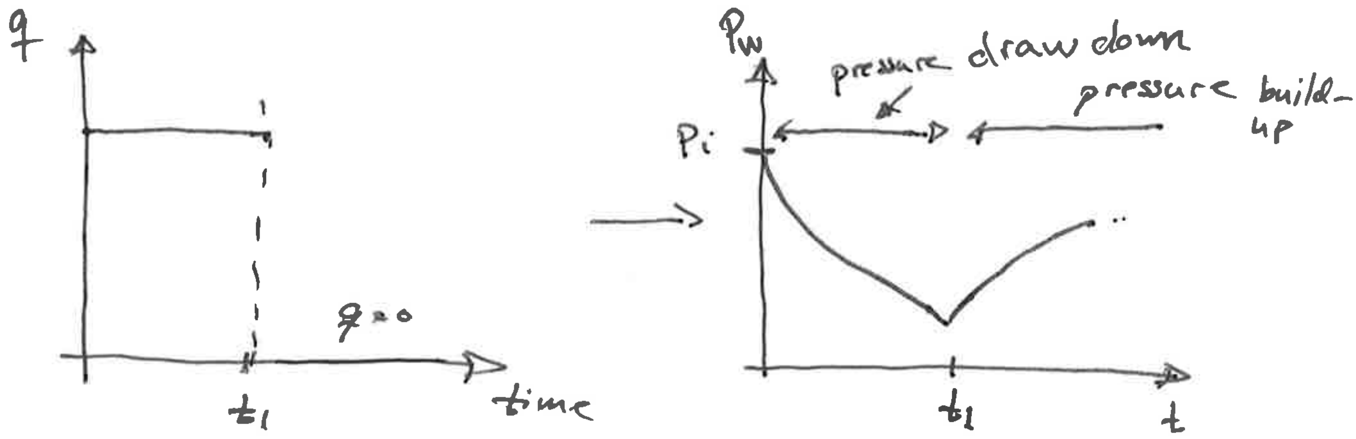
Well testing:

input: measured ~~pr~~ well pressure, flow rates, PVT-data of the fluids

1) Mathematical model that describes how the reservoir pressure change as a function of time

$\longrightarrow$ Diffusivity equation

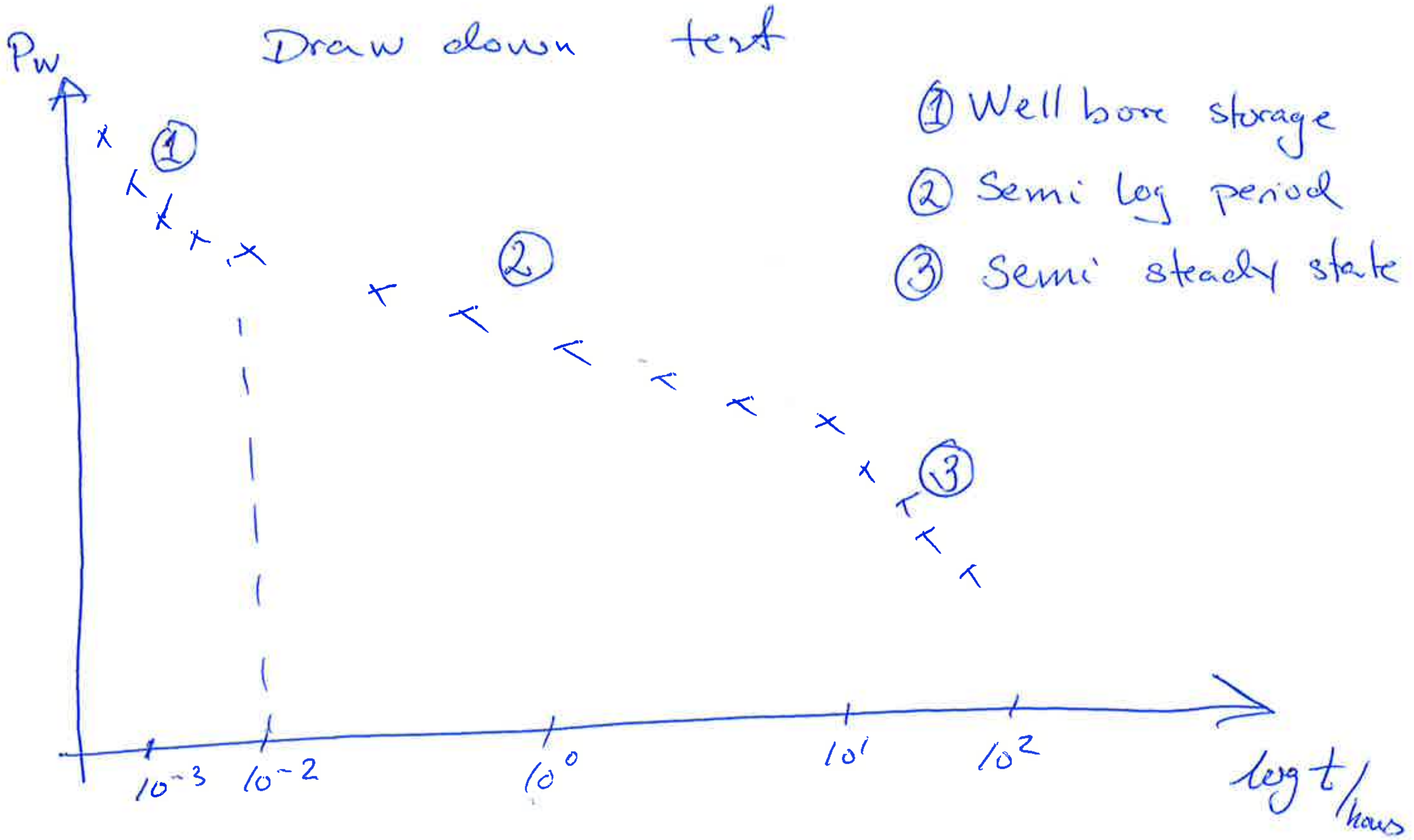
2) The diffusivity equation can be solved for different boundary conditions



3) We can get information about:

- well storage capacity
- skin factor
- reservoir permeability
- drainage area (shape area)
- average reservoir pressure

Draw down test



1 Well bore storage
2 Semi log period
3 Semi steady state

① Wellbore storage

$$c_f = -\frac{1}{V_f}\frac{dV_f}{dp_f} \qquad (1)$$

production $$Q_f^s = \frac{\Delta V_f^s}{t} = \frac{1}{B_f}\frac{\Delta V_f}{t} \qquad (2)$$

assume $c_f \approx$ constant

(1) $\Longrightarrow$ $$\underbrace{\int_{p_i}^{p} c_f V_f \, dp_f}_{c_f V_f (p - p_i)} = -\int dV_f = -\Delta V_f$$

(= produced fluids)

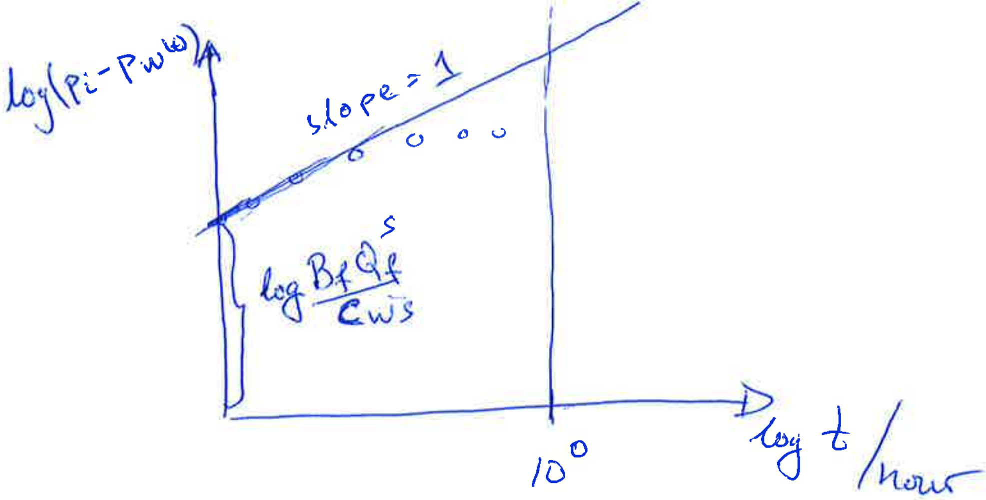
$$c_f V_f (p - p_i) = -\Delta V_f$$

(2) $\Longrightarrow$ $$Q_f^s = \frac{1}{B_f} = -\frac{1}{B_f}\frac{c_f V_f (p - p_i)}{t}$$

$$p_w(t) = p_i - \frac{B_f Q_f^s \cdot t}{\underbrace{V_f c_f}_{C_{ws}}}$$

C_{ws} = wellbore storage

$$\log(p_i - p_w(t)) = \log\left(\frac{B_f Q_f^s}{C_{ws}} t\right) = \log\frac{B_f Q_f^s}{C_{ws}} + \log t$$

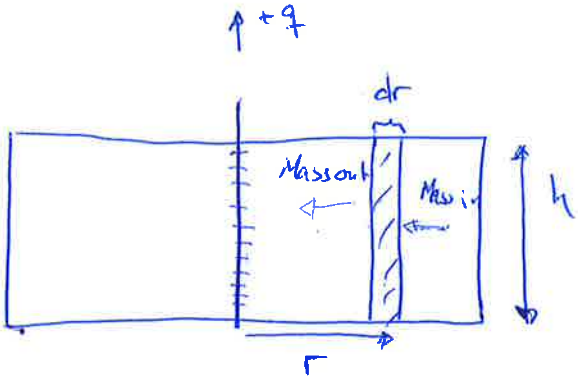


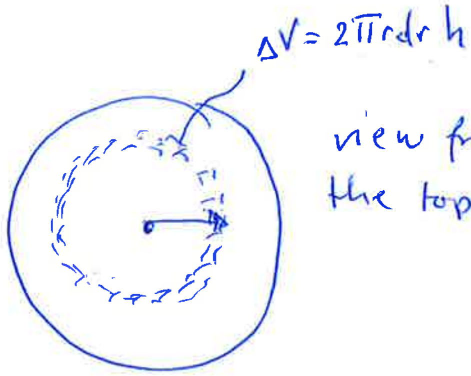
log(pi-pw(t))
slope = 1
log Bf qf s / Cws
10^0
log t /hour

~~Eor~~

Two equations ① conservation of mass
② Darcy law

view from side





view from the top

(Assumptions : homogeneous, well perforated in the whole section)

① $\frac{\text{Mass in}}{\text{time}} - \frac{\text{Mass out}}{\text{time}} = \frac{\overset{\sim \Delta V}{\text{chang in mass}}}{\text{time}}$

$$\underbrace{(q \cdot \rho)_{r+dr}} - (q \cdot \rho)_r = \frac{d(\rho \cdot \Delta V \cdot \varphi)}{dt}$$

$\frac{\text{Volume}}{\text{time}} \times \frac{\text{mass}}{\text{Volume}} = \frac{\text{mass}}{\text{time}}$

$$f(x+\Delta x) = f(x) + \frac{1}{1!} f'(x) \Delta x + \frac{1}{2!} f''(x) \Delta x^2 + \cdots$$

$$\to (q \cdot \rho)_r + \frac{\partial}{\partial r}(q \cdot \rho)\, dr + \cdots$$

$$\frac{\partial}{\partial r}(q \cdot \rho)\, \cancel{dr} = \frac{d}{dt}\left(\rho\, 2\pi r\, h \cdot \cancel{dr} \cdot \varphi\right)$$

$$\boxed{\frac{\partial}{\partial r}(q \cdot \rho) = 2\pi r h \frac{d}{dt}(\rho \cdot \varphi)} \quad (i)$$

② Darcy law ;

$$q = \frac{k \cdot 2\pi r h}{\mu} \frac{\partial p}{\partial r} \qquad (ii)$$

(i) & (ii)

pressure pressure

$$\Rightarrow \boxed{\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial p}{\partial r}\right) = \frac{1}{\eta}\frac{\partial p}{\partial t}}$$

$$\eta = \frac{k}{\mu \varphi c_t}, \quad C_t = \text{total compressibility}$$

$$C_t = C_p + C_f$$

C_p: pore compressibility

C_f: fluid compressibility

$$\frac{\partial(\rho \cdot \varphi)}{\partial t} = \varphi \frac{\partial \rho}{\partial t} + \rho \frac{\partial \varphi}{\partial t}$$

$$\frac{\partial \varphi}{\partial t} = \frac{\partial \, V_p/V_b}{\partial t} = \frac{1}{V_b}\frac{\partial V_p}{\partial t}, \quad C_p = -\frac{1}{V_p}\frac{\partial V_p}{\partial P_s}$$

$P_s \to -P$

$$\partial V_p = C_p V_p \, \partial P$$

P ← fluid pres.

$$\frac{\partial \varphi}{\partial t} = \frac{1}{V_b} C_p V_p \frac{\partial p}{\partial t} = \varphi C_p \frac{\partial p}{\partial t}$$

$$\frac{\partial \rho}{\partial t} = \frac{\partial \, m/V_p}{\partial t} = m \frac{\partial \frac{1}{V_p}}{\partial t} = -\frac{m}{V_p^2}\frac{\partial V_p}{\partial t}$$

$$c_f = -\frac{1}{V_p}\frac{\partial V_p}{\partial P} \Rightarrow \partial V_p = -C_f V_p \, \partial P$$

$$\frac{\partial \rho}{\partial t} = \frac{m C_f \cancel{V_p}}{V_p^{\cancel{2}}}\frac{\partial P}{\partial t} = \rho C_f \frac{\partial p}{\partial t}$$

$$\rightarrow \frac{\partial}{\partial t}(\rho\varphi) = \varphi\rho C_p \frac{\partial p}{\partial t} + \varphi\rho C_f \frac{\partial p}{\partial t} = \varphi\rho\underbrace{(C_p + C_f)}_{= C_t}\frac{\partial p}{\partial t}$$

For diffusive processes : $\boxed{D = \frac{L^2}{4t}}$

For pressure : $\eta = \frac{L^2}{4t}$

$$k = 1\,D \simeq 1(\mu m)^2 = 10^{-12}\,m^2$$

$$\mu = 1\,cP = 10^{-3}\,Pa\cdot s$$

$$C_t = 10^{-5}/psi \simeq 1.45\cdot 10^{-9}\ 1/Pa$$

$$\varphi \simeq 0.3\cancel{8}$$

$$\eta = \frac{10^{-12}\,m^2}{10^{-3}\,Pa\,s \cdot 0{,}3\cancel{8} \cdot 1{,}45\cdot 10^{-9}\ 1/Pa} \simeq \underline{\underline{2{,}3\ m^2/s}}$$

$$L = 7\,cm = 7\cdot 10^{-2}\,m$$

$$t = \frac{L^2}{4D} = \frac{(7\cdot 10^{-2}\,m)^2}{4\cdot 2{,}3\,m^2/s} = \underline{5{,}3\cdot 10^{-4}\,s}$$

$$L = 1\,km \Rightarrow t = \frac{(10^3\,m)^2}{4\cdot 2{,}3\,m^2/s} = 1{,}087\cdot 10^5\,s \simeq \underline{\underline{30\ hours}}$$