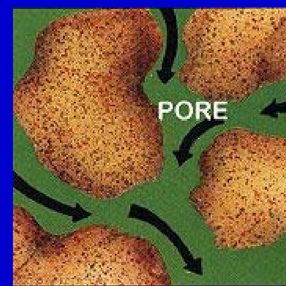
Reservoir Properties

Geol493K

Porosity and Permeability

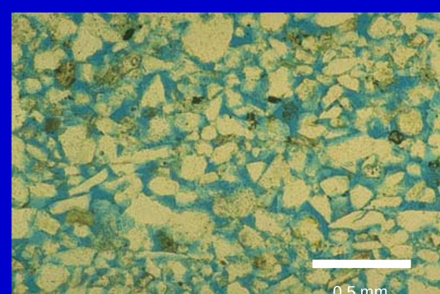


Porosity and Permeability

- Porosity: % of void space in rock
- Permeability: Ease of fluid flow

Porosity

Volume % of open space



Porosity

- Total Porosity (%)
- Porosity (Ø)= (bulk volume – grain volume)/bulk volume
- Effective Porosity= Interconnected pores

Conventional View of Porosity

- 0-5% Negligible
- 5-10% Poor
- 10-15% Fair
- 15-20% Good
- 20-25% Very Good

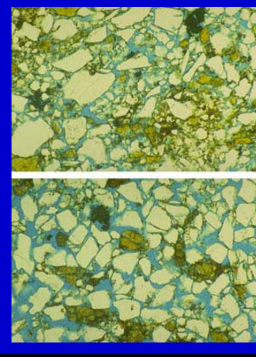
For gas, lower porosity is still viable

Hydrofracturing makes low porosity less of a problem

Primary Porosity

- Controlled by:
  - Degree of Uniformity of Grain Size
    - Sorting
  - Shape of the Grains
  - Method of Deposition (Manner of Packing)
  - Compaction
  - Cementation

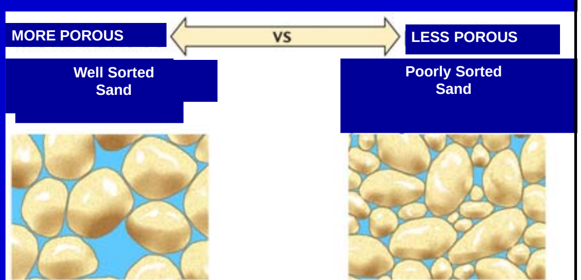
Sorting



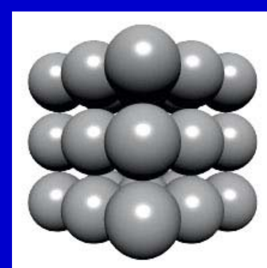
Poor Sorting

Intermediate Sorting

Porosity Varies with **Sorting**

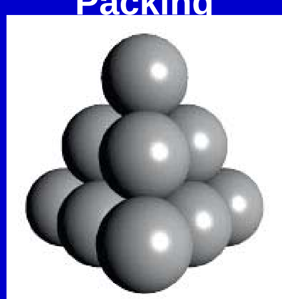


Packing



Cubic Packing 47% porosity in the ideal situation

Packing



Rhombohedral Packing 26% porosity in the ideal situation

Secondary Porosity

- Additional open space developed after sedimentation:
  - Dissolution
  - Dolomitization
  - Fracturing

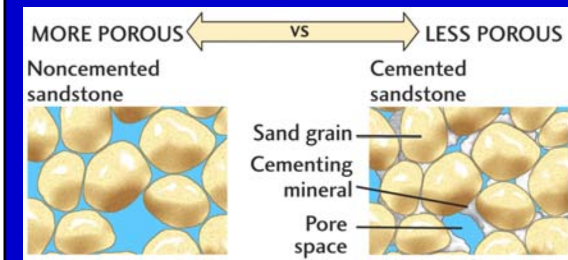
Modifications to Porosity

Sandstone
- Pressure Solution
- Cementation
- Fracturing

– Carbonate
- Compaction – 2 to 20%
- Solution
- Recrystalization – Dolomitization
- Fracturing
- Cementation

– Shale
- Compaction – 50%
- Bound Water Expulsion

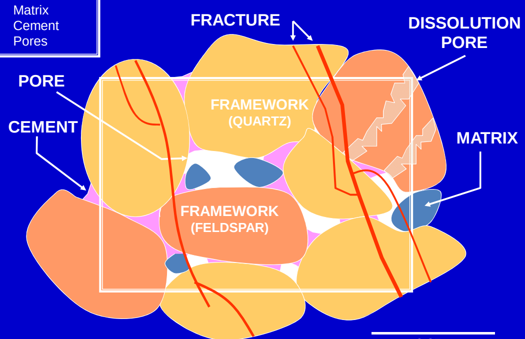
Porosity Varies with % **Cement**



POROSITY IN SANDSTONE

Sandstone Comp.
- Framework
- Matrix
- Cement
- Pores

1. Primary and secondary "matrix" porosity system
2. Fracture porosity system



Porosity Varies with **Fracturing**

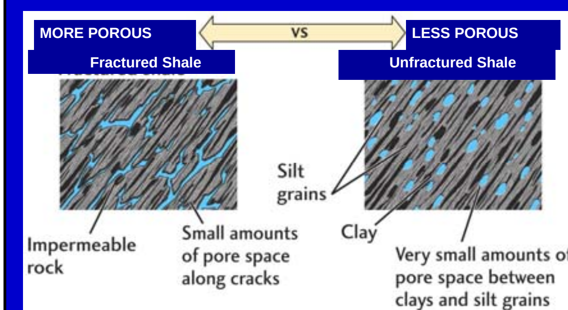


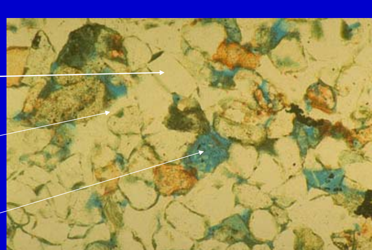
Figure 13.7

Secondary Porosity

Quarts Grain

Quartz cement

Dissolved Feldspar



2 mm

Wilcox Fm. South Texas

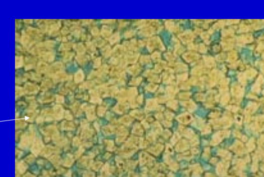
Dolomitization

Calcite ($CaCO_3$)

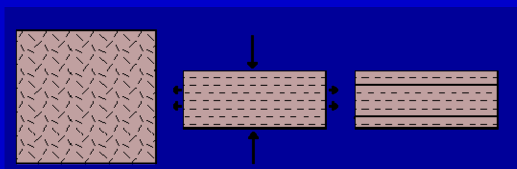
Antrim Fm. Michigan

Dolomite CaMg $(CO_3)_2$

Volume decrease leads to new porosity



Shale



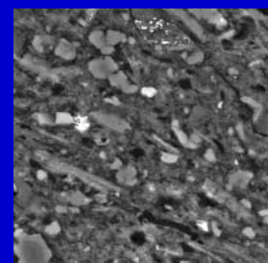
Wet Mud

Compacted Sediment (water expelled)

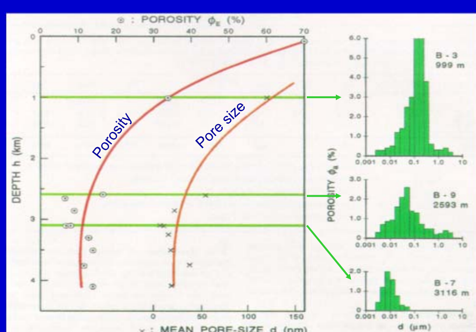
Cemented Shale

Shale

Microphotograph



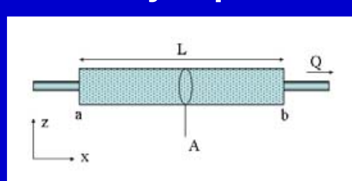
Shale



Permeability

- Ability of fluids to flow through Porous Media
- Permeable
  - Large Well-Connected Pores
- Impermeable
  - Smaller, Fewer or Less Interconnected Pores

Darcy Equation



$$Q = \frac{-\kappa A}{\mu}\frac{(P_b - P_a)}{L}$$

Permeability

Pressure Gradient

Volumetric Flow Rate

Viscosity

Permeability Values

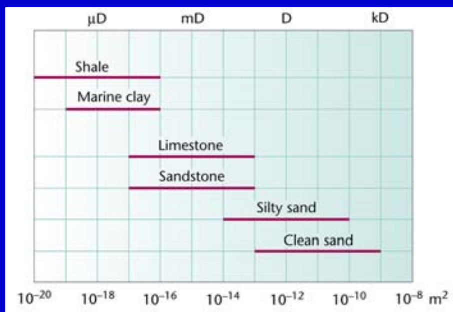
- 1-10 md Fair
- 10-100 md Good
- 100-1000 md Very good

Md = millidarcies

Darcy = units of length^2

Varies over 3 orders of magnitude or more

Typical Permeabilities of Sedimentary Rocks



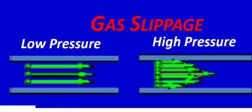
Alled and Allen, 2013

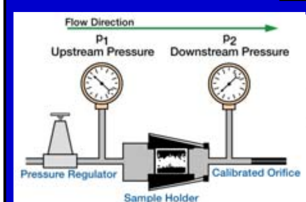
Permeability Measurements

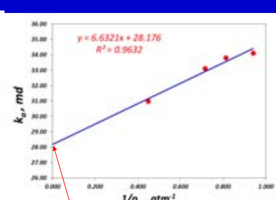
- Porosity can be measured by logs (density, neutron)
- Permeability needs cores to do lab injection tests

PERMEABILITY MEASUREMENT

$$Q = \frac{-\kappa A}{\mu} \frac{(P_b - P_a)}{L}$$

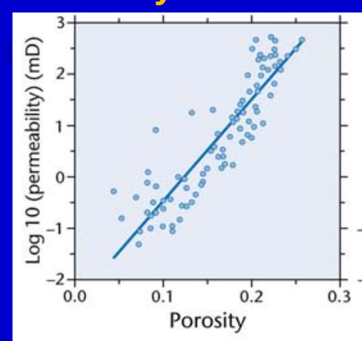






Regress to ΔP = ∞

Porosity vs. Permeability

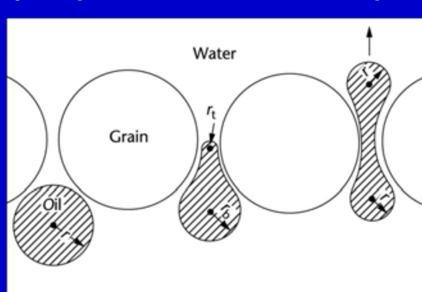


Log-normal plot

They are correlated, but they are not the same thing!

Allen & Allen, 2013

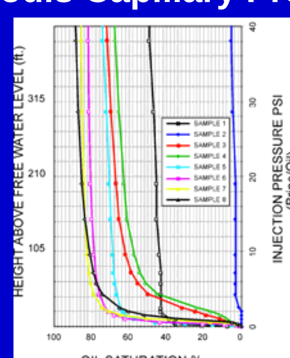
Capillary Pressure – Two fluid system



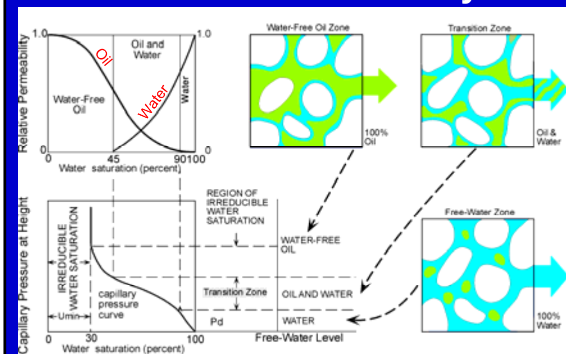
$P = \frac{2\gamma}{r}$ $\frac{2\gamma}{r_t} > \frac{2\gamma}{r_b}$ $\frac{2\gamma}{r} = \frac{2\gamma}{r}$

Water-wet reservoir

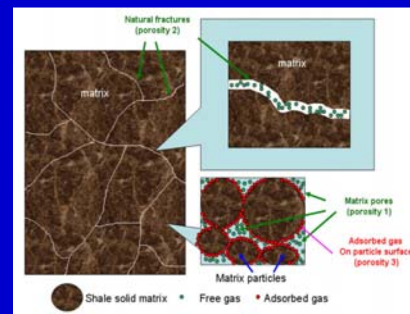
St. Louis Capillary Pressure



Relative Permeability

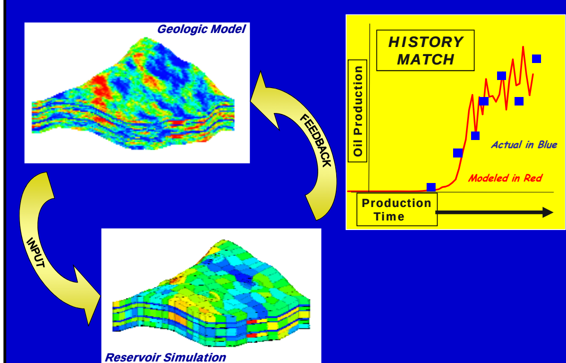


Shale Gas Reservoirs



Matrix Gas
Fracture Gas
Adsorbed Gas = Attached to the surface of the organic matter

Reservoir Simulation

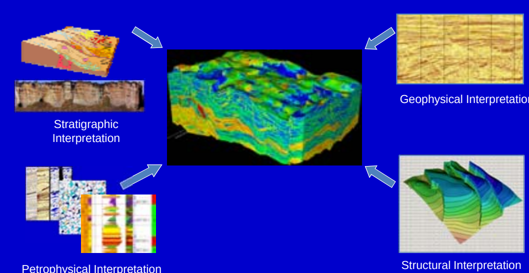


Courtesy of ExxonMobil

33

A Geologic (Static) Model

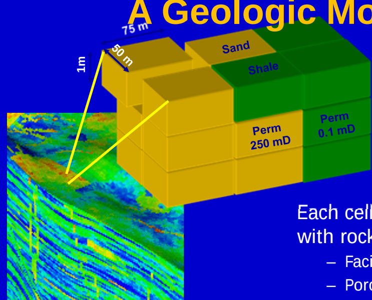
An integration of all geologic, geophysical, petrophysical and interpreted or conceptual information about a reservoir into a single 3D numerical description of that reservoir



Courtesy of ExxonMobil

34

A Geologic Model



Each cell can be populated with rock & fluid Properties:
- Facies
- Porosity
- Permeability
- Fluid Saturation
- Etc.

Courtesy of ExxonMobil

35

Take Home Ideas

- Petroleum exists in the pore space
- Compaction & cementation decrease porosity
- Dissolution, fracturing and dolomitization increase porosity
- Permeability controls migration and production
- Oil, gas and water impede each other's flow
- Reservoir models are necessary to manage reservoirs effectively