UREP

CSM

Progress Report

Impact of confinement on dew point pressure in unconventional gas condensate reservoirs

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Importance

- Condensation especially around the wellbore decreases the well deliverability significantly
- Better estimation of dew point pressure helps to manage production by minimizing condensate drop-out in gas condensate reservoirs

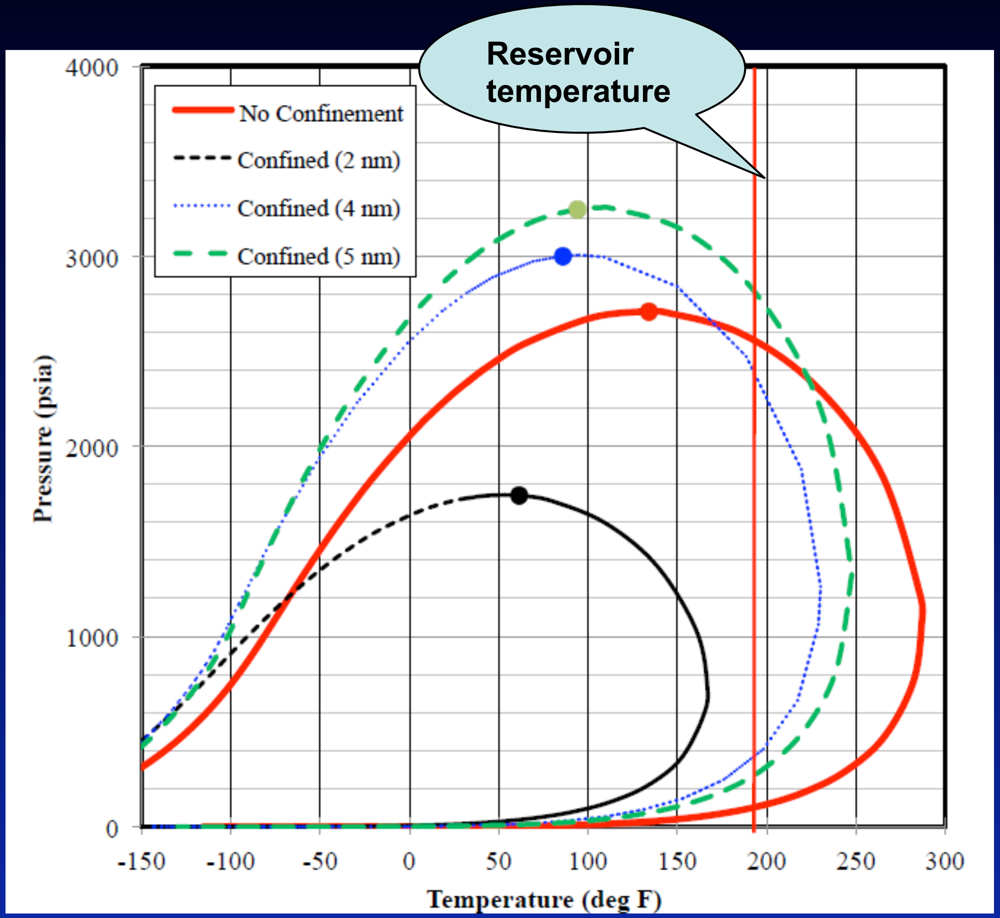
Importance

- Dew-point pressures obtained from PVT data do not represent the phase behavior in confinement of nano-pores
- When the condensate drop out begins, liquid and gas phase pressures are different by an amount controlled by the effect of confinement
- The two most important effect of confinement is the increased capillary pressure and surface force interactions

Current Status

The phase behavior we predict by PVT experiments or simulations don't duplicate with the observed data

We need to modify either our experiments or our models to get a correct prediction



Kanin Sapmanee, 2011
(Based on modified pseudo-critical properties)

Peng-Robinson EOS

In 1976, a PhD student, Peng, and his advisor, Robinson, modeled the phase behavior of pure methane in a PVT cell and developed the famous Peng-Robinson Equation of State

- Peng-Robinson equation is currently the best EOS for gas reservoir modeling
- Many modifications have been introduced to the Peng-Robinson EOR either to improve its vapor pressure prediction or to obtain better results for liquid phase.

Peng-Robinson EOS

$$P = \frac{RT}{(V-b)} - \frac{a}{\left[V(V+b)+b(V-b)\right]}$$

$$a = 0.45724\frac{\left(RT_c\right)^2}{P_c}\left[1+m\left(1-\sqrt{T_r}\right)\right]^2$$

$$b = 0.07780\frac{RT_c}{P_c}$$

$$m = 0.37464 + 1.54226\omega - 0.26992\omega^2$$

$$T_r = \frac{T}{T_c}$$

- Experiment was done with pure methane (single component)
- Experiment was done in a PVT cell (no confinement effect)

Forces acting in Pore Confinement

- Between gas molecules
  - Van der Waals forces
- Between gas and oil molecules
  - Capillary forces
- Between gas molecules and pore walls
  - Adsorption forces
  - Electrostatic forces

Improving the EOS for Nano-Porous Reservoirs

Two Approaches

Analytical corrections by adding the effects of all forces

Experimental corrections by adding the confinement conditions to PVT cells

Modeling PR EOS by Adding Capillary Effect

Capillary Flash Flow Diagram

Estimate P_l ,σ

Calc P_c and P_g for a given r_c

Estimate K value

Calc liquid and gas mole fractions

Calc z-factor for both phases

Calc fugacity values for both phases

Check equivalency of fugacity values

NO

Update K value

Check condition for P_{dew}

NO

Update Pl

Calc σ and Pc

Check Pc equality

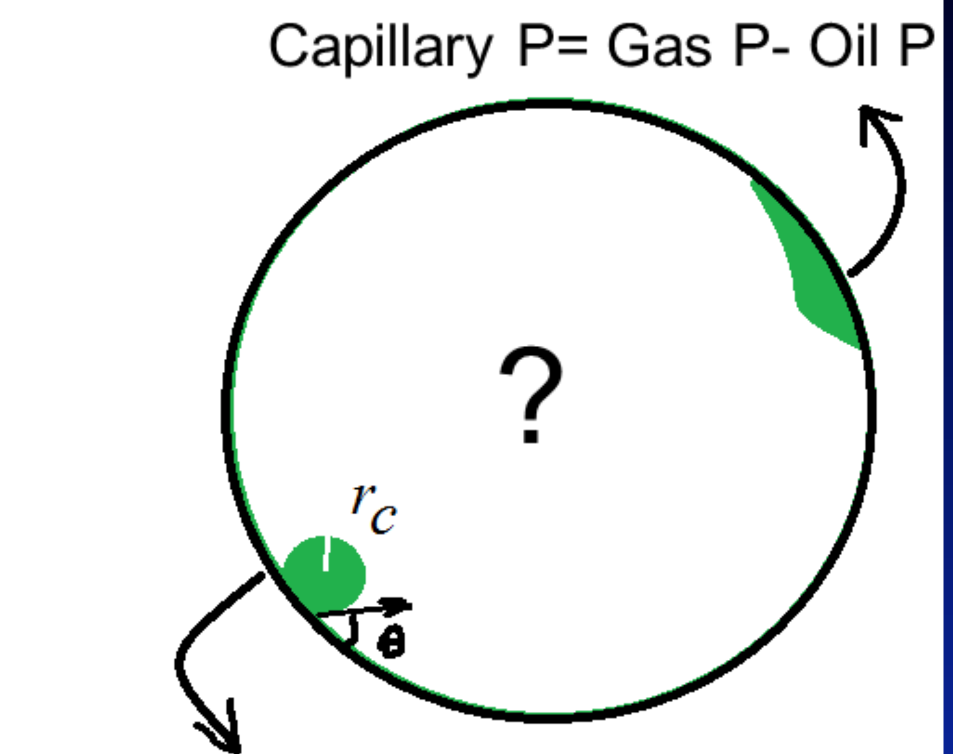
NO

Update σ

P_l: liquid pressure
P_c: capillary pressure
P_g: gas pressure
r_c: radius of curvature
P_{dew}: dew point pressure
σ : interfacial tension

Modeling PR EOS by Adding Capillary Effect

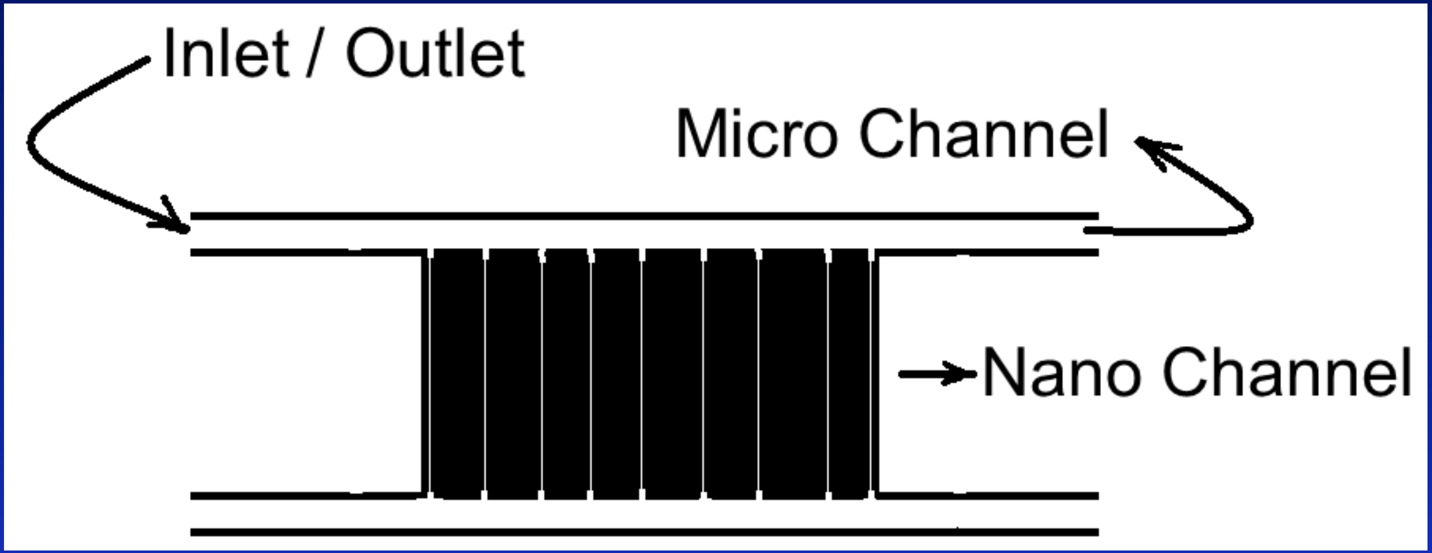
- Is oil always wetting phase in presence of gas?
- We would do the experiment to observe condensation shape
- Pore chemistry changes wettability
- Adding capillary pressure to our flash calculation code resulted in convergence problems (work on progress)



$$P_c = \frac{2\sigma\cos\theta}{r_c}$$

Laboratory Experiment (Only Observation)

- Nano chips made of silicon
- Have two size channels: micro channels and Nano channels
- Change inlet and outlet orientation

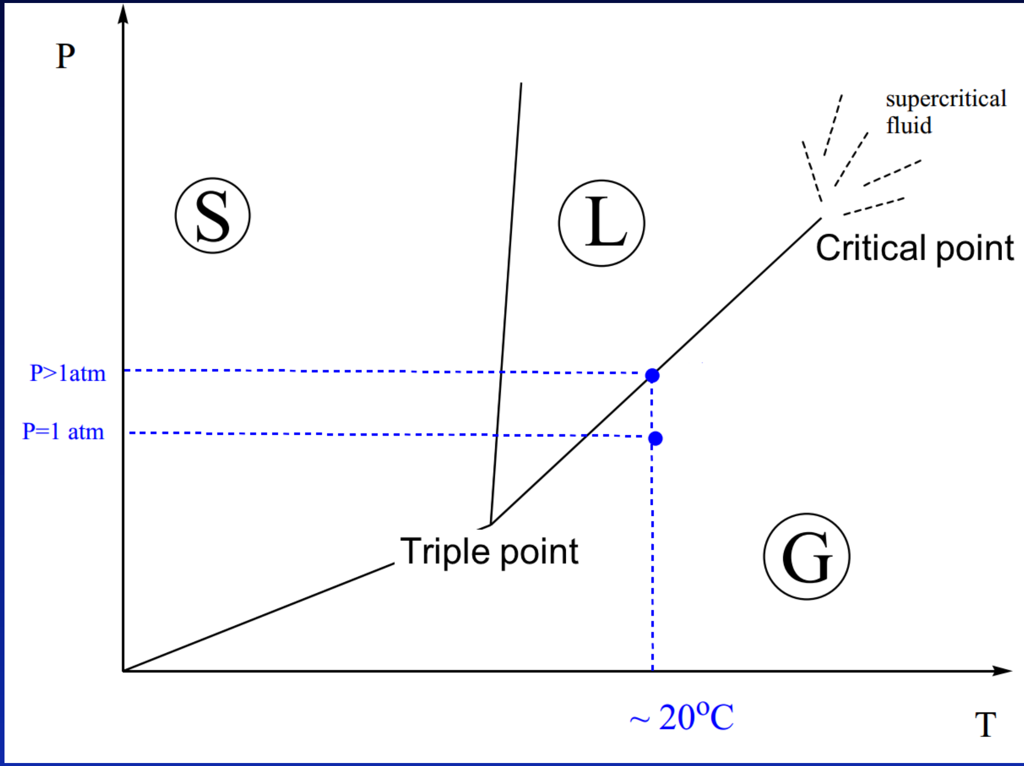


Our Nano-PVT Cell

- Limitation to increase the temperature above 100 F
- Limitation to increase the pressure above 800 psi
- Pressurize hydrocarbon in the silicon chips at different temperatures
- Observe in which size of channels condensation would happen first

Butane Phase Diagram

- Butane is a good candidate
- At room temperature needs a few atm to condensate
- Pressurize it at different T and record P to plot the phase diagram
- See if nano size cells cause a shift of the diagram



Thank You