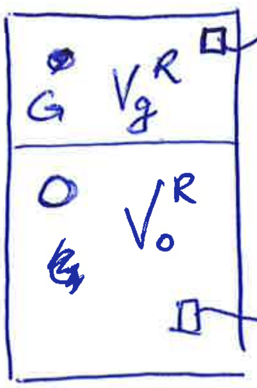
Material balance

- amount of oil in place
- —— " —— gas —— " ——
- Drive mechanism
    - expansion of gas
    - —— " —— oil (or gas dissolved in oil)
    - reservoir compaction
    - active ~~aquifer~~ aquifer

- ~~e~~ Knowledge can be extracted from
    - measured production data
    - PVT properties of fluid
    - compressibillity (expansion of fluids and compaction of the rock)
    - average reservoir pressure



$$\Delta V_g^R \longrightarrow \Delta V_{g,g}^S + \Delta V_{o,g}^S$$

phase

which reservoir phase it originates from

$$\Delta V_o^R \longrightarrow \Delta V_{o,o}^S + \Delta V_{g,o}^S$$

reservoir condition [Rm^3]

V_g^R

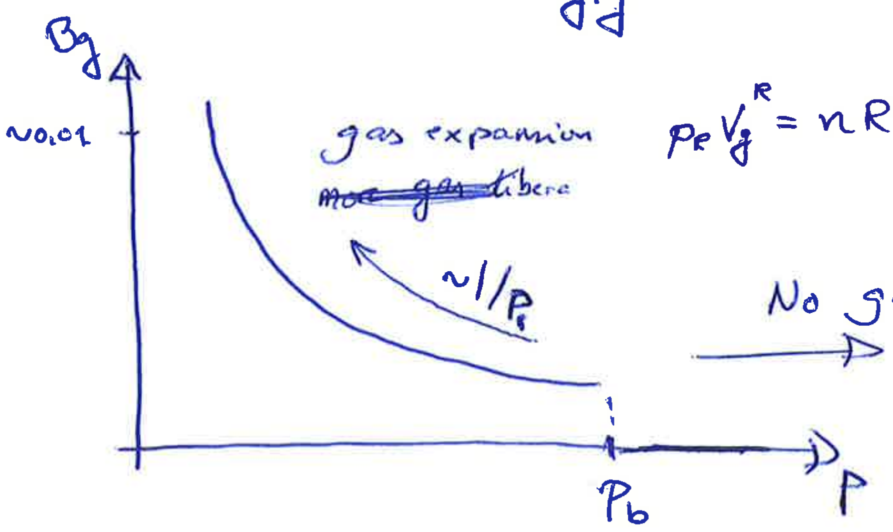
V_o^R

- volumes are measured at surface conditions

volume factors

1) $$B_g(p) = \frac{\Delta V_g^R(p)}{\Delta V_{g,g}^S} \qquad \frac{[Rm^3]}{[Sm^3]}$$

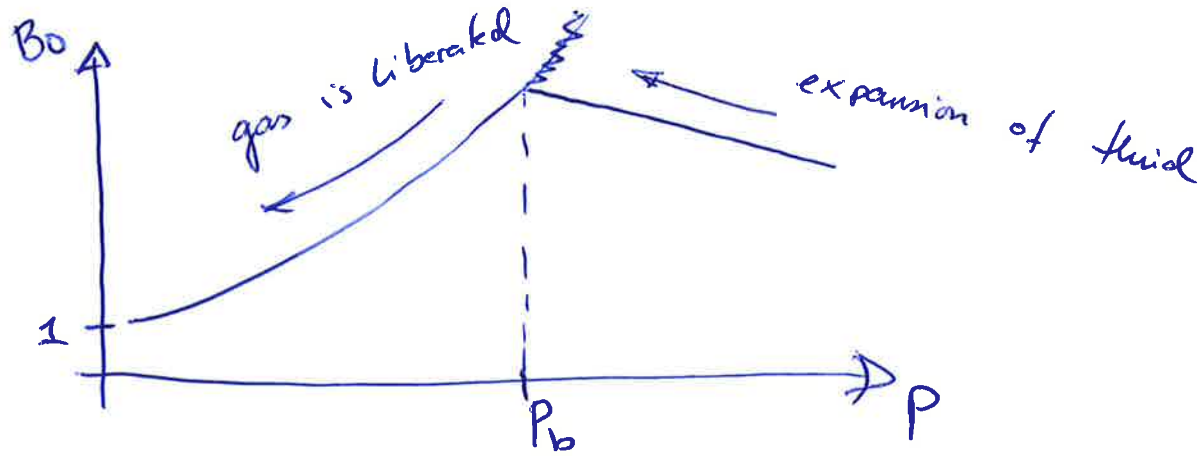
$$p_R V_g^R = nRT \Rightarrow V_g^R = \frac{nRT}{p} \sim 1/p$$



No gas in the reservoir →

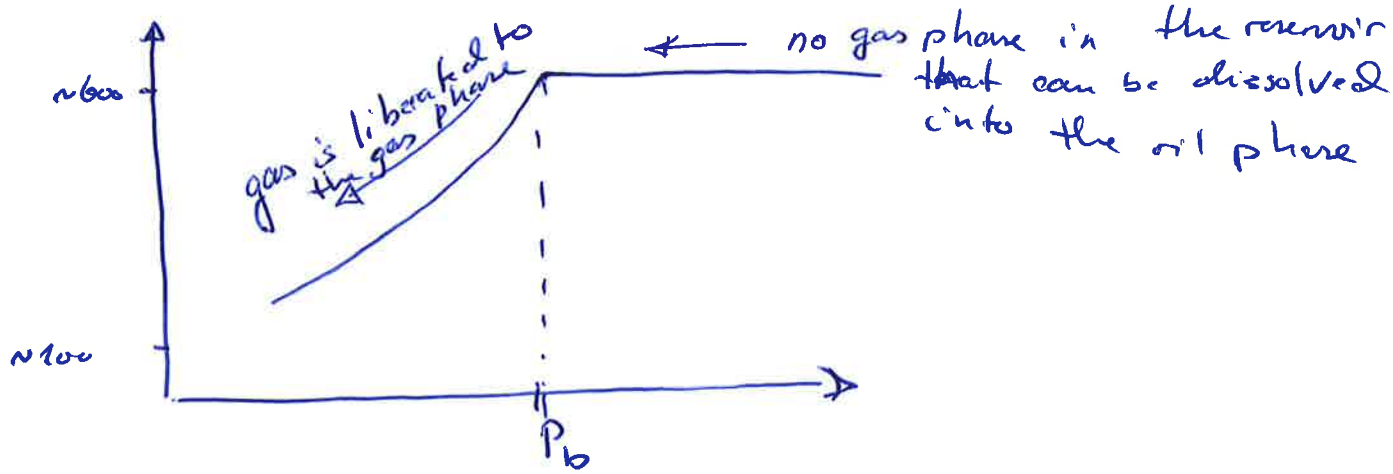
2) volume factor for oil

$$B_o(p) = \frac{V_o^R(p)}{V_{o,o}^S} \quad \frac{[Rm^3]}{[Sm^3]}$$



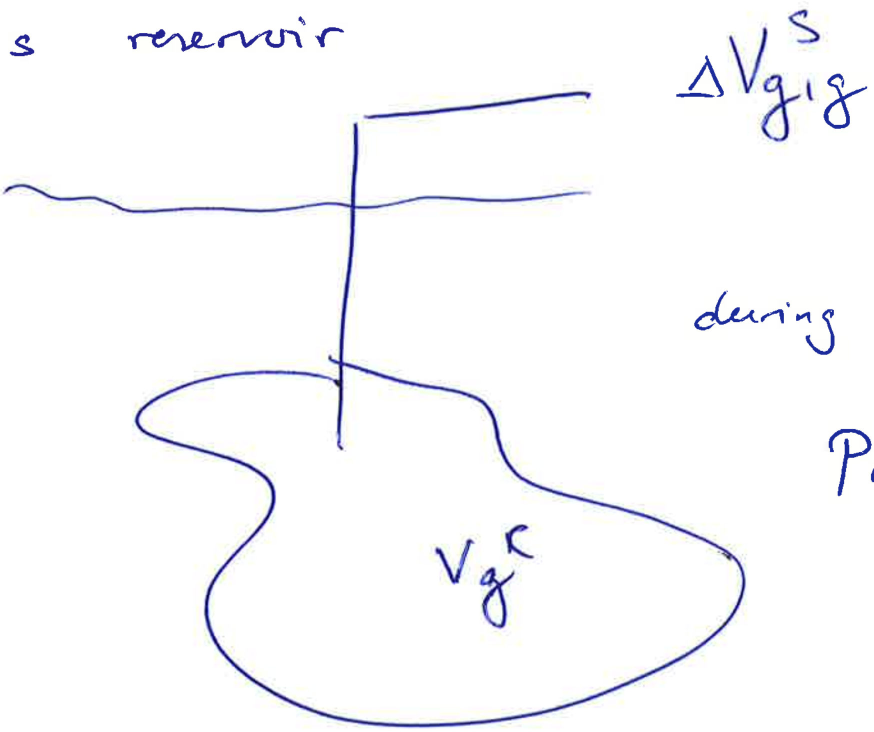
3) Dissolved gas oil ratio

$$R_s(p) = \frac{\Delta V_{g,o}^S(p)}{\Delta V_{o,o}^S} \quad \frac{[Sm^3]}{[Sm^3]}$$



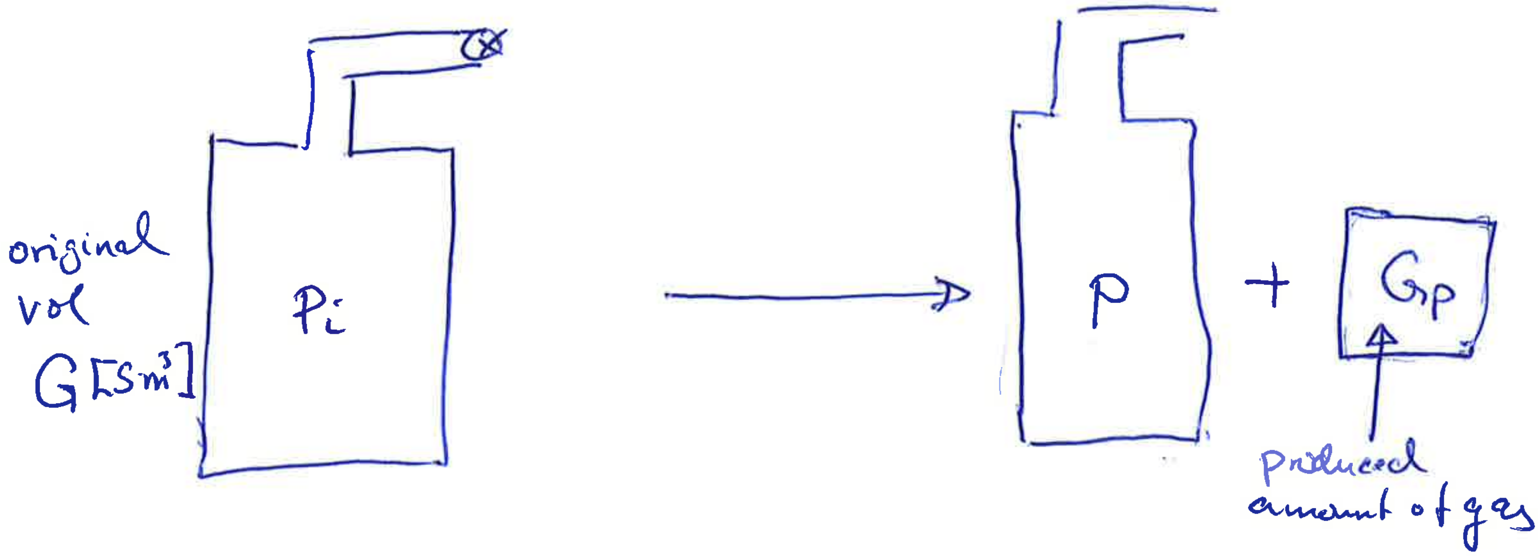
How is this useful ?

Ex. Gas reservoir

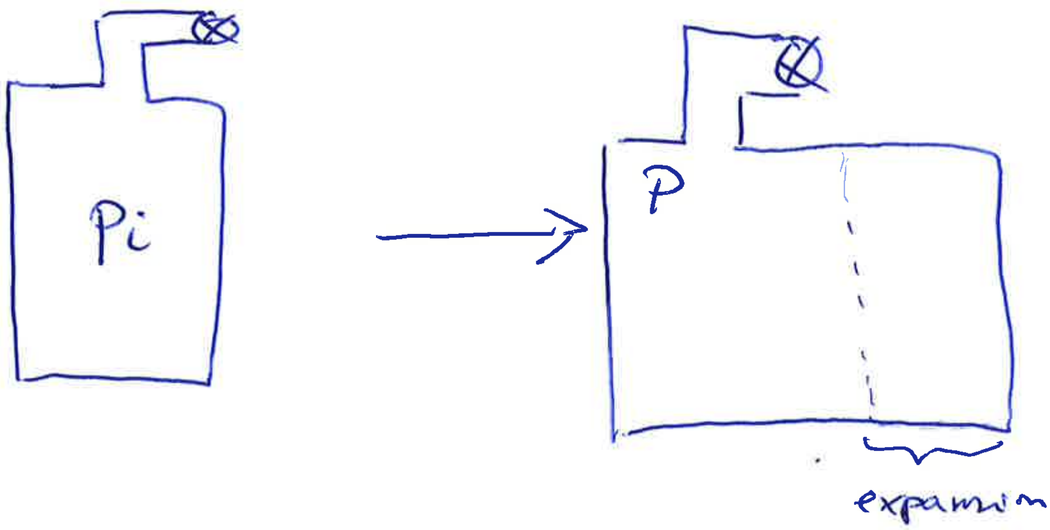


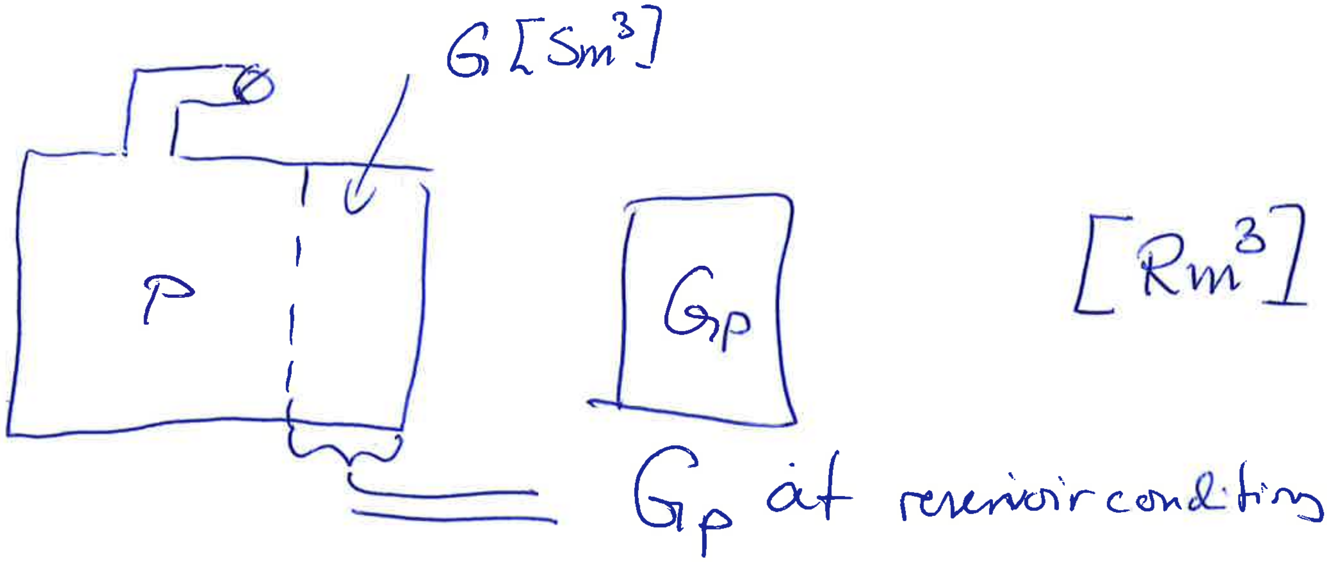
during production

$P_i \longrightarrow P$



virtual expansion





~~original~~ volume of gas @ p_i $\quad G \cdot B_g(p_i) \equiv G B_{g,i}$ [Rm³]

$\left[B_g(p_i) = \frac{V_g^R}{V_{g,g}^S} \Leftrightarrow V_g^R = B_g V_{g,g}^S \right]$

——— " ——— @ p : $\quad G \cdot B_g(p) \equiv G B_g$ [Rm³]

produced volumes in Rm³ $\quad G_p B_g$

[Rm³] virtual expansion in the reservoir = produced volume

$$G B_g - G B_{g,i} = G_p B_g$$

$$G - G \frac{B_{g,i}}{B_g} = G_p \quad (*)$$

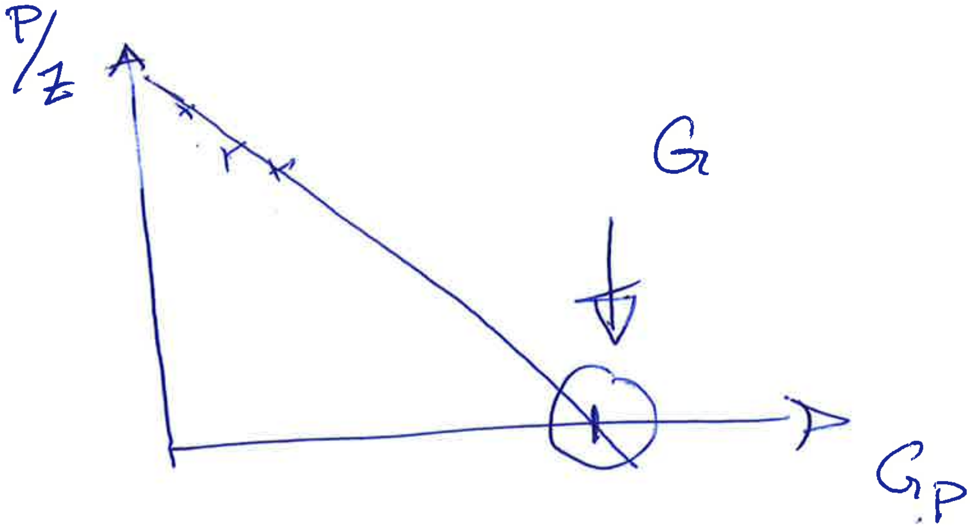
$$V_g^R = \frac{ZnRT}{p} \Rightarrow \frac{B_{g,i}}{B_g} = \frac{V_g^R(p_i)/V_{g,g}^S}{V_g^R(p)/V_{g,g}^S} = \frac{V_g^R(p_i)}{V_g^R(p)}$$

$$\Rightarrow \frac{B_{g,i}}{B_g} = \frac{Z(p_i)\, nRT_i/p_i}{Z(p)\, nRT/p} = \frac{Z_i}{Z}\,\frac{P}{P_i}\,\frac{T_i}{T}$$

$Z_i \equiv Z(p_i)$

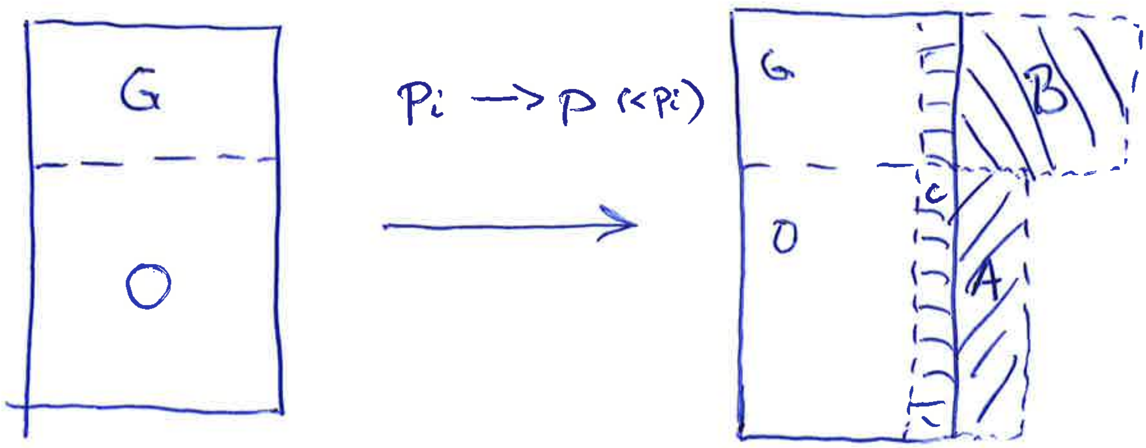
$$\text{from } (*) = G - G \frac{Z_i}{P_i}\frac{P}{Z} = G_p$$

$$\frac{P}{Z} = \frac{P_i}{Z_i}\left[1 - \frac{G_p}{G}\right] \times \frac{T}{T_i}$$



Material balance for an oil reservoir

↪ virtual expansion



= expansion of oil + dissolved gas in the oil

= expansion of gas

= reduction in hydrocarbon pore volum (HCPV) due to expansion of water & compaction of the rock