Note Title 9/10/2018

Development of Gas Material Balances

② Pot Aquifer Gas MB

① Straight-Line Gas MB

ASSUMPTIONS SLMB:

* (a) $HCPV_g$ (V_{gR}) = constant during depletion

(b) Const. T_R

(c) No injected gas

(d) Produced "Surface Gas" is "surface wet gas volume"

$$G_p = G_{pw} = G_{pd} + \underbrace{\underbrace{N_p \left(\frac{\rho_{\bar{o}}}{M_{\bar{o}}}\right)}_{n_{p\bar{o}}} \underbrace{\left(\frac{RT_{sc}}{p_{sc}}\right)}_{23.68\ Sm^3/kg\text{-mole}}}_{GEQ}$$

Actual produced surface gas @ STC

(e) Real Gas Law applies

$$pV_g = nRTZ$$

(f) "G_{pw}" $= n\left(\frac{RT_{sc}}{p_{sc}}\right)$

Surface Gas Volumes Used in Any/All "p/Z" gas material balances are $G_{pw} \rightarrow n$

SLMB:

$$pV = nRTZ \Rightarrow V_{gR} = \frac{n_{gR}\, R\, T_R\, Z}{p_R}$$

$$V_{gRi} = V_{gR} \quad \text{at any } p_R < p_{Ri}$$

$HCPV_{gi}$

$$\frac{n_{gRi}\, \cancel{R}\, \cancel{T_R}\, Z_i}{p_{Ri}} = \frac{n_{gR}\, \cancel{R}\, \cancel{T_R}\, Z_R}{p_R}$$

Molar Material Balance

$$n_{gR} = n_{gRi} - n_p$$

$$\frac{n_{gRi}\, Z_i}{p_{Ri}} = \frac{(n_{gRi} - n_p)\, Z_R}{p_R}$$

$$\frac{p_R}{Z_R} = \left(\frac{n_{gRi}}{n_{gRi}} - \frac{n_p}{n_{gRi}}\right)\frac{p_{Ri}}{Z_i}$$

$$\frac{p_R}{Z_R} = \left(1 - \frac{n_p}{n_{gRi}}\right)\frac{p_{Ri}}{Z_i}$$

$$\frac{n_p \left(\cancel{\frac{R T_{sc}}{p_{sc}}}\right)}{n_{gRi}\left(\cancel{\frac{R T_{sc}}{p_{sc}}}\right)} = \frac{G_{pw}}{G_w} = \frac{G_p}{G}$$

$$\boxed{\frac{p_R}{Z_R} = \frac{p_{Ri}}{Z_i}\left(1 - \frac{G_p}{G}\right)} \quad \text{SLMB}$$

② Pot Aquifer Gas M.B.

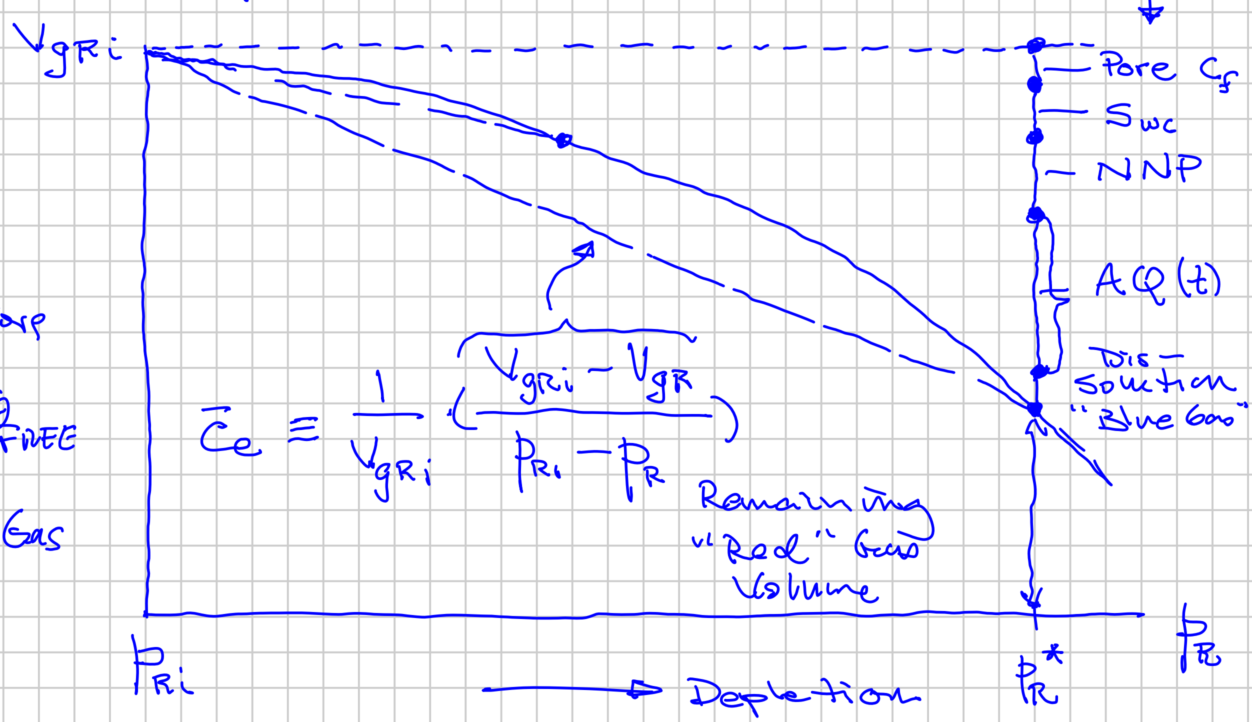
(b)−(f) same assumptions

(a) $V_{gR} \neq$ constant

$$C \equiv -\frac{1}{V}\frac{dV}{dp}$$

$p = p_R$

HCPV$_g$ (p_R)



V_{gR} = Reservoir Pore Volume containing INITIAL FREE GAS − Produced Gas

$$\bar{C}_e \equiv \frac{1}{V_{gRi}}\left(\frac{V_{gRi} - V_{gR}}{p_{Ri} - p_R}\right)$$

Pot Aq. $\quad C_f(\underline{\underline{p_R}}) \quad C_{tw}(\underline{\underline{p_R}})$

99%
GMB+AQ $\quad C_f$ = const $\quad C_w$ = const $\quad R_{sw} = 0$
Blue Gas

Development of Pot Aquifer Gas M.B. Eq.

$$V_{gRi} = \left[\frac{n_{gRi}\, R\, T_R\, Z_i}{p_{Ri}}\right]$$

After Depletion to p_R, $V_{gR} < V_{gRi}$

$$\frac{V_{gRi}}{V_{gRi}}\, V_{gR} = \frac{n_{gR}\, R\, T_R\, Z_R}{p_R} \quad ; \quad n_{gR} = n_{gRi} - n_p$$

$$V_{gRi} = \left[\frac{(n_{gRi} - n_p)\, R\, T_R\, Z_R}{p_R} \cdot \left(\frac{V_{gRi}}{V_{gR}}\right)\right]$$

$$\frac{n_{gRi}\, \cancel{R}\, \cancel{T_R}\, Z_i}{p_{Ri}} = \frac{(n_{gRi} - n_p)\, \cancel{R}\, \cancel{T_R}\, Z_R}{p_R} \cdot \left(\frac{V_{gRi}}{V_{gR}}\right)$$

$$\frac{p_R}{Z_R}\left(\frac{V_{gR}}{V_{gRi}}\right) = \frac{p_{Ri}}{Z_i}\left(\frac{n_{gRi} - n_p}{n_{gRi}}\right)$$

$$\frac{p_R}{Z_R}\underbrace{\left(\frac{V_{gR}}{V_{gRi}}\right)} = \frac{p_{Ri}}{Z_i}\left(1 - \frac{G_p}{G}\right)$$

Current Reservoir Volume Containing "Red" Gas " ——— "

——————————————— ———— above

Initial Reservoir Volume Containing "Red" Gas " ----- "

$$\bar{c}_e \equiv \frac{1}{V_{gRi}}\left(\frac{V_{gRi} - V_{gR}}{p_{Ri} - p_R}\right) \Rightarrow \underbrace{\left(\frac{V_{gR}}{V_{gRi}}\right)} = \left[1 - \bar{c}_e(p_R)\,(p_{Ri} - p_R)\right]$$

$$\boxed{\frac{p_R}{Z_R}\left[1 - c_e(p_R)\,(p_{Ri} - p_R)\right] = \frac{p_{Ri}}{Z_i}\left(1 - \frac{G_p}{G}\right)}$$

$$\bar{c}_e(p_R) = \frac{\bar{c}_f(p_R) + \bar{c}_{tw}(p_R)\,S_{wc} + \overset{\text{NNP + AQ}}{M}\left(\bar{c}_f(p) + \bar{c}_{tw}\right)}{1 - S_{wc}}$$

$(1 - c_e \Delta p) < 1$ Shrinkage of Red Gas Reservoir Volume

Brief Comment on Limitation of "Pot Aquifer"

– AQ volume "encroachment"

There's a delay between p_{Rg} drops and p_{RAQ} drops the same amount

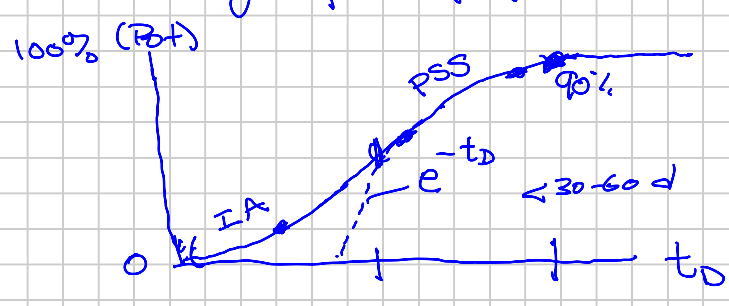
How much delay?

How much less shrinkage of $\Delta V_{gR,AQ}(t)$

Aquifer Models:

1. Hurst van Everdingen ($\sim$ o Aq. Influx $\Rightarrow$ Pot Aq.)
   - Solves the Aq. diffusivity eq. (Superposition)

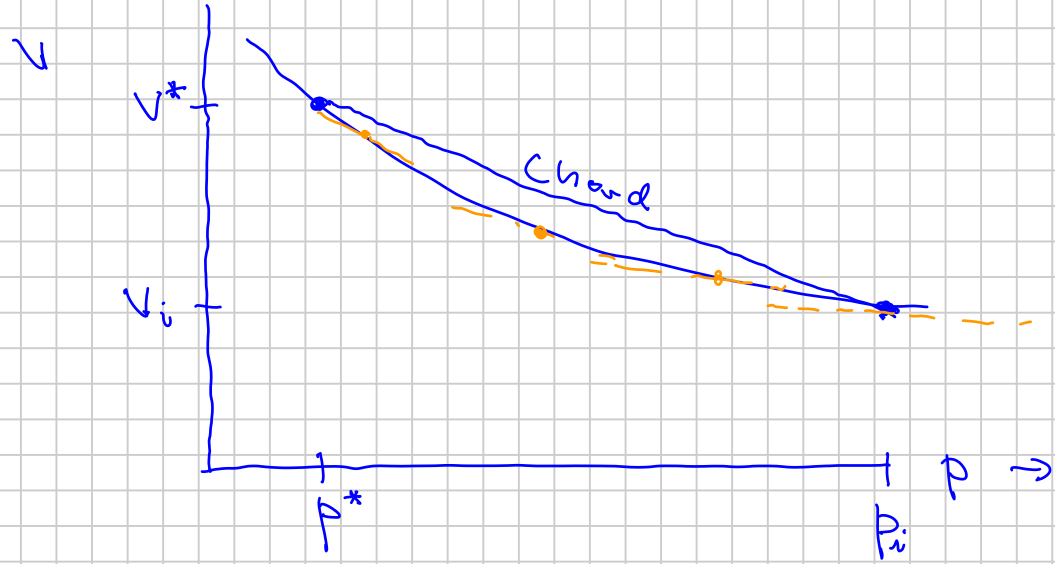
2. Schilthuis (IA)



3. ?

4. Fetkovich (PSS)

5. Carter-Tracy



"Cumulative" Compressibility

$$\bar{c}(p) \equiv \frac{1}{V_i} \underbrace{\frac{V(p) - V_i}{p - p_i}}_{\text{Chord Slope from } (p_i, V_i)}$$

$\bar{c}(p)$ finds directly V^* $(p = p^*)$
from initial (p_i, V_i)