How much oil is in place?
How much oil is recoverable?
How can I maximize oil recovery?

Under economic constraints
Origin of Petroleum

Diagram showing the process of petroleum formation, from sedimentary deposits to oil migration.
Where are the resources?
Traps

Dome trap

Fault trap

Unconformity trap

Salt dome trap
Rock Properties

Porosity \( \phi \) = \( \frac{V_p}{V_b} \)

Permeability - ability of porous media to transmit fluids

\[
q = -\frac{KA}{\mu} \left[ \frac{\Delta p}{\Delta L} + \rho g \frac{\Delta z}{\Delta L} \right]
\]
Rock Properties

\[ S_o = \frac{V_o}{V_p} \]

\[ \sum S_i = 1 \]
Rock Properties

- Grain size
- Sorting
- Packing

COARSE GRAIN ROCK
NO MIXING
FINE GRAIN ROCK
NO MIXING
EXCELLENT SORTING

COARSE GRAIN ROCK
WITH FINES IN THE PORES

FINE GRAIN ROCK
WITH LARGER PARTICLES "FLOATING"
POOR SORTING

Porosity = 47.6%
Porosity = 25.96%
Reservoir Engineering

How much oil is in place?

Volumetric Method

\[ N = \frac{7758Ah\phi(1 - S_w)}{B_o} \]

- **N**, oil-in-place, stb
- **A**, area, acres
- **h**, thickness, ft
- **\phi**, porosity
- **S_w**, water saturation
- **B_o**, Formation volume factor, rbbl/stb
Petroleum Fluids

Composition

- Fluids found in petroleum reservoirs consist of petroleum and brine

- Petroleum maybe gaseous, liquid or solid

- Chemical composition of petroleum
  - Molecules contain C and H
  - Alkane series form basis $C_n H_{2n+2}$

- Natural gases consist of 10,000s of compounds, but are mostly methane, > 90%

- Crude oils consist of 100,000s of compounds, including methane
Petroleum Fluids

Properties

• Density = mass per unit volume
• For crude oils, the density (or gravity) is expressed on the API scale, American Petroleum Institute

\[ API = \frac{141.5}{Sp.Gr.} - 131.5 \]

• If Sp. Gr. = 1.0, then °API = 10
Petroleum Fluids

Properties

• For gases, the density is expressed as the specific gravity with respect to the density of air at the same T and P.

\[ Sp.Gr.(Air = 1) = \frac{\text{density of gas at } T \text{ & } P}{\text{density of air at same } T \text{ & } P} \]

• The Sp. Gr. of a gas may be estimated by:

\[ Sp.Gr.(Air = 1) = \frac{\text{M.W. of gas}}{\text{M.W. of air} \approx 29} \]

• Example: Methane, MW = 16, the Sp. Gr. (air = 1) = 0.55.
Petroleum Fluids

Properties

*Viscosity* is the fluid property, which describes how much force (energy) is required to cause it flow.

The higher the viscosity, the more force required.

Viscosity usually decreases as the T increases.

The common unit of viscosity in the oil field is the Poise or 1/100th of Poise, the centipoise.

\[ 1P = \frac{dyne - sec}{2 cm} \]

Typical crude oil viscosity is 0.5 to 1.5 cp.

Typical gas viscosity is 0.01 cp.
Petroleum Fluids

As crude oil flows from the Reservoir to the surface, $P$ and $T$ decrease and gas is Evolved.

Remaining volume of 1 barrel of oil from the subsurface after gas has bubbled out.

Number of barrels of Reservoir oil to produce 1 barrel of stock tank oil

Formation Volume Factor
Reservoir Engineering

How much oil is in place?

3D view of a multilayered reservoir, colors show oil saturation
How much oil is in place?

withdrawal = Expansion of oil and dissolved gas
+ Expansion of gascap gas
+ Reduction in HCPV due to connate water expansion and decrease in the pore volume
+ Net water influx
Reservoir Engineering

How much can be recovered?

One barrel of Oil-in-place

\[
\{ \text{Recover } \sim 25\% \text{ of OIP} \\
\text{From primary reservoir energy} \}
\]

?
Reservoir Engineering

How much can be recovered?

Secondary oil recovery
Production from an oil reservoir can be enhanced by pumping water into the reservoir to displace the oil
Reservoir Engineering

How much can be recovered?

One barrel of Oil-in-place

\{ 
  Recover \sim 25\% \text{ of OIP} \\
  From secondary means \\
  Recover \sim 25\% \text{ of OIP} \\
  From primary reservoir energy
\}
Reservoir Engineering

How much can be recovered?

Enhanced oil recovery (EOR)

Production from an oil reservoir can be enhanced by:
1. Injecting CO2 to displace and swell the oil
2. Injecting surfactants …
3. Injecting polymers..
4. Steamflooding…
Reservoir Engineering

How much can be recovered?

One barrel of Oil-in-place

\[
\begin{align*}
\text{Recover } & \sim 25\% \text{ of OIP} \\
\text{From primary reservoir energy} \\
\text{Recover } & \sim 20\% \text{ of OIP} \\
\text{From EOR methods} \\
\text{Recover } & \sim 25\% \text{ of OIP} \\
\text{From secondary means} \\
\text{Recover } & \sim 25\% \text{ of OIP} \\
\text{From primary reservoir energy}
\end{align*}
\]
### Reservoir challenges: Multilateral wells

<table>
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<th>Lith</th>
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<td>Strawn</td>
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![Diagram showing well placement and reservoir layers](image.png)
Reservoir challenges: Impact of deposition on performance

SRV, frac spacing and azimuth are key for well placement and spacing strategies.

Optimization dependent on:

1. Natural geologic and petrophysical features thickness, stresses, natural fractures, barriers