Improvement in Natural Gas Production using 3M™ Novec™ Fluorinated Surfactants

Acknowledgement

This work was performed at the University of Texas at Austin within the Gas Condensate Research effort. This work was under the direction of Dr. Gary Pope and Dr. Mukul Sharma

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Objectives

- Investigate the use of surfactants to increase the relative permeability of gas and condensate fluids under two-phase steady state flow corresponding to dynamic condensate banking near well.
- Measure steady state relative permeability before and after surfactant treatments under reservoir conditions and over a range of temperatures, pressures and flow rates
- Investigate surface reactions and changes in wettability for different types of rocks and for a variety of surfactants

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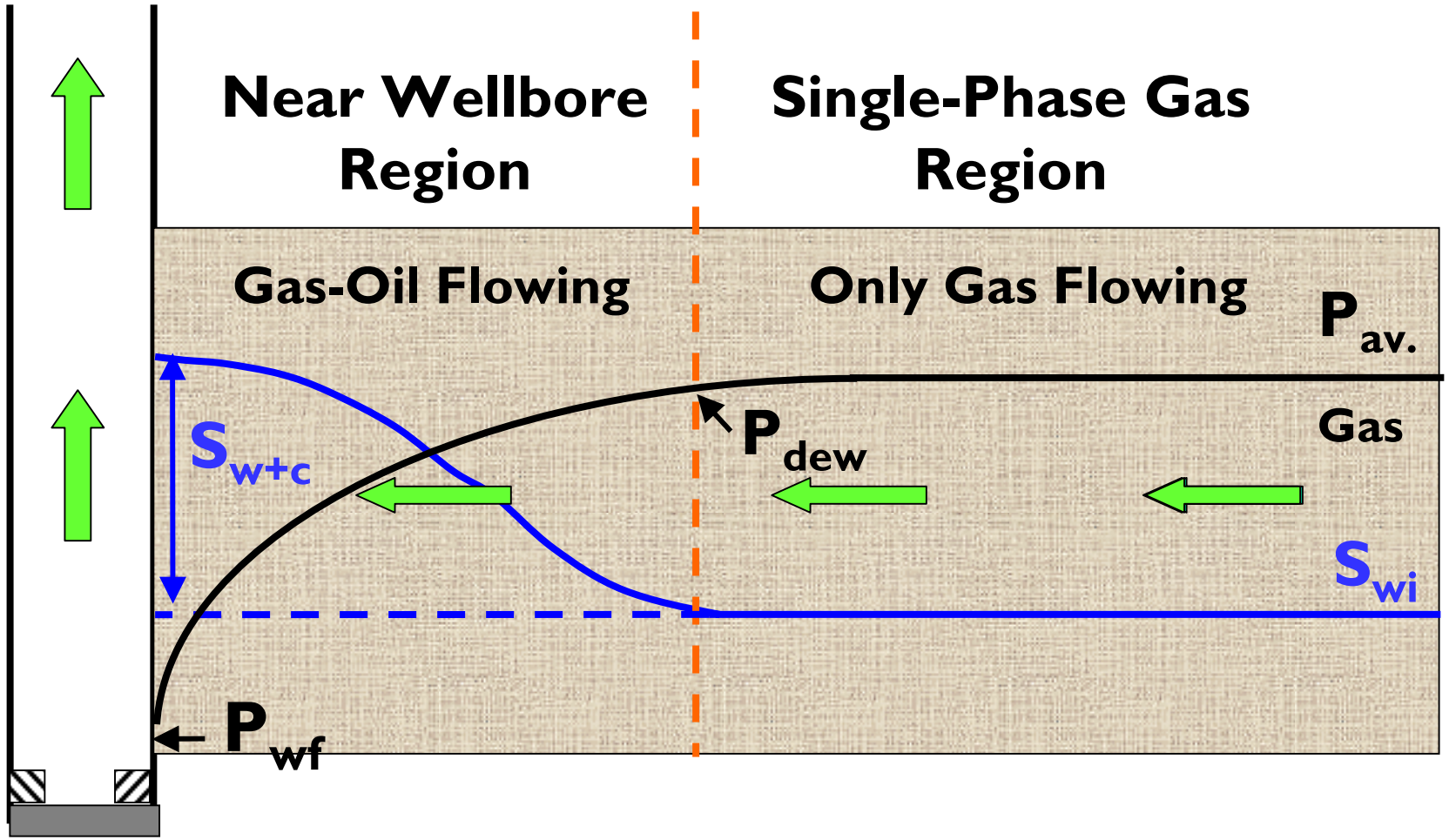
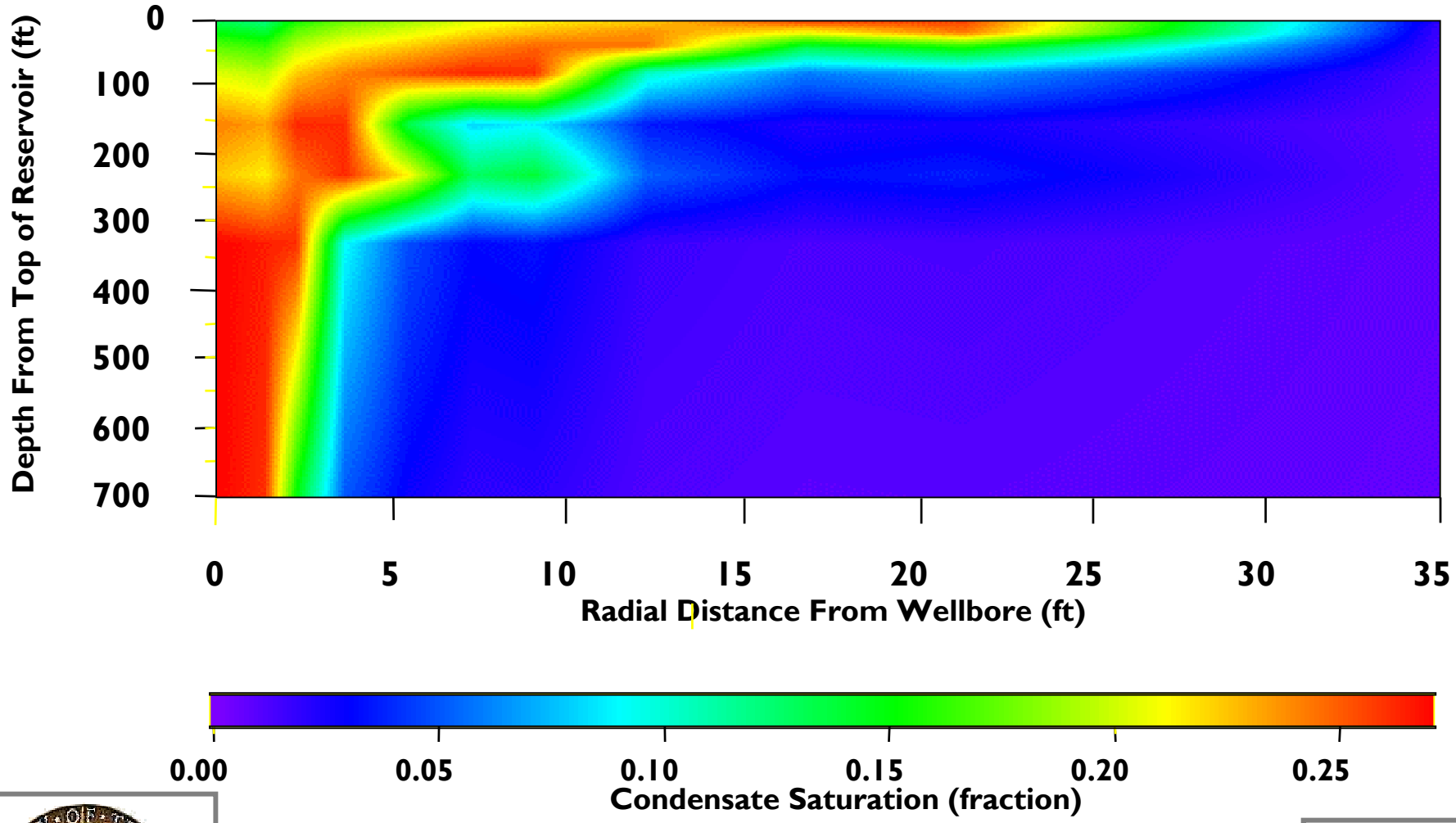
Schematic of Condensate Banking Problem



Calculated Near-Wellbore Condensate Saturation



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Conclusions

- Gas relative permeability during two-phase steady state core floods decreased by about 90% due to condensate and water blocking
- Gas relative permeability decreased about the same percentage in high permeability cores as in low permeability cores

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Conclusions

- More severe reduction in gas productivity during two-phase flow occurred at high water saturation.
- Methanol treatment can temporarily increase the gas production of both low and high permeability cores until the condensate builds up again.
- Methanol treatment removes both water and condensate by a multi-contact miscible displacement.

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Hypothesis

- Surfactant changes the wettability of the rock surface to intermediate-wet which decreases the residual saturations of the condensate and water resulting in an increase in the relative permeabilities of gas and condensate.

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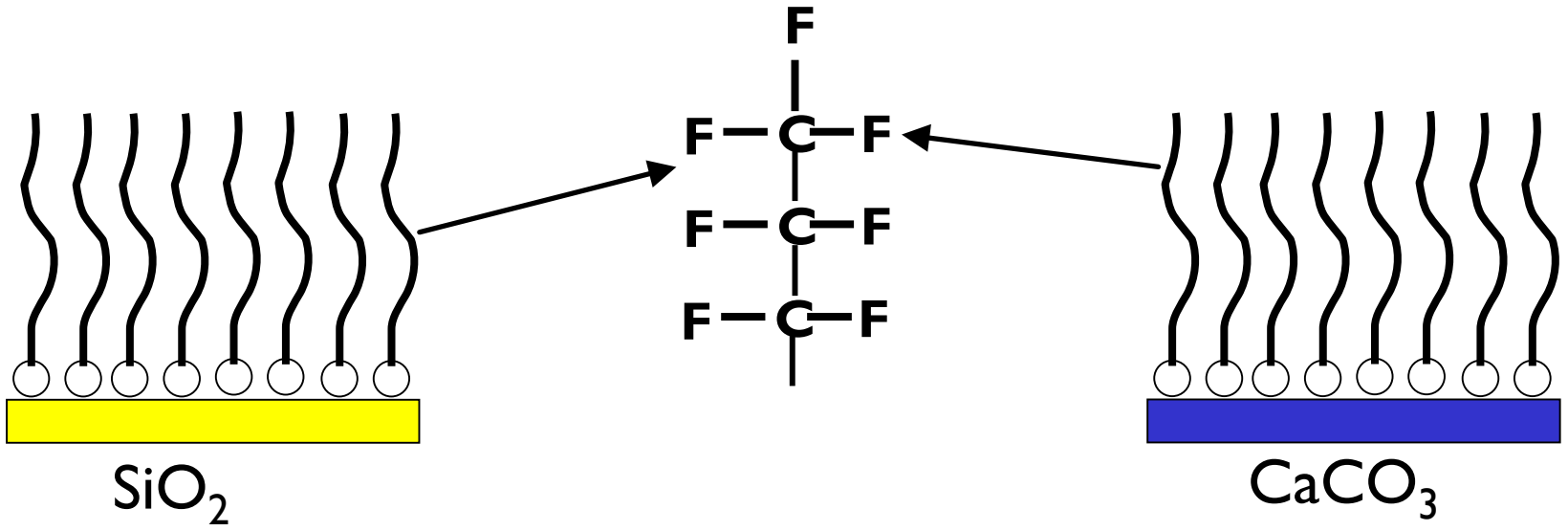
General Surfactant Requirements



- Surfactant should be soluble in solvents such as methanol
- Fluorochemical chain repels water and oil
- Surfactant needs to associate with surface and be retained for long periods of time at high temperatures on the order of 200-300°F
- Surfactant needs to be stable for long times at high temperatures

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Experimental Conditions

- **Core flood experiments at 145°F / 250°F**
  - Single-Phase Pressure = 3,000 / 4,000 psi
  - Two-Phase Pressure = 1,200 / 1,500 psi
  - Initial water saturation= 0-50%
  - Berea sandstone (100-300 md)
  - High velocities = 1,000-20,000 cc/min

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RESULTS

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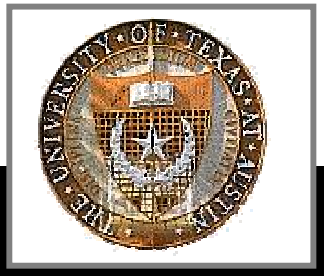
Summary of Sandstone Treatments with 2% FC

Temp.	Surfactant	Permeability (md)	Flow rate in core (cc/hr)	Relative permeability of gas before treatment	Relative permeability of gas after treatment	Improve-ment Ratio, PI
145°F	FC4430	230	85	0.01	0.030	2.73
145°F	FC4430	95	85	0.04	0.103	2.86
250°F	FC4430	115	330.2	0.080	0.246	3.08
250°F	FC4430	216	2340	0.067	0.181	2.70

Analytical: SEM, TOF-SIMS and ESCA show thorough treatment of rock surface



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Conclusions

- Treatment with 3M™ Novec™ FC-4430 Fluorosurfactant shows an increase in gas productivity index (PI) by a factor of 2-3X in this study.

- Treatment does not damage the cores that were tested.

- FC-4430 surfactant treatment in this study resulted in significant increases in PI at both at 145°F and 250°F.

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