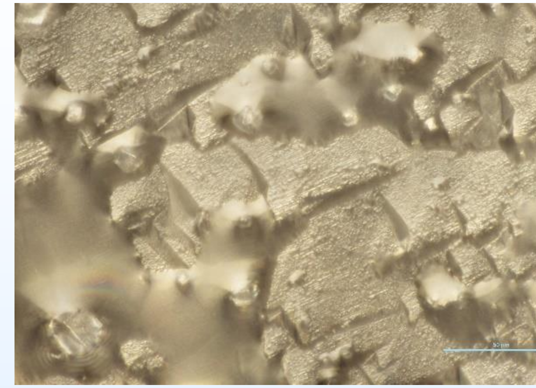
Imbibition Test: Surfactants in PW/16



Chemically Functional Micromodel

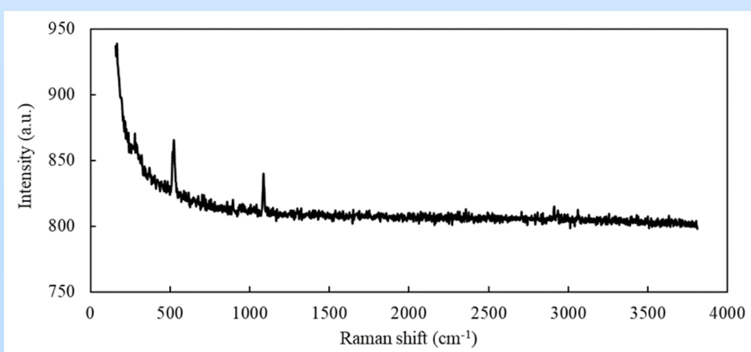




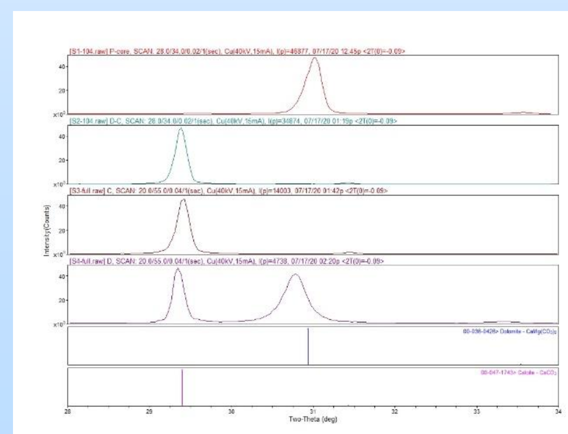


- Calcite deposition
- Dolomite conversion

Raman

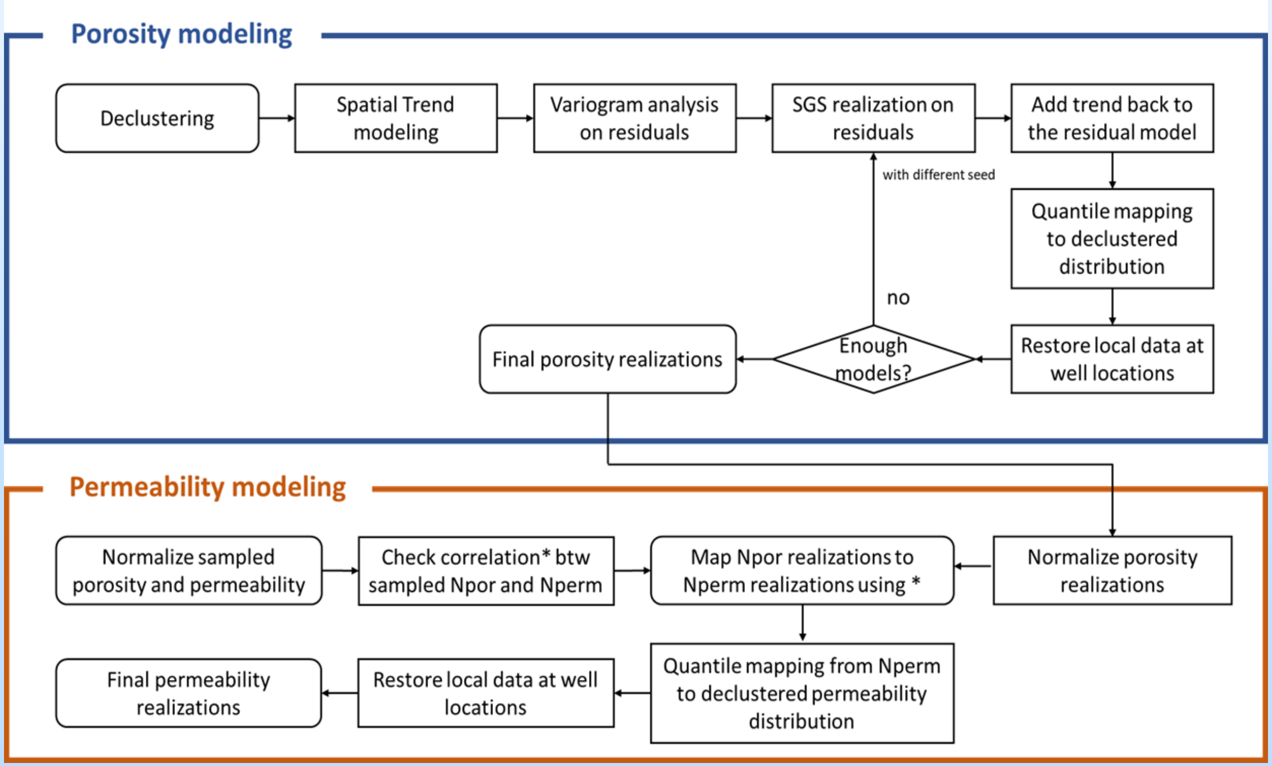


XRD



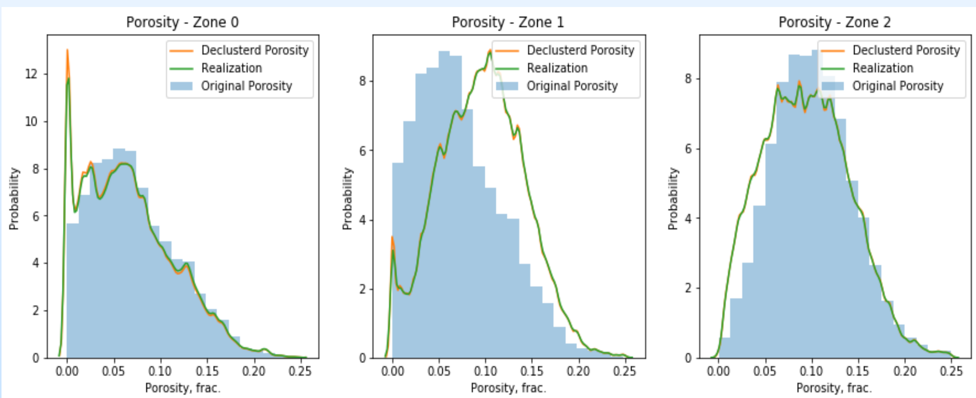
Task 2: Reservoir Characterization and Design of Single-Well Test

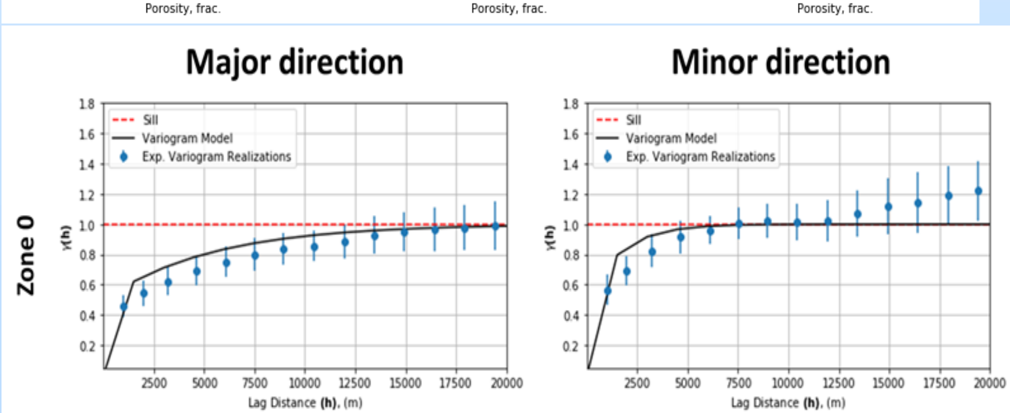
a. Developed subsurface data workflows for data checking, debiasing and scale corrections, and spatial continuity modeling.
b. Calculation of multiple stochastic models integrating debiased statistics, expert knowledge and all salient uncertainty sources.



Subsurface Data Analytics and Stochastic Heterogeneity Modeling

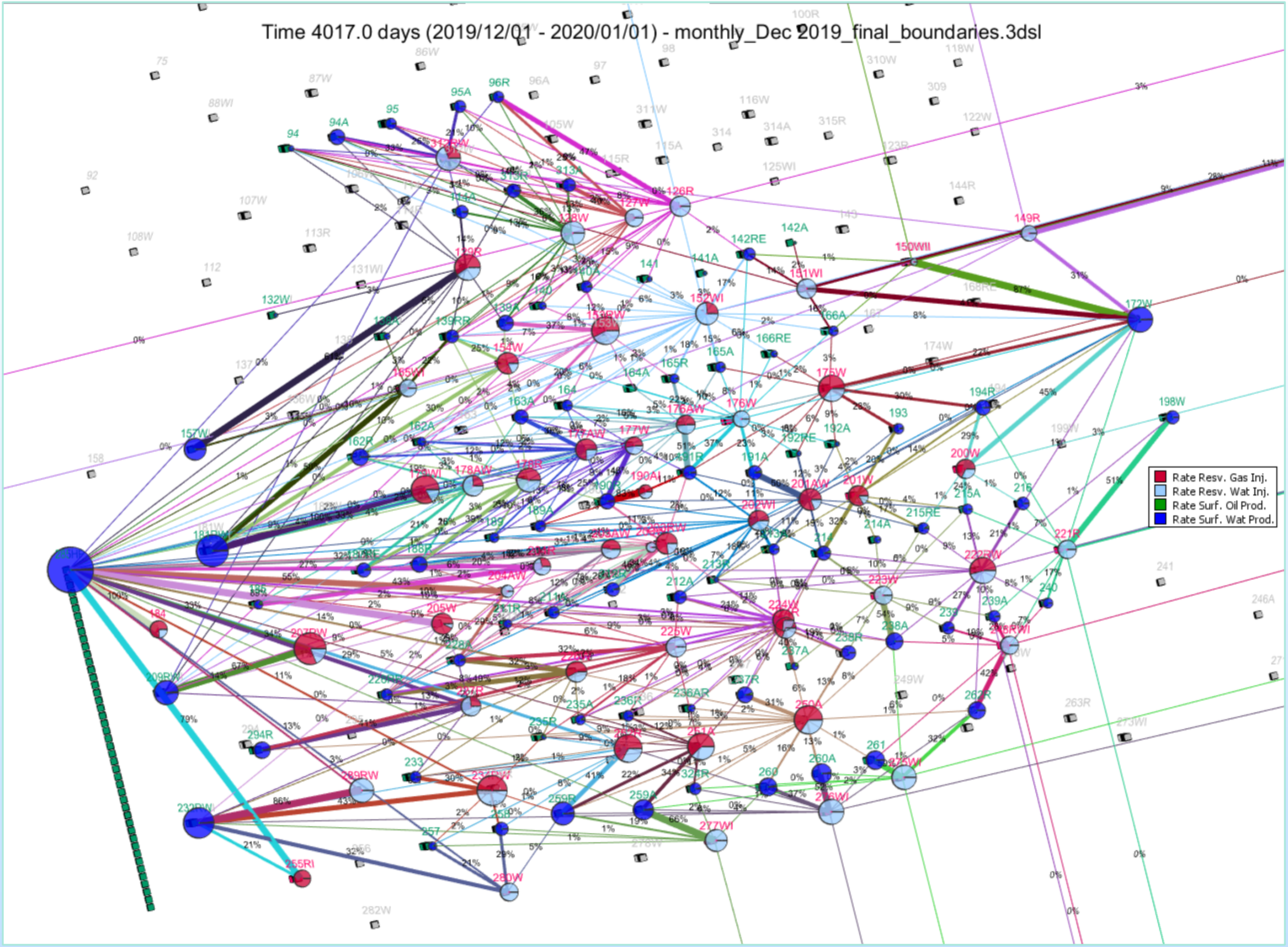
c. Workflow performance metrics have been met for planned workflow development and model calculation, along with quantitative metrics to evaluate model performance.
d. Current focus is on identification, prioritization of local study candidates to direct detailed physics-based modeling.





Quantitative model checking with representative, corrected target statistics.

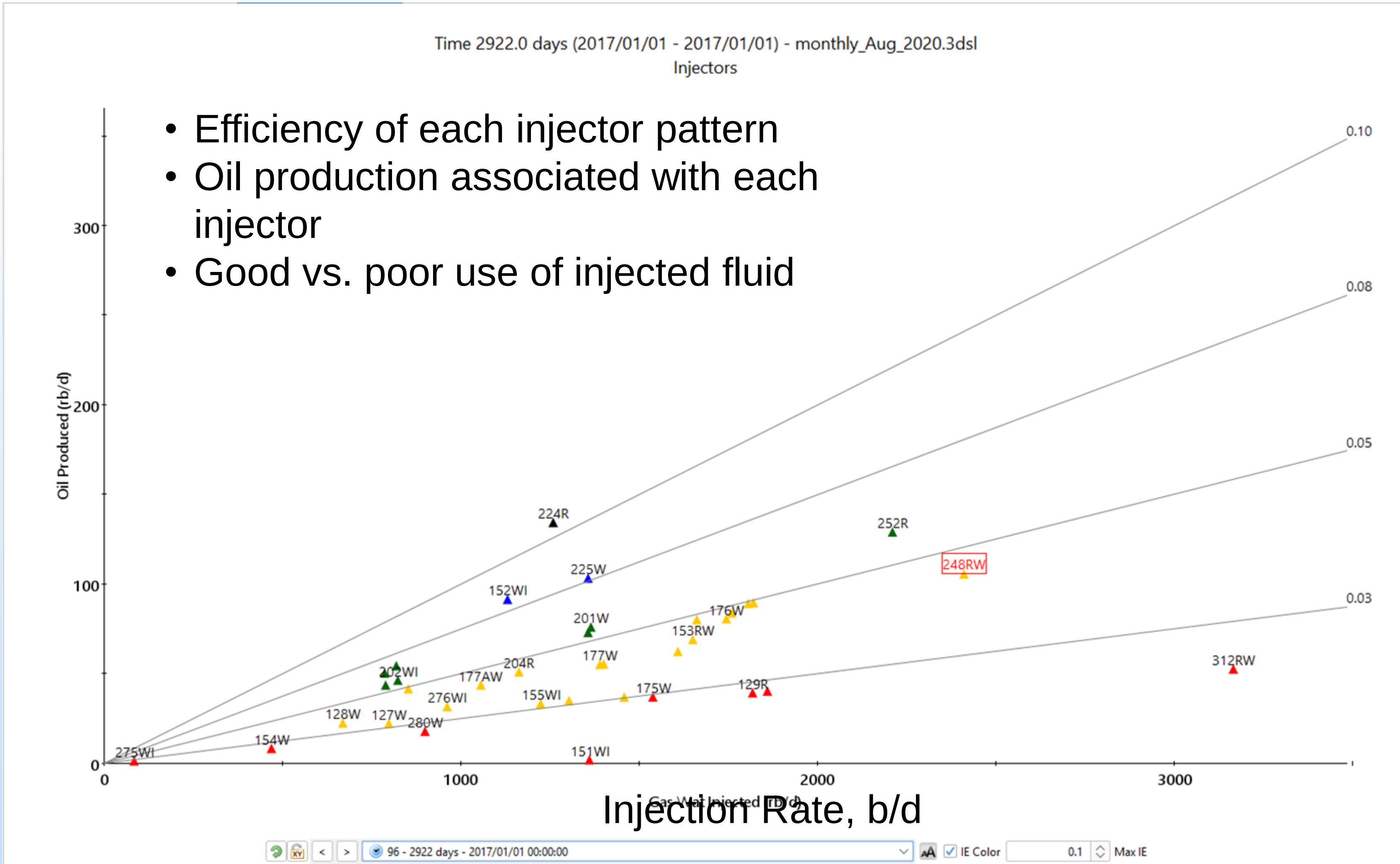
Model Results: Flux Pattern Map



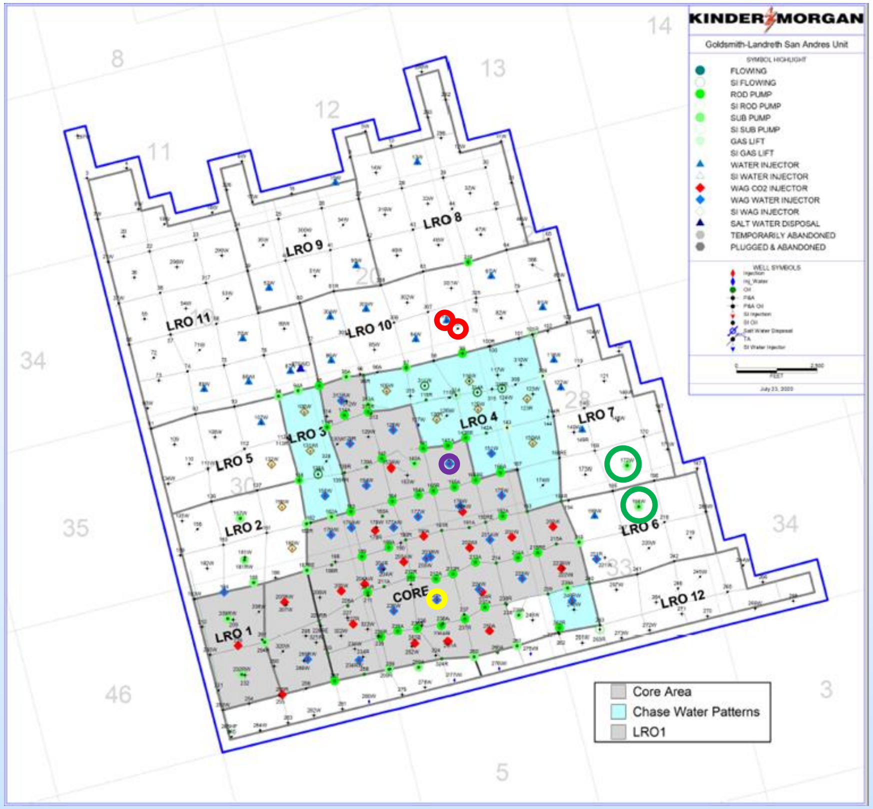
- Streamline model
- Rates between well pairs
- Oil allocation to inj-prod pairs

Model Results: Injection Efficiency

- Efficiency of each injector pattern
- Oil production associated with each injector
- Good vs. poor use of injected fluid



Candidates for Well Tests



- ❑ Initial screening yields following candidates for potential well test
- ❑ Candidates may change upon further scrutiny after model analysis

<u>Single well test (Huff & Puff type)</u>

- 172W and 178W
- Very low GOR – not exposed to CO2
- Workover needed to convert

<u>83W well to well with 83R</u>

- Restore 83R
- Injection profile
- Tracer survey/PTA
- Supply fresh water
- Pre/Post saturation log

<u>225W Pattern</u>

- Injection profile
- Tracer survey/ PTA
- Supply fresh water & produced water
- Pre/Post saturation log

<u>152W Pattern</u>

- Restore pattern wells
- Injection profile
- Tracer survey/PTA
- Supply fresh water
- Pre/Post saturation log

Summary

- Brine composition has been optimized
- Four chemicals have been identified that can recover oil from bypassed regions
- Developed dolomite-micromodels
- Developed geostatistical reservoir characterization
- Two wells have been identified for single well tests
- One well-pair and two well patterns have been identified for multi-well tests

➢ Single-well chemical tests will be conducted in the next phase

➢ Well patterns will be characterized further before multi-well test