Reservoir Properties

Geology 493

Porosity and Permeability

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

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

Porosity Varies with Sorting

<table>
<thead>
<tr>
<th>MORE POROUS</th>
<th>VS</th>
<th>LESS POROUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well Sorted Sand</td>
<td>Poorly Sorted Sand</td>
<td></td>
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</tbody>
</table>

Porosity and Packing

- Cubic Packing 47% porosity in the ideal situation
- 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
  - Recrystallization – Dolomitization
  - Fracturing
- Cementation
- Shale
  - Compaction – 50%
  - Bound Water Expulsion

Porosity Varies with % Cement

Porosity Varies with Fracturing

Secondary Porosity

Dolomitization

Porosity in Sandstone

Porosity Varies with Fracturing

Dolomitization

Calcite (CaCO₃)

Antrim Fm. Michigan

Dolomite CaMg (CO₃)₂

Volume decrease leads to new porosity

Wilcox Fm. South Texas

2 mm

0.25 mm

Figure 13.7
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

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

\[ Q = -\frac{k A (P_b - P_a)}{\mu} \]

Log-normal plot

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

Porosity vs. Permeability

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

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

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

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