Research Summary

Dual-Porosity Model of Multi-Scale Fractures in Source Rocks

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Problem Statement

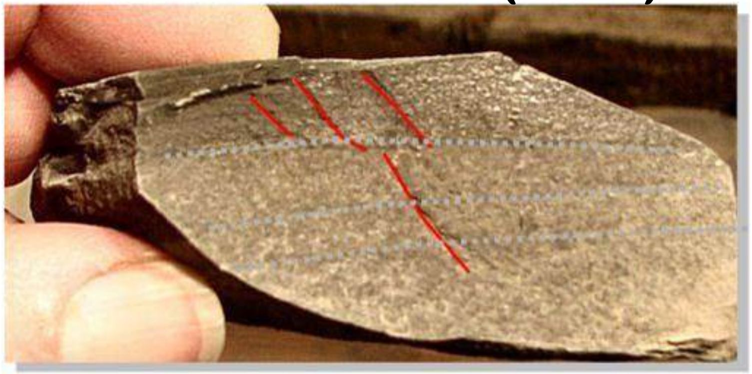
Field Scale (m)

Macro fractures
tectonic events burial and uplifting folding and faulting, etc.

Core Scale (cm)

No fracture

Micro Scale (mm)



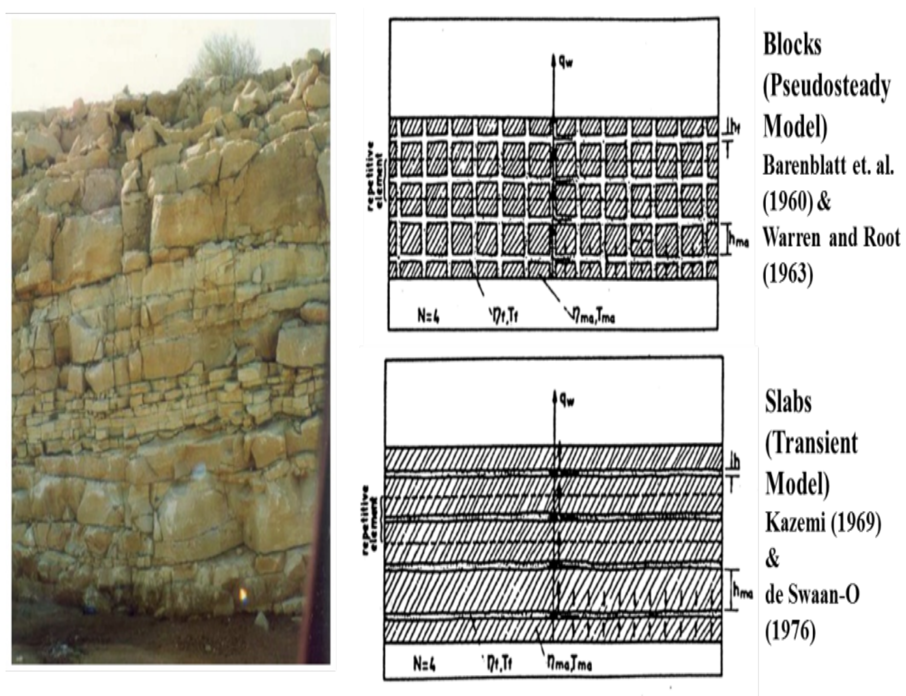
Micro fractures
hydrocarbon generation by thermal maturation

Macro fractures form continuum while micro fractures are discrete

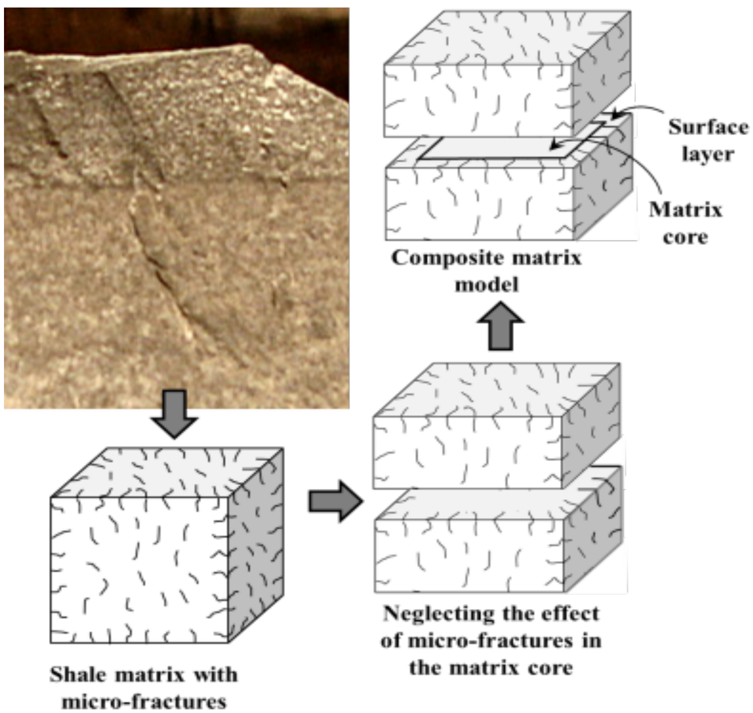
Triple-porosity model is not appropriate

Conceptual Model

Macrofracture Modeling



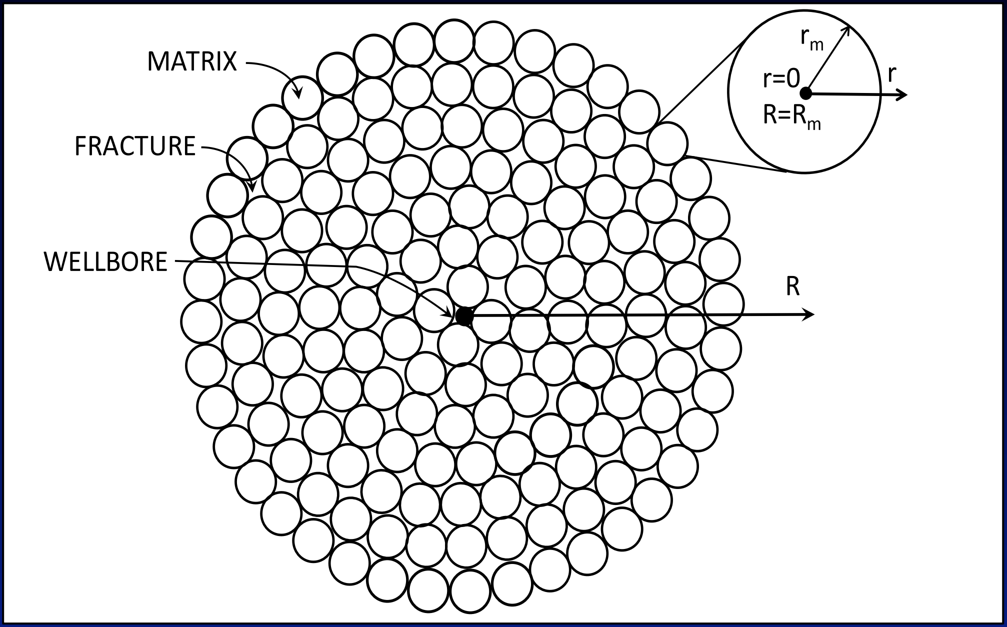
Microfracture Modeling



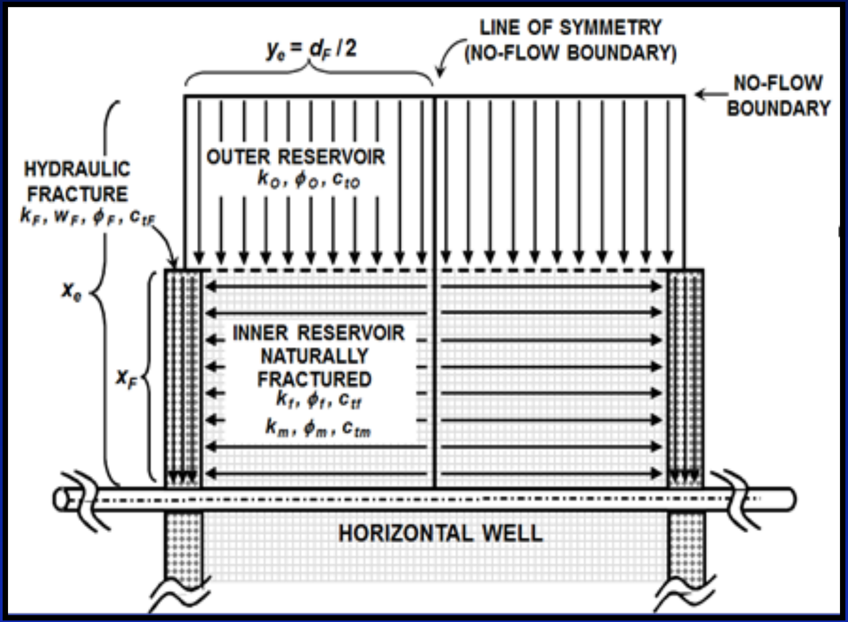
Dual-porosity idealizations of naturally fractured reservoirs (Najurieta, 1980)

Composite matrix model to idealize flow in micro-fractured shale matrix

Mathematical Formulation



Extension to fractured horizontal wells through tri-linear flow model

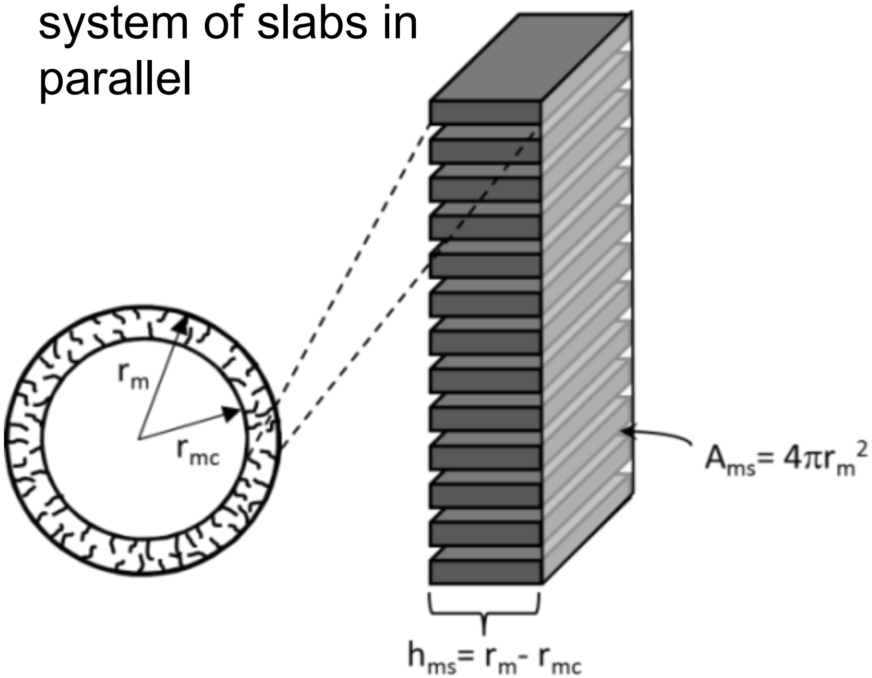


- Radial flow system with vertical well
- Spherical geometry for matrix
- Single Phase, isotropic permeability
- Composite matrix: surface-layer of microfractures and homogeneous core

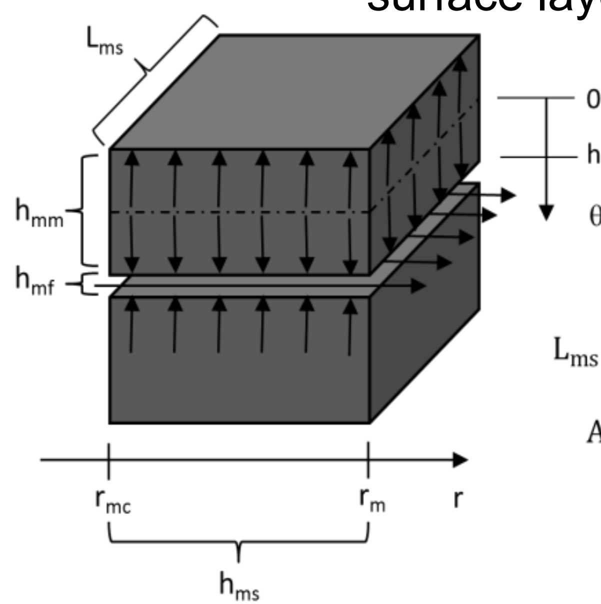
Mathematical Formulation

- Flow in a microfractured spherical matrix block

fractured matrix-surface layer by a system of slabs in parallel



Geometry of the matrix and fracture slabs used to represent the matrix surface layer



$$L_{ms} = \frac{A_{ms}}{n_{ms}(h_{mm} + h_{mf})}$$

$$A_{ms} = 4\pi r_m^2$$

Solution

Solution in the Laplace Transform domain;

$$\bar{m}_{fD} = \frac{K_0\left(\sqrt{u}R_D\right)}{s\sqrt{u}R_{wD}K_1\left(\sqrt{u}R_{wD}\right)}$$

$K_0(z)$ and $K_1(z)$ are modified Bessel functions

where $u = sf(s)$ and $f(s) = 1 - \lambda f_m(s) f_f(s)$ where $\lambda = \sigma L^2 \left(\frac{2k_{mf} r_m}{3k_f h_f}\right)$

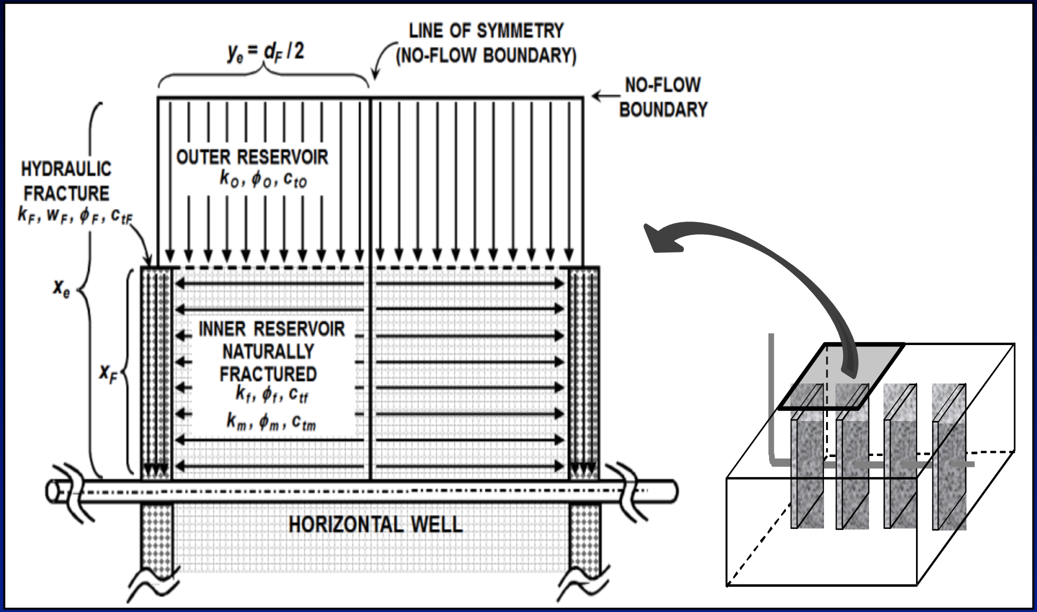
and $$f_f(s) = \left(\frac{h_{mf} r_{mD}}{5\sqrt{u_m}h_{mm}}\right)\left\{\frac{\left(\sqrt{u_m} - f_{mf}\right) - \left(\sqrt{u_m} + f_{mf}\right)\exp\left[2\sqrt{u_m}\left(r_{mD} - r_{mcD}\right)\right]}{\left(\sqrt{u_m} - f_{mf}\right) + \left(\sqrt{u_m} + f_{mf}\right)\exp\left[2\sqrt{u_m}\left(r_{mD} - r_{mcD}\right)\right]}\right\}$$

$$u_m = sf_m(s) \qquad f_m(s) = \left[1 + \sqrt{\frac{\lambda_m \omega_m}{3s\eta_{mfDi}}}\tanh\left(\sqrt{\frac{3\omega_m}{\lambda_m}s\eta_{mfDi}}\right)\right]\eta_{mfDi}$$

$$f_{mf} = \frac{h_{mm}^2 \lambda_m}{12 r_{mcD} L^2}\left[\sqrt{s\eta_{mDi}}\,r_{mcD}\coth\left(\sqrt{s\eta_{mDi}}\,r_{mcD}\right) - 1\right]$$

Solution

- Extension to Multiple Fractured Horizontal Wells with SRV



Trilinear Model

Brown et al. (2009) developed a trilinear model to simulate the pressure transient and production behavior of fractured horizontal wells in shale.

$$\beta_F = \sqrt{\alpha_O} \tanh\left[\sqrt{\alpha_O}\left(y_{eD} - \frac{w_D}{2}\right)\right]$$

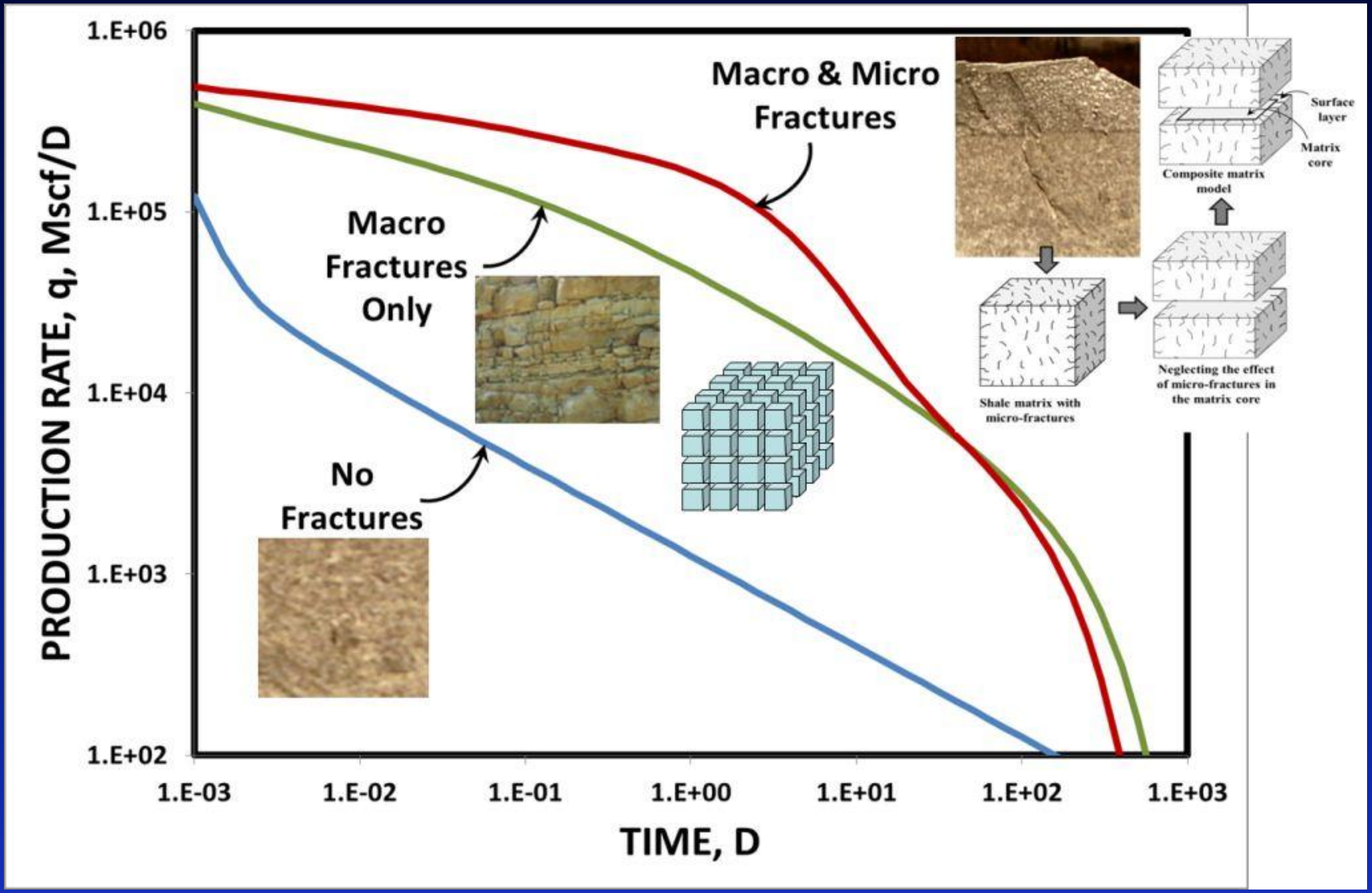
Solution is given by

$$\bar{m}_{wD} = \frac{\pi}{C_{FD} s \sqrt{\alpha_F} \tanh\left(\sqrt{\alpha_F}\right)} + \frac{s_c}{s} \qquad \alpha_F = \frac{2\beta_F}{C_{FD}} + \frac{s}{\eta_{FD}} \qquad \alpha_O = \frac{\beta_O}{C_{RD} y_{eD}} + u \qquad u = sf(s)$$

$f(s)$ definition is replaced by microfracture solution

Model Results

Comparison of production of a fractured horizontal well in homogeneous reservoir and dual-porosity reservoirs with and without microfractures



The thicker the surface layer the higher the contribution of the matrix at intermediate times

Influence of microfractures is more pronounced for lower matrix permeabilities

The conductivity of microfractures is relatively unimportant