Unconventional Reservoir Engineering Project

Colorado School of Mines

November 16, 2012

Topics of Interest

- The Impact of Nano-filtration on Compositional Variation and Osmotic Pressure in Confined Environments
- Numerical Solution of Thermodynamic Equilibrium in Confined Environments Using Black Oil Formulations
- Numerical Modeling of Fluid Equilibrium and Flow Using Multiple-Porosity Approach

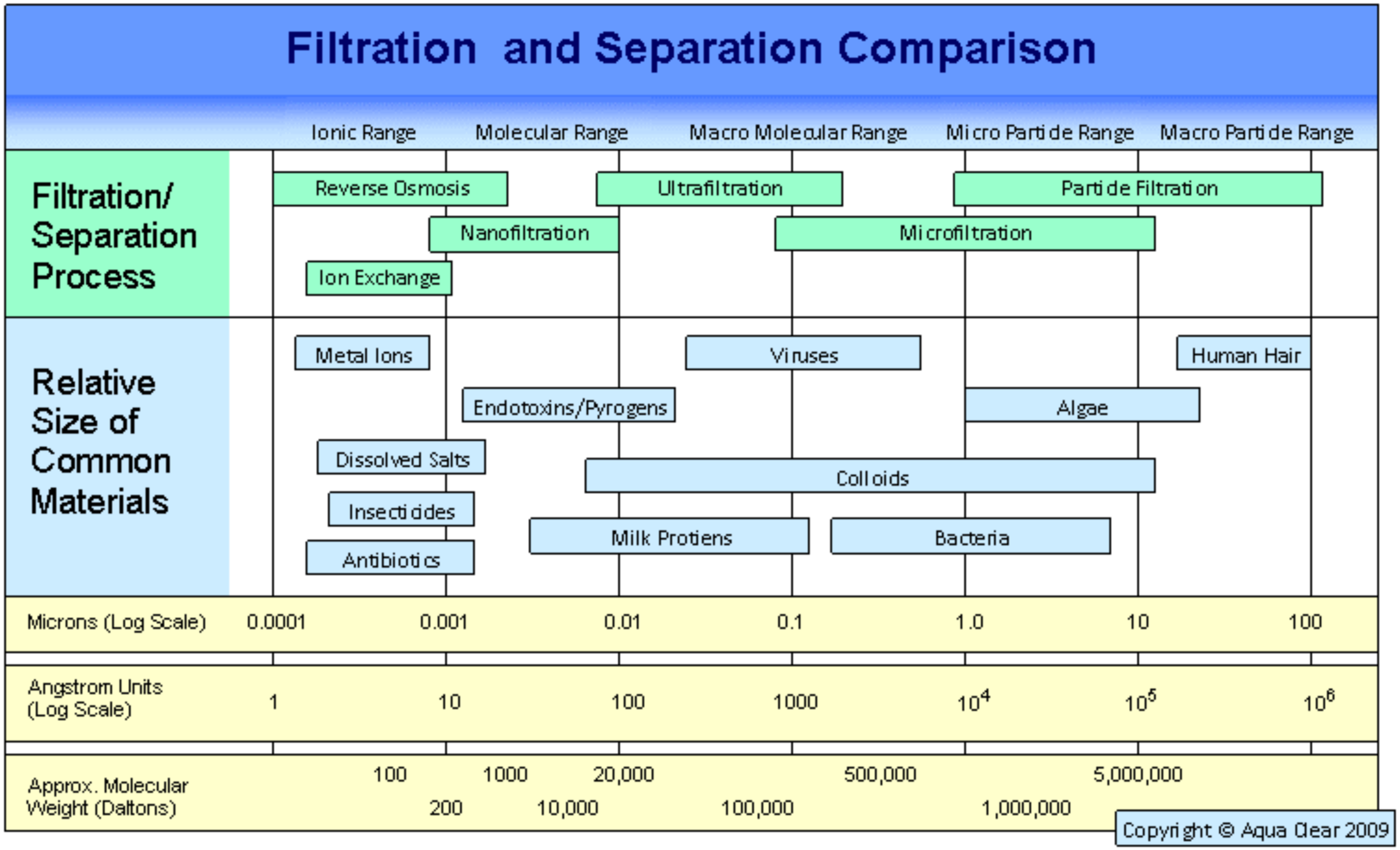
Nano-filtration

Migration of hydrocarbons through nano-sized pore throats results in the filtration of heavier components

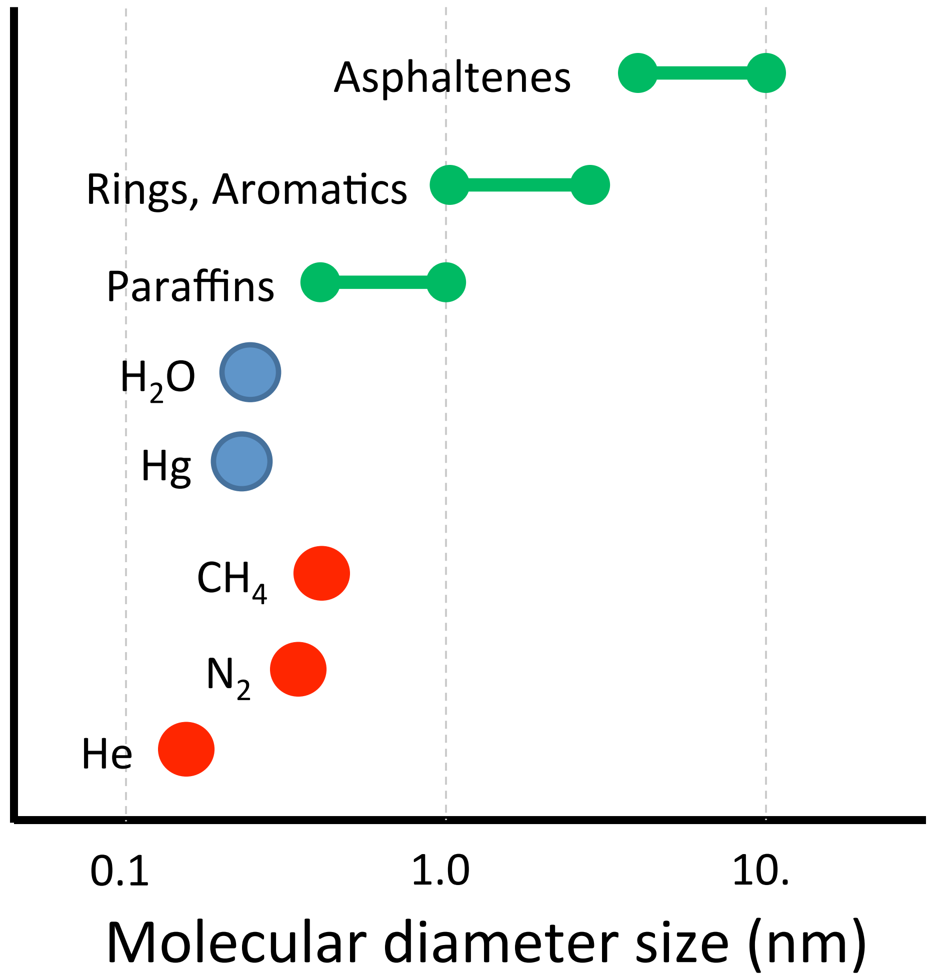
Outcomes of filtration are:

1. compositional variation
2. osmotic pressure difference

Compositional Variation

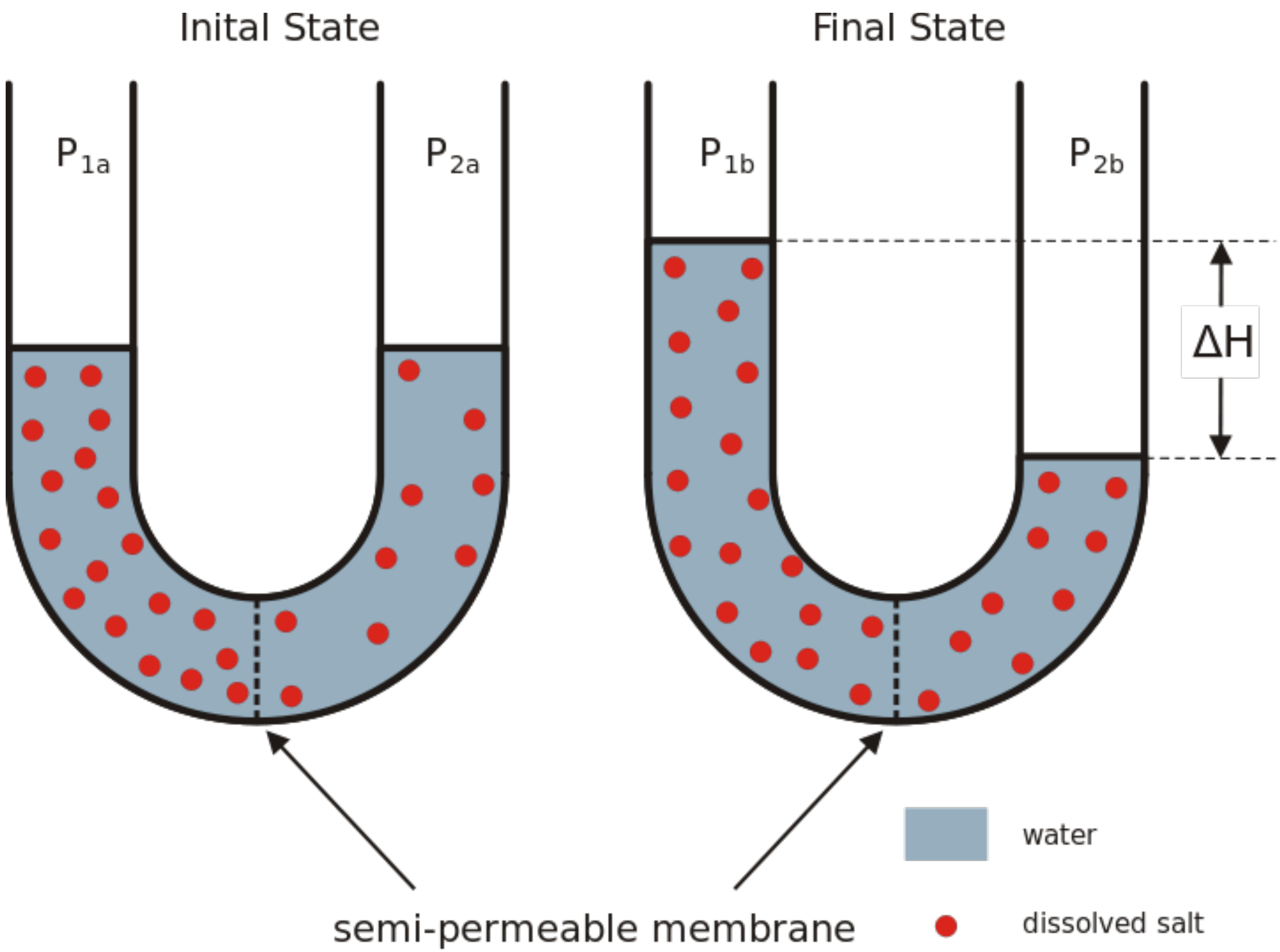


Compositional Variation



Modified from Nelson (2009)

Osmosis (Wikipedia)

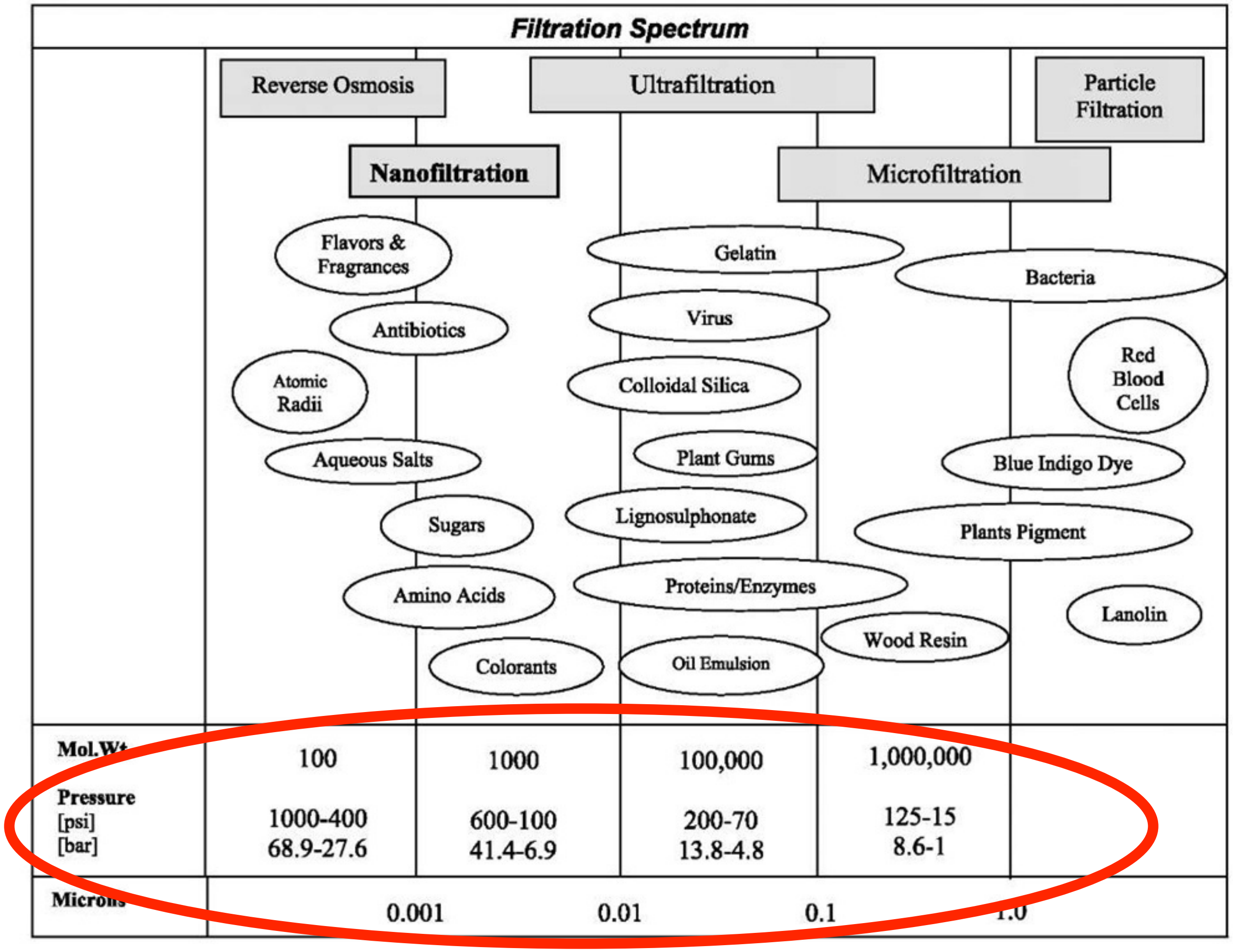


Osmotic Pressure

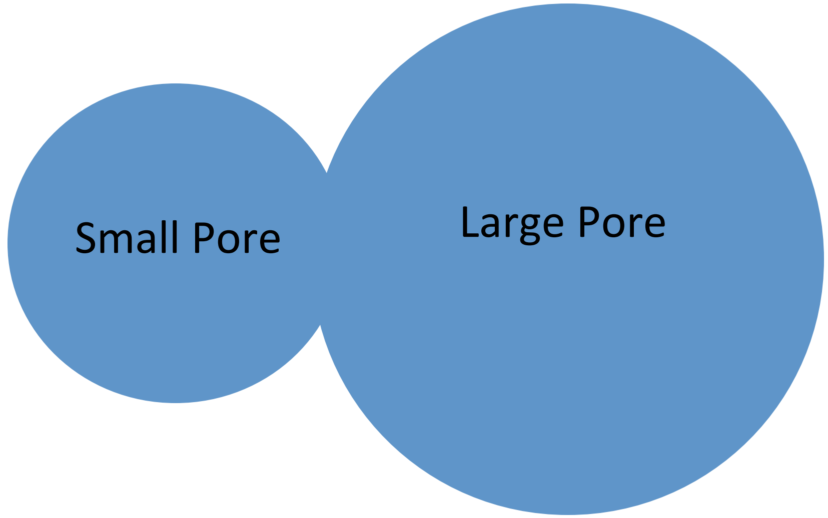
Osmotic pressure is the pressure which needs to be applied to a solution to prevent the inward flow of water across a semipermeable membrane. It is also defined as the minimum pressure needed to nullify osmosis.

Wikipedia (2012)

Pressure Magnitude



Study Objectives



Smaller Molecules
Lower IFT
Higher GOR
Lower Pressure
Higher Surface Forces
Higher Capillary Pressure
Excessive Pc Suppression?

Larger Molecules
Higher IFT
Lower GOR
Higher Pressure
Lower Surface Forces
Lower Capillary Pressure
Excessive Pc Suppression?

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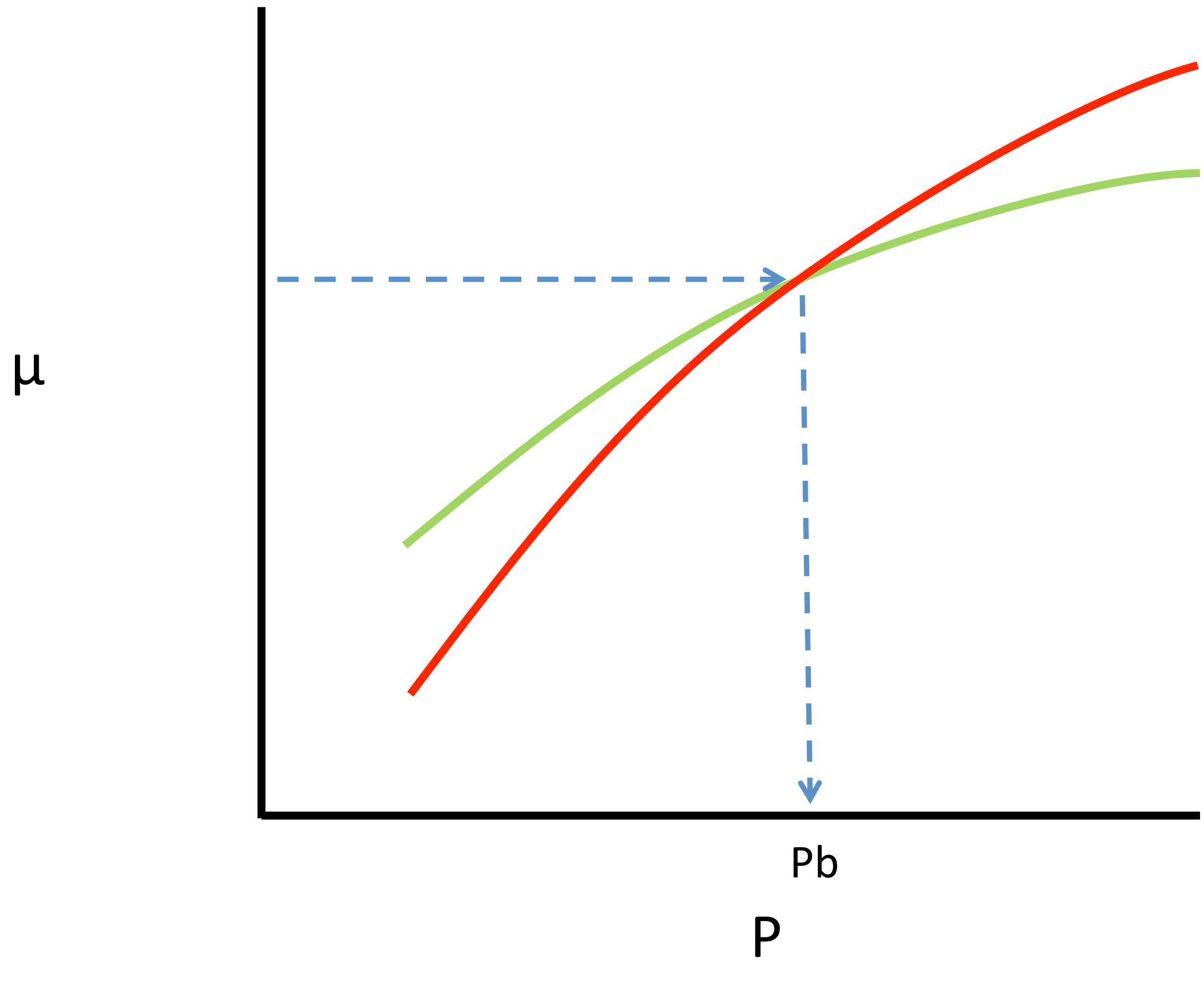
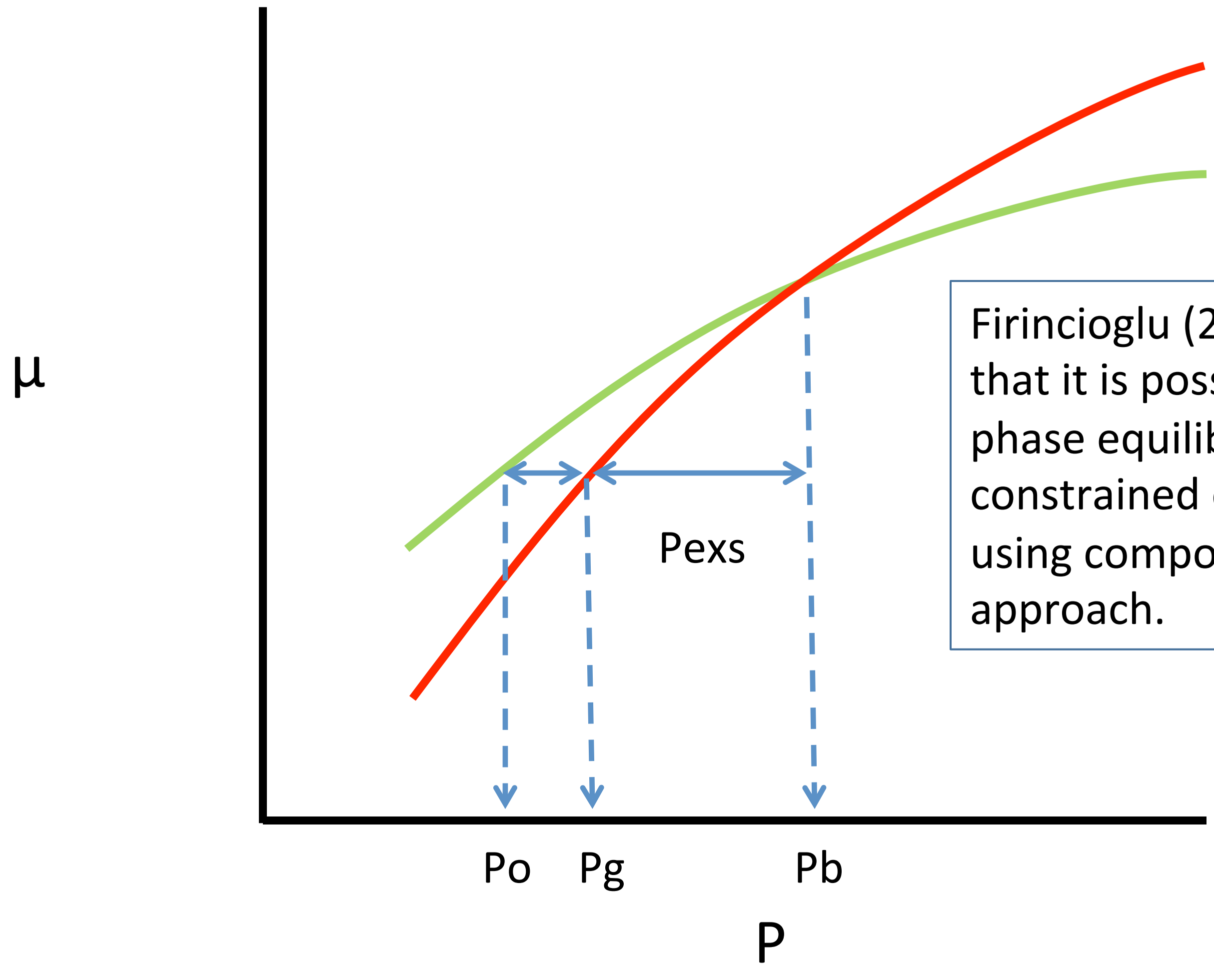
Bulk Thermodynamics

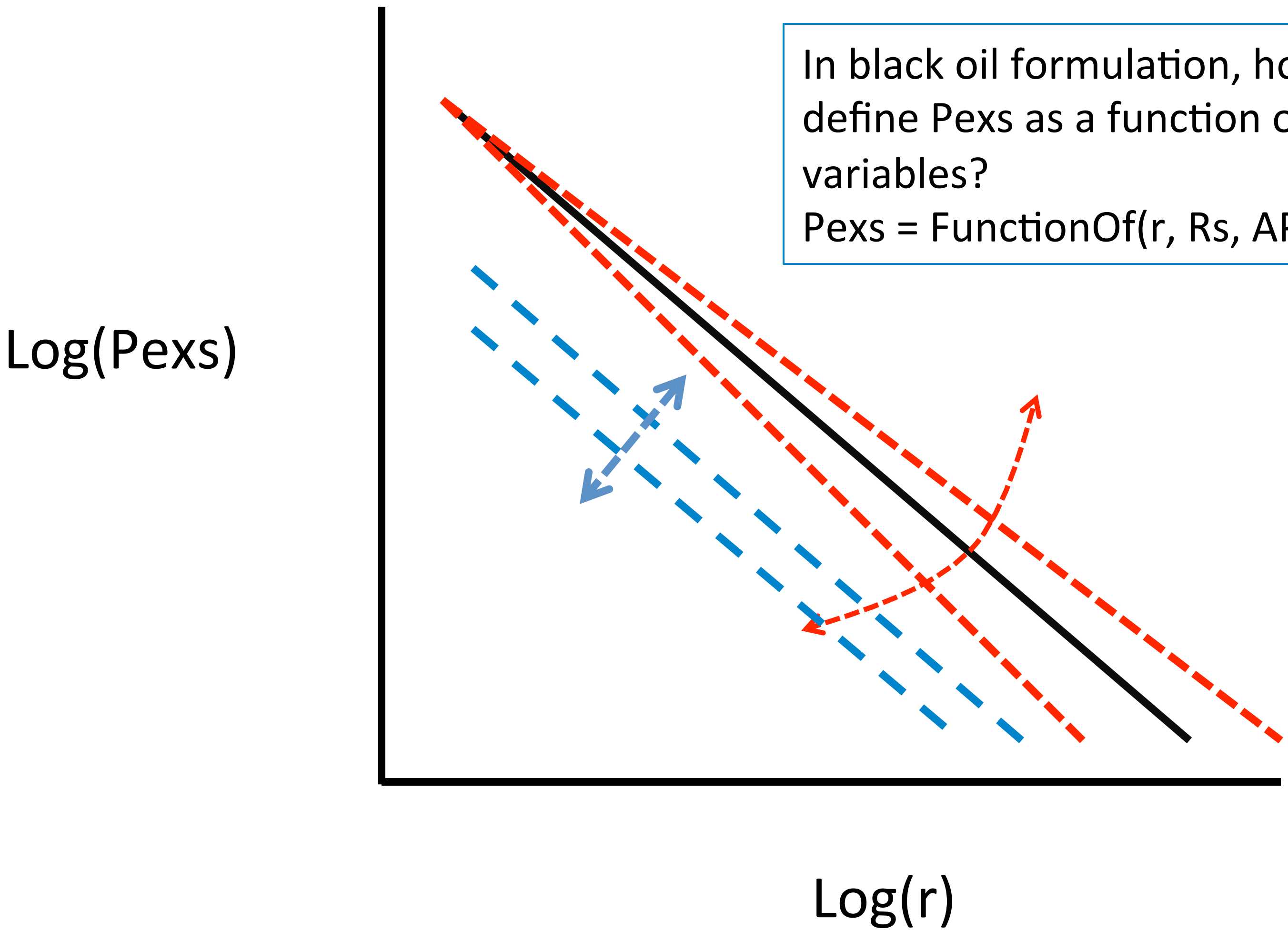


Constrained Thermodynamics



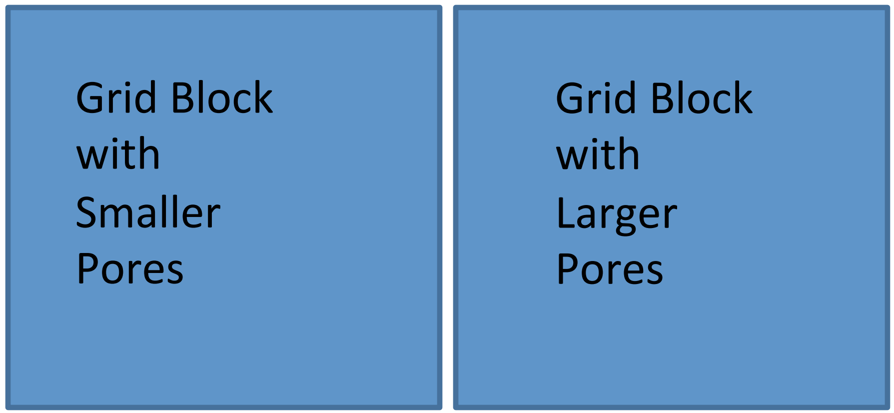
Firincioglu (2012) has shown that it is possible to solve for phase equilibrium in constrained environments using compositional approach.

Excess Suppression



In black oil formulation, how can we define Pexs as a function of available variables?
Pexs = FunctionOf(r, Rs, API, SG, Pc, ?)

Study Objectives



Using a simulator with black oil formulation, how do we achieve hydrodynamic equilibrium (i.e. initialization of the simulation model) between two grid blocks? If the two grid blocks have different pore sizes resulting in:

- different Pc
- different excess suppression
- different Rs (filtration and osmotic pressure)

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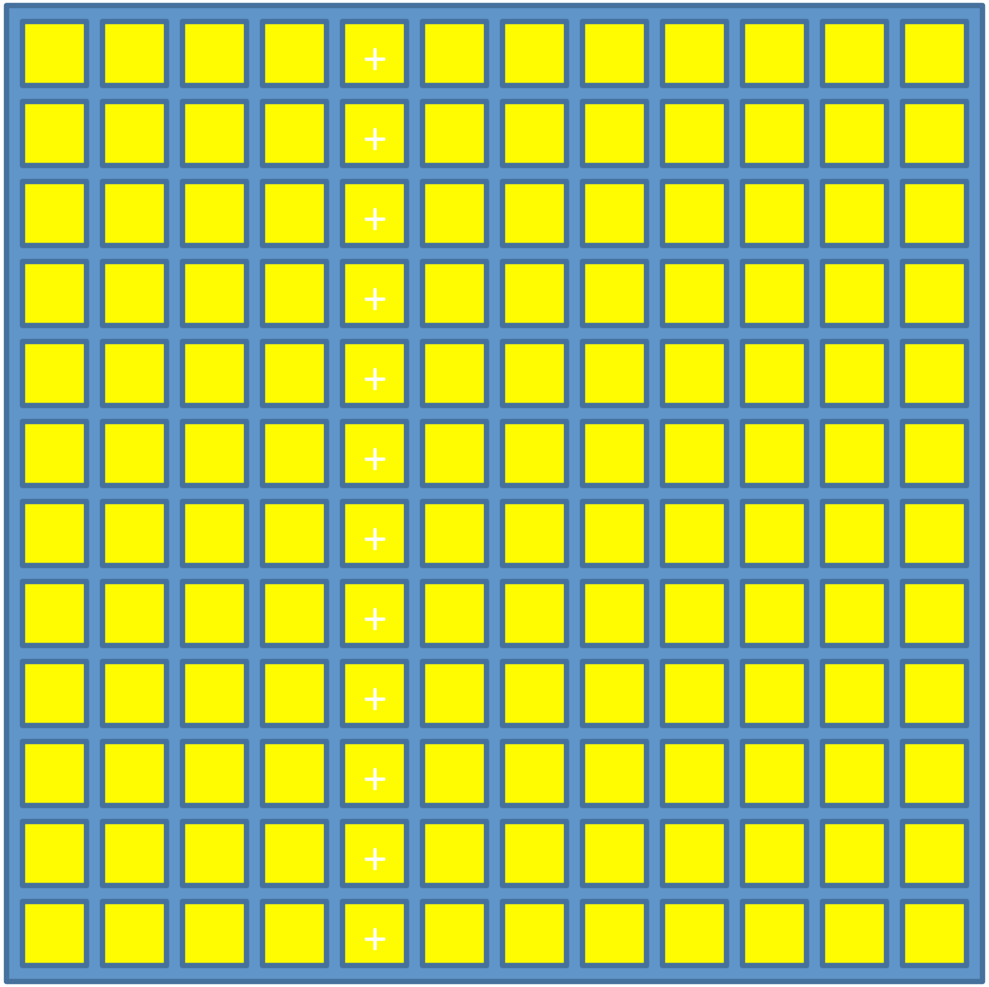
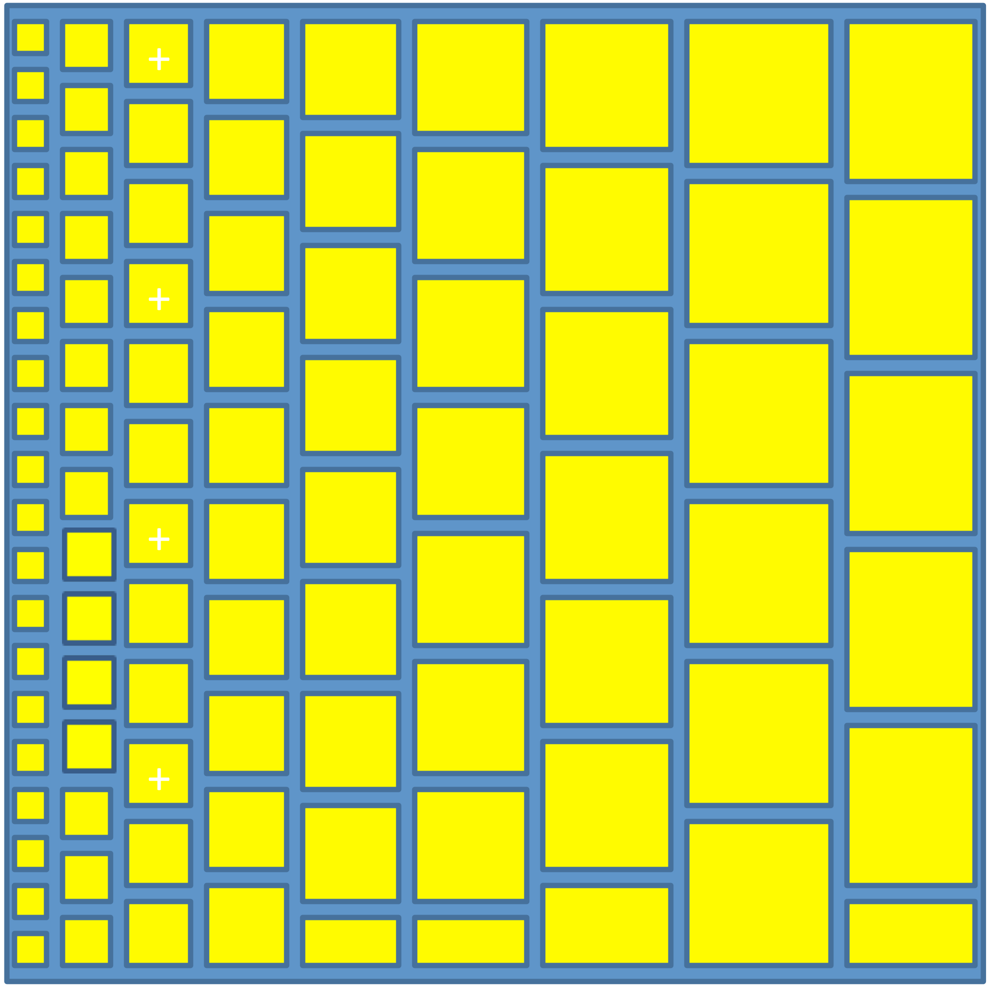
Dual-Porosity Systems



In existing simulators, dual porosity formulation assumes that ALL of the matrix can be represented as uniform blocks in continuum.

This formulation assumes that all of these uniform blocks have the same pore size distribution and pore throat size distribution, and can be represented using a single saturation value and a single capillary pressure value.

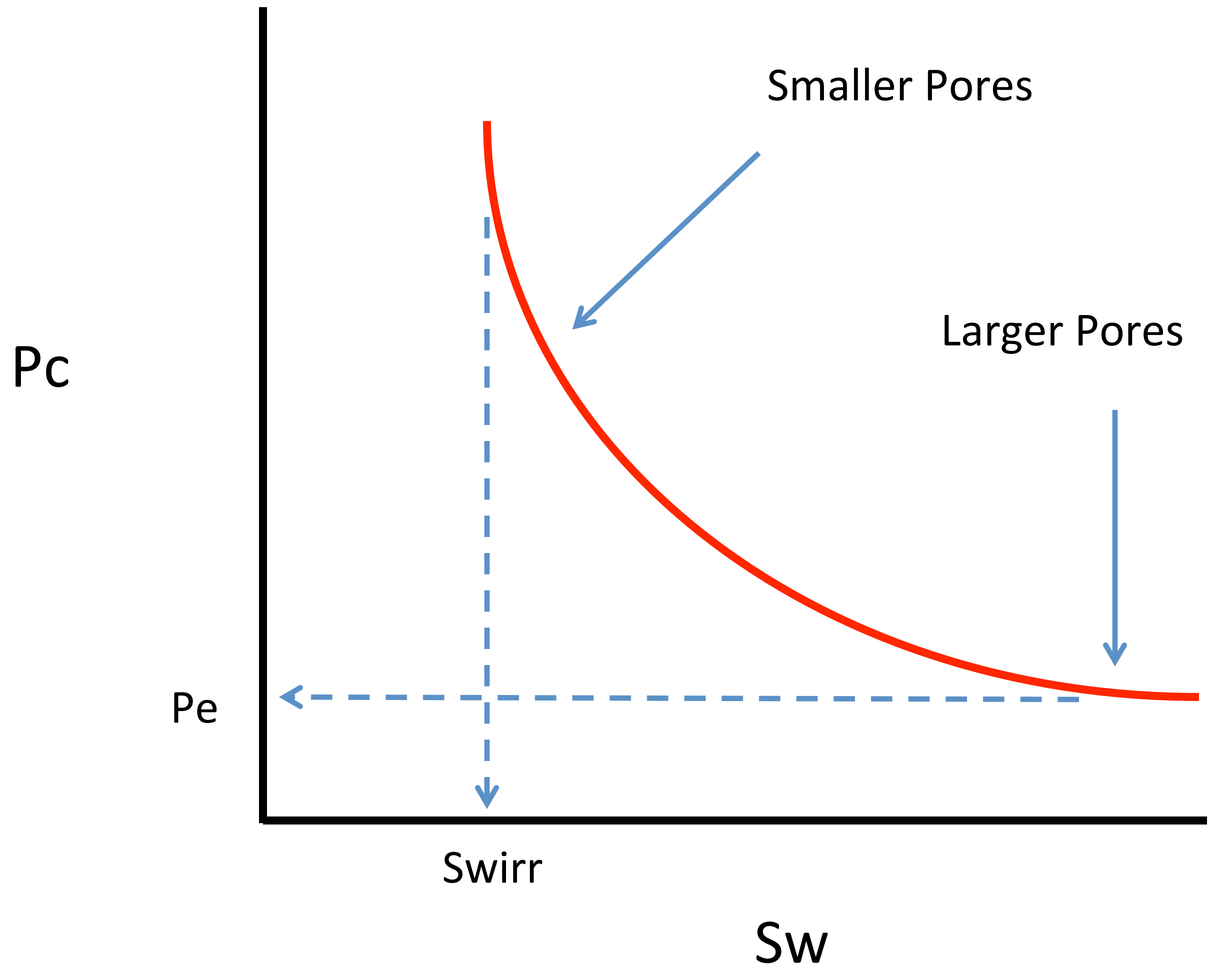
Multiple-Porosity Systems



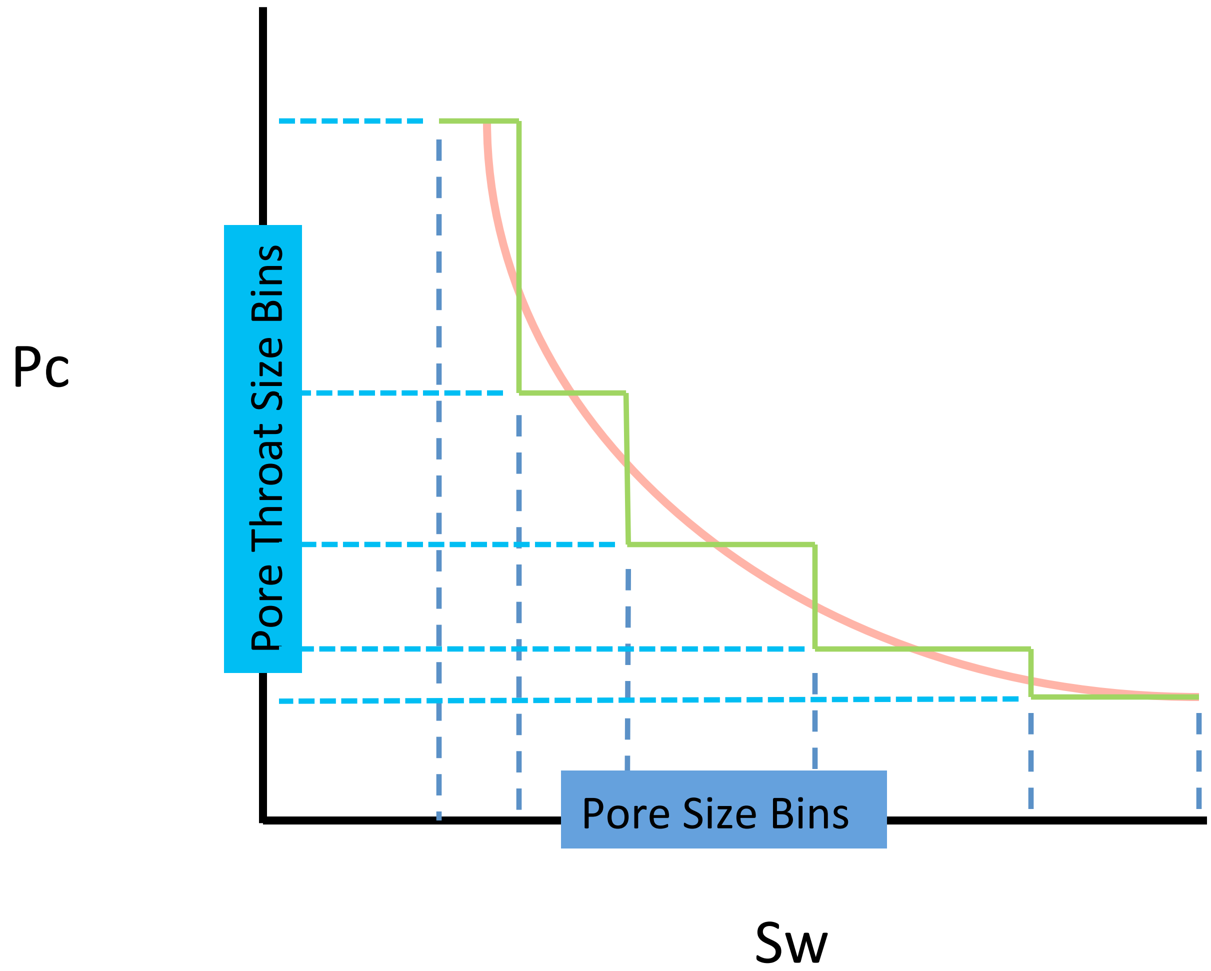
Instead of assuming uniformly distributed matrix, what if we distribute the pores and the pore throats based on capillary pressure function?

We should have many matrix blocks that represent small pores and few matrix blocks that represent large pores.

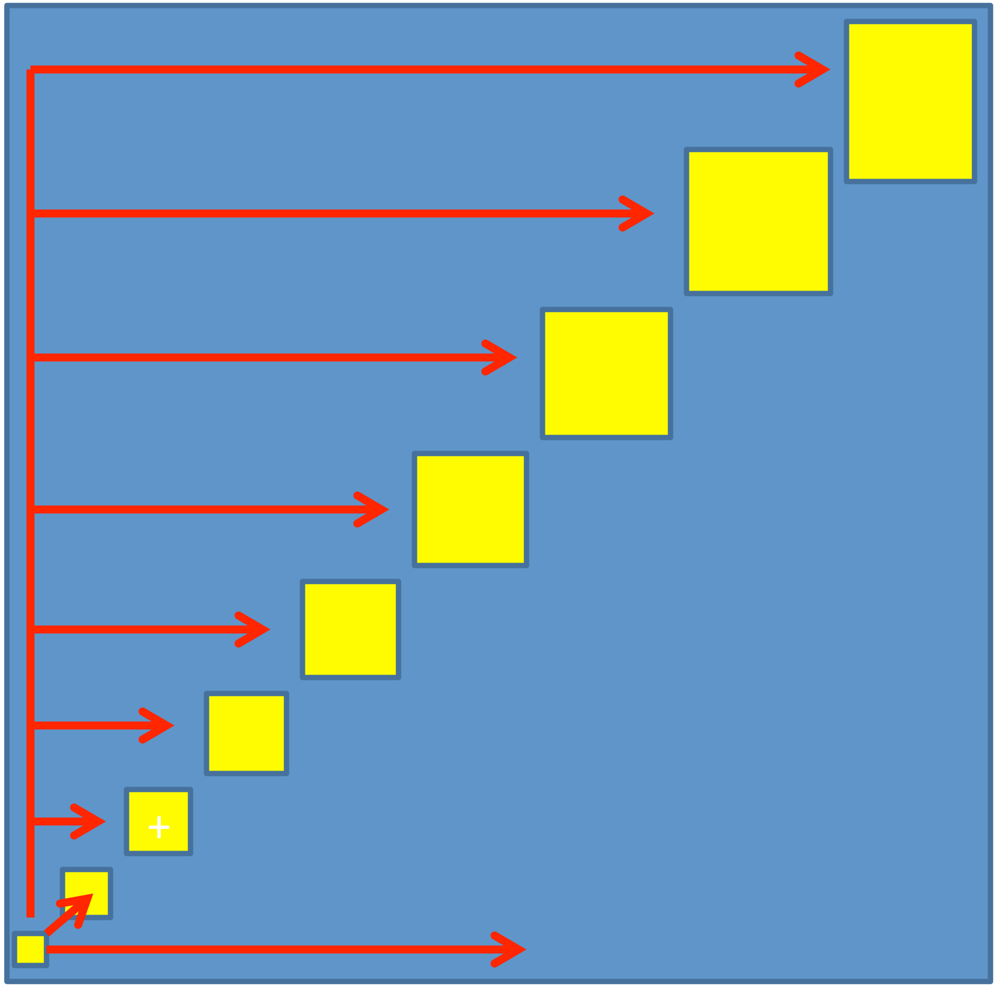
Characteristic Pc Curve



Discretized Pc Curve

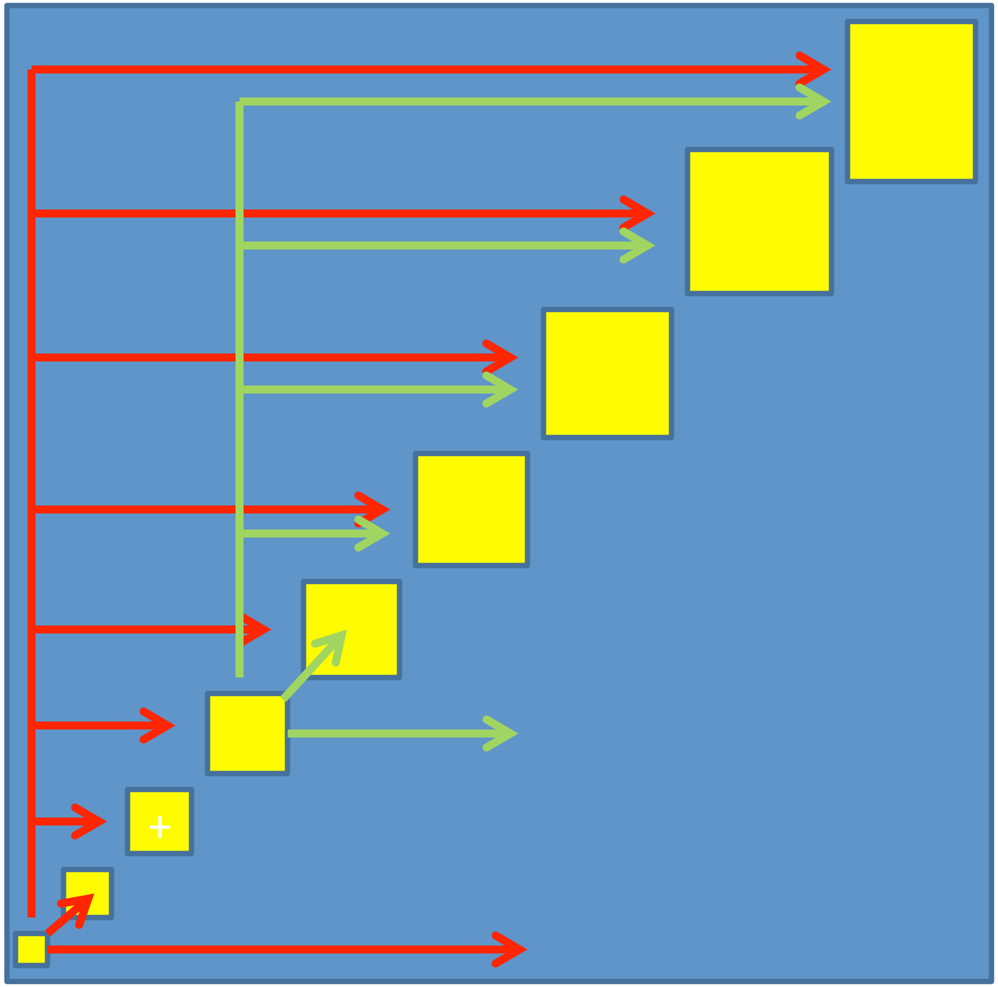


Numerical Solution



The new distribution will require the smallest pores to be connected to all of the larger pores, as well as to the natural fractures (or to the largest pores that dominate the flow).

Numerical Solution



Same connectivity logic applies to all of the intermediate pore sizes.

Study Objectives

- Identify the best method to convert capillary pressure curves to pore size and pore throat size bins and to automate the method
- Incorporate n-Porosity approach into numerical simulator, and investigate how the connectivity among different pores should be distributed and formulated
- Investigate the impact of pore throat size distribution on different flow types, and on the overall flow behavior

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Thank You