Progress Report

Flow in Layered Unconventional Reservoirs

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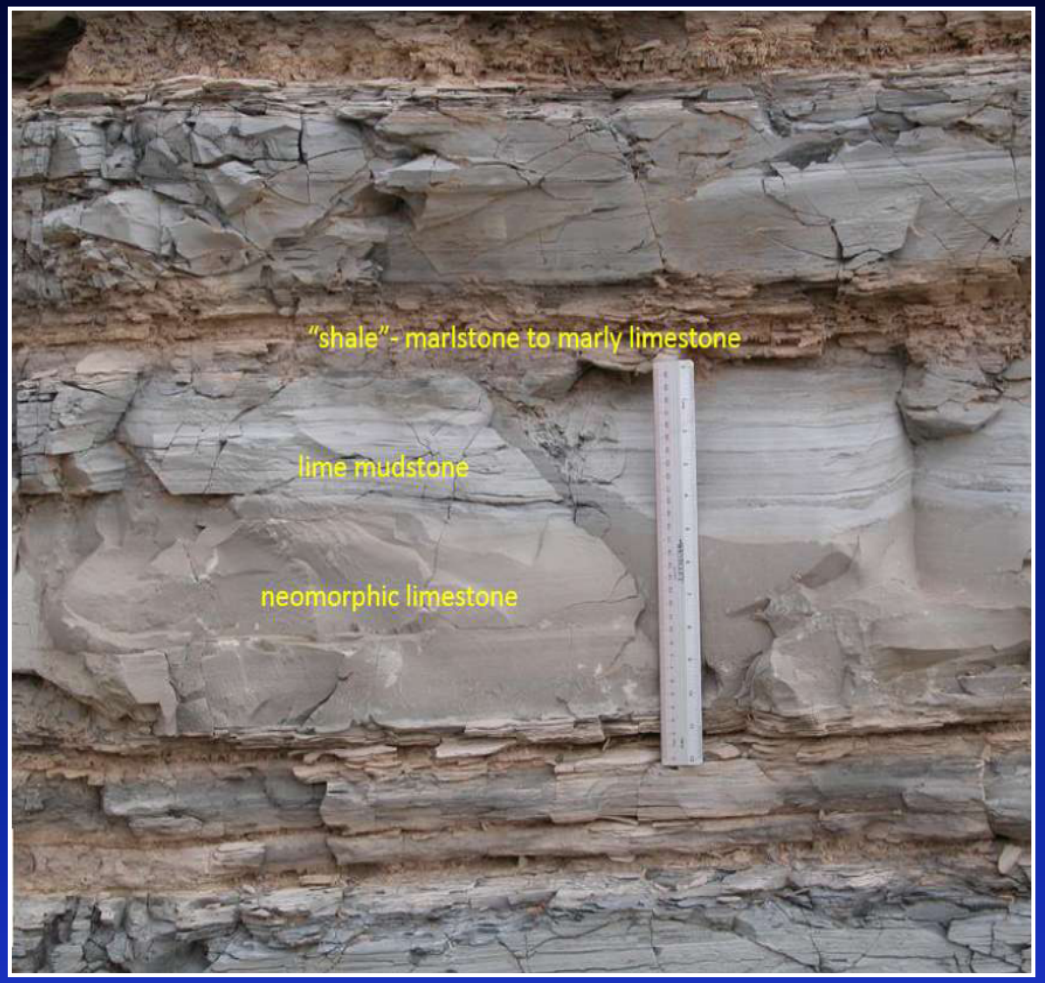
Problem Statement

Layered Unconventional Reservoirs

Producing layers sandwiched between layers of very tight (source) rock

Horizontal wells
Hydraulic fractures
Multiple phases
…



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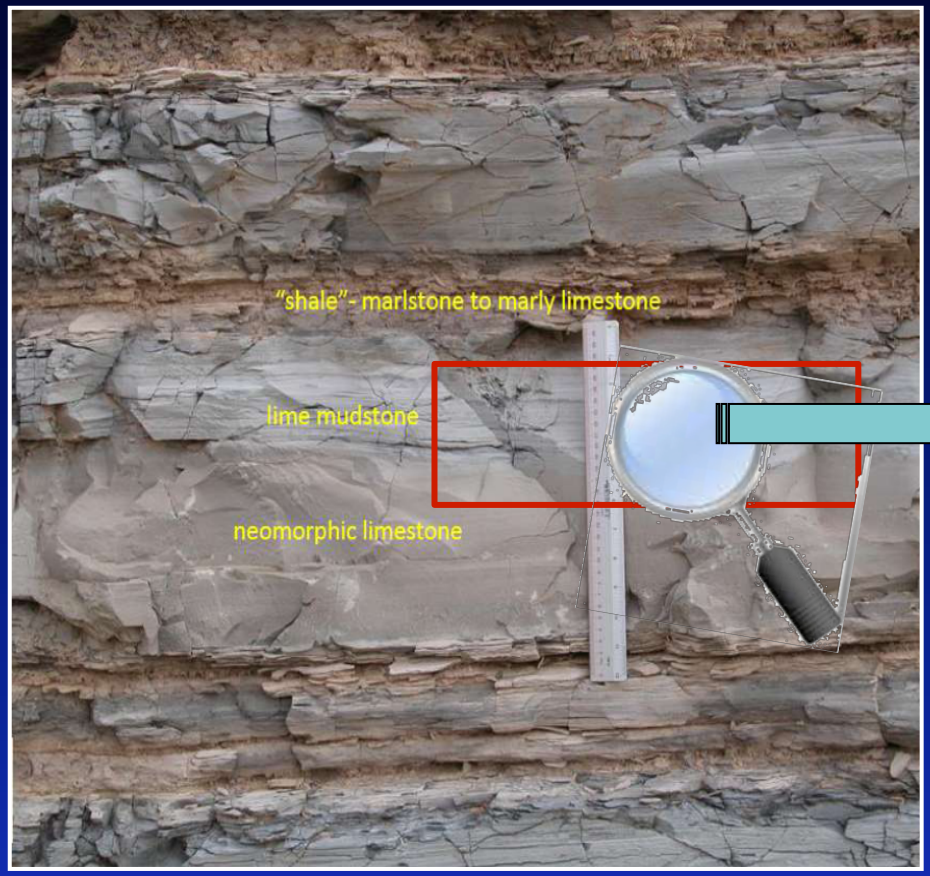
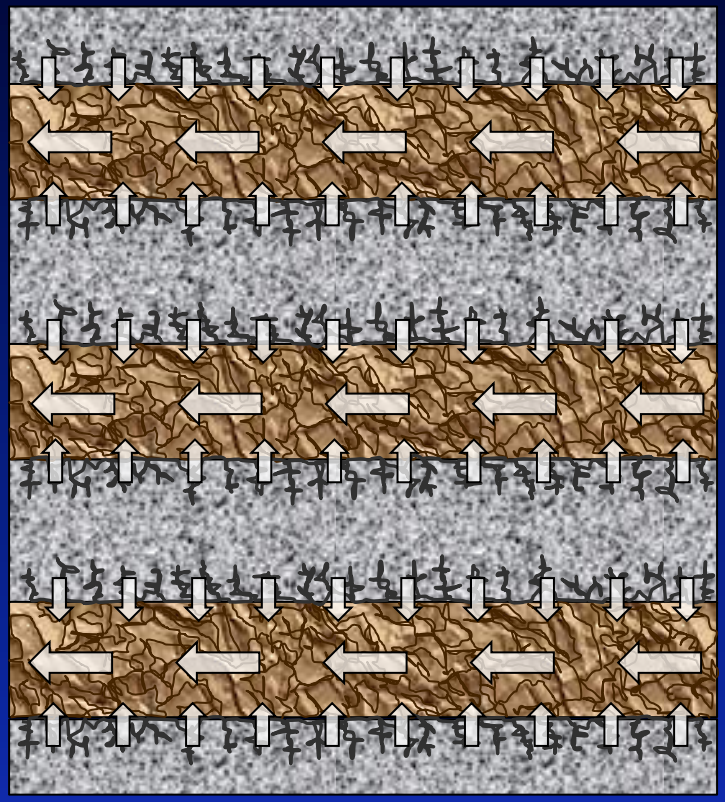




Production from thin, fractured layers

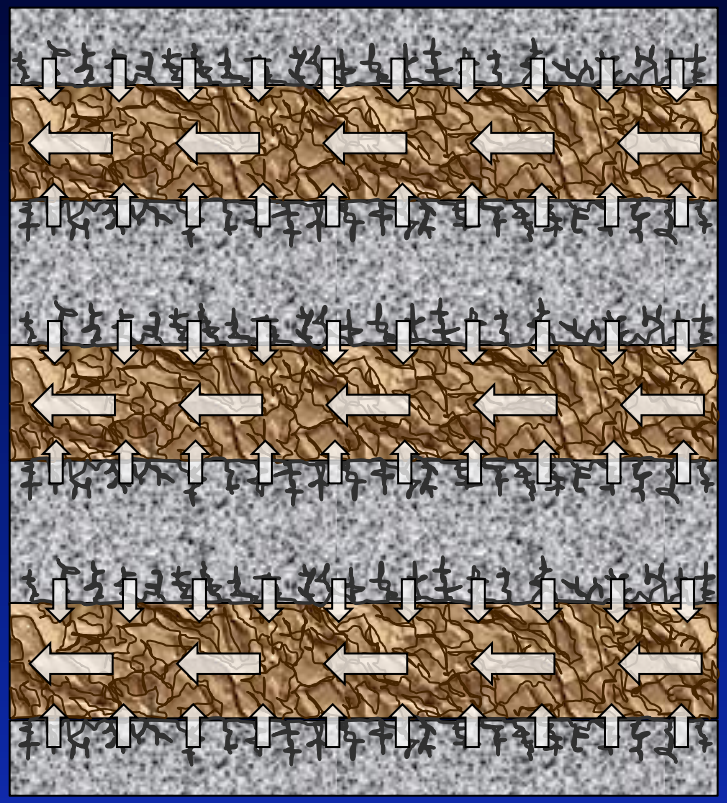
Problem Statement

Support from the source rock layers

Source rock may feed into the producing layer if it has fractures

Productive layers are usually adjacent to thermally mature, kerogen-rich shales.

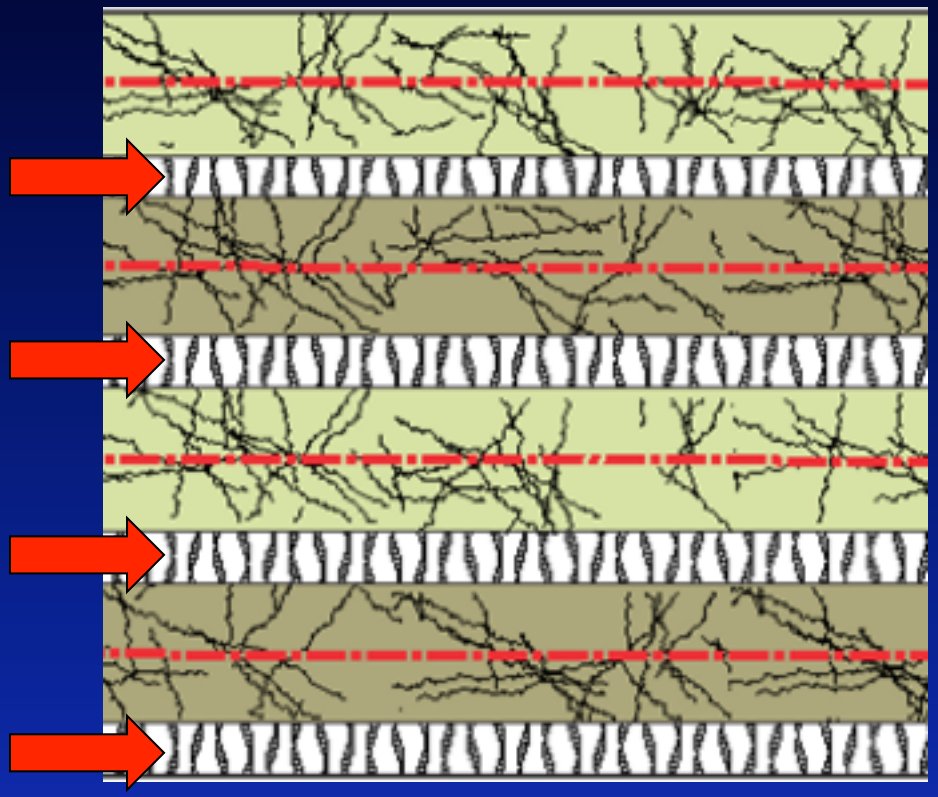
In these cases, both the source and producing rocks have a high fracture density along with a large residual oil content



Perception of the Physical Model

Interaction between source and producing layers

Maturation and migration of hydrocarbons cause a highly permeable (fractured) layer on the surface of the source rock adjacent to the producing layer

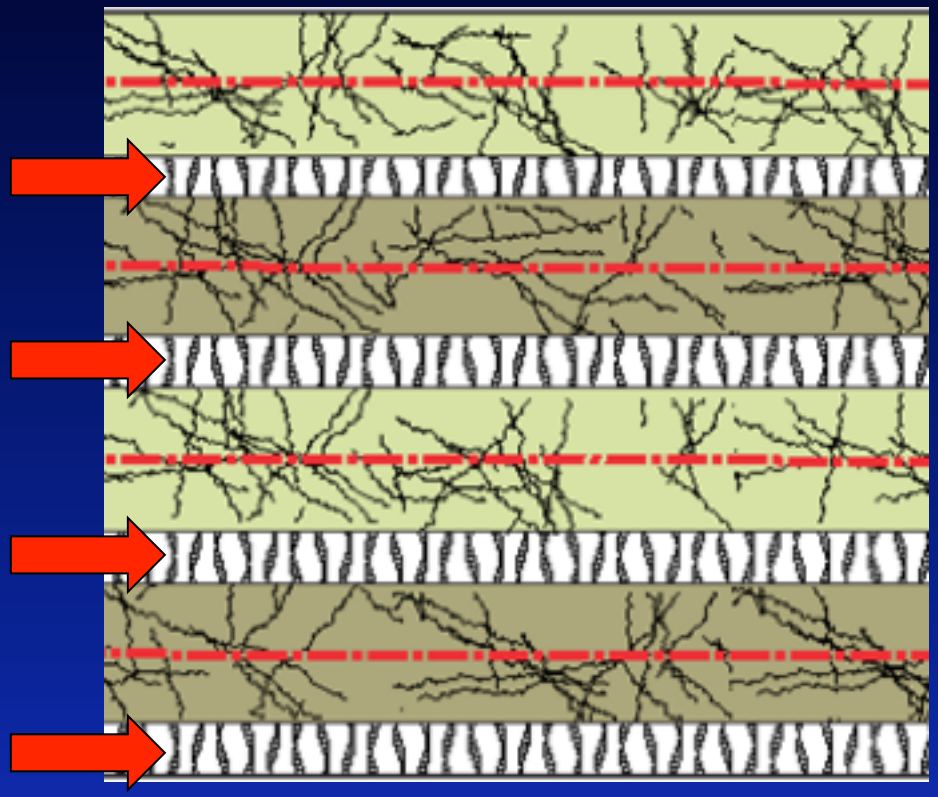


Perception of the Physical Model

Interaction between source and producing layers

Production from the producing layer causes flow and pressure drop in this boundary layer

Depletion of the boundary layer causes pressure and concentration gradients in the source layer and instigates diffusive and advective flows



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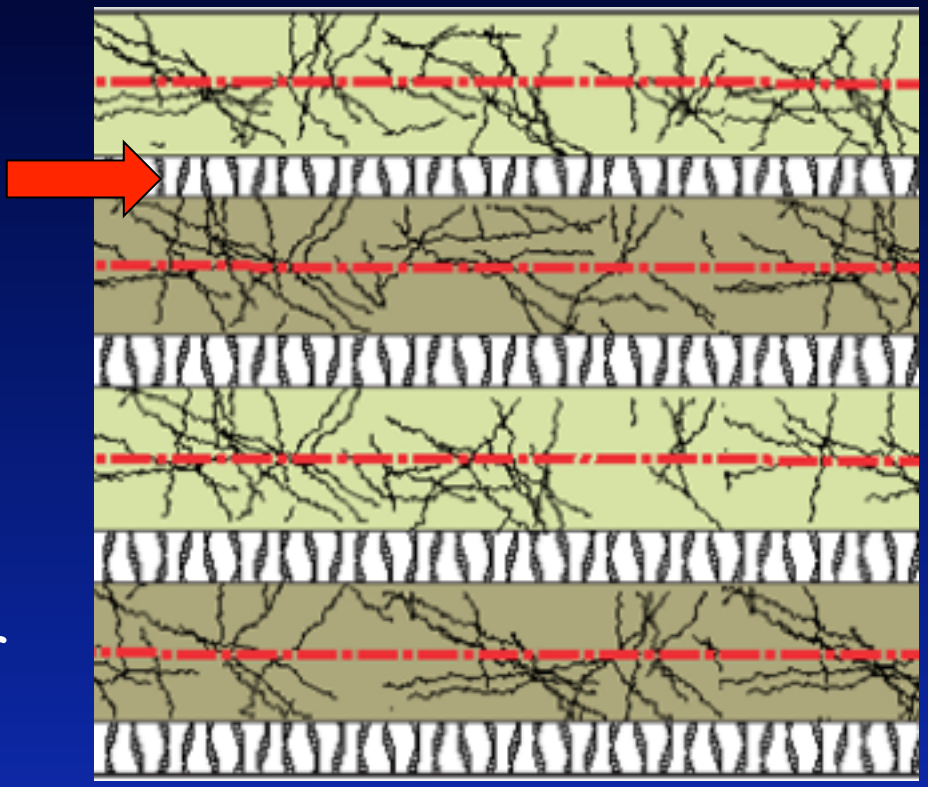
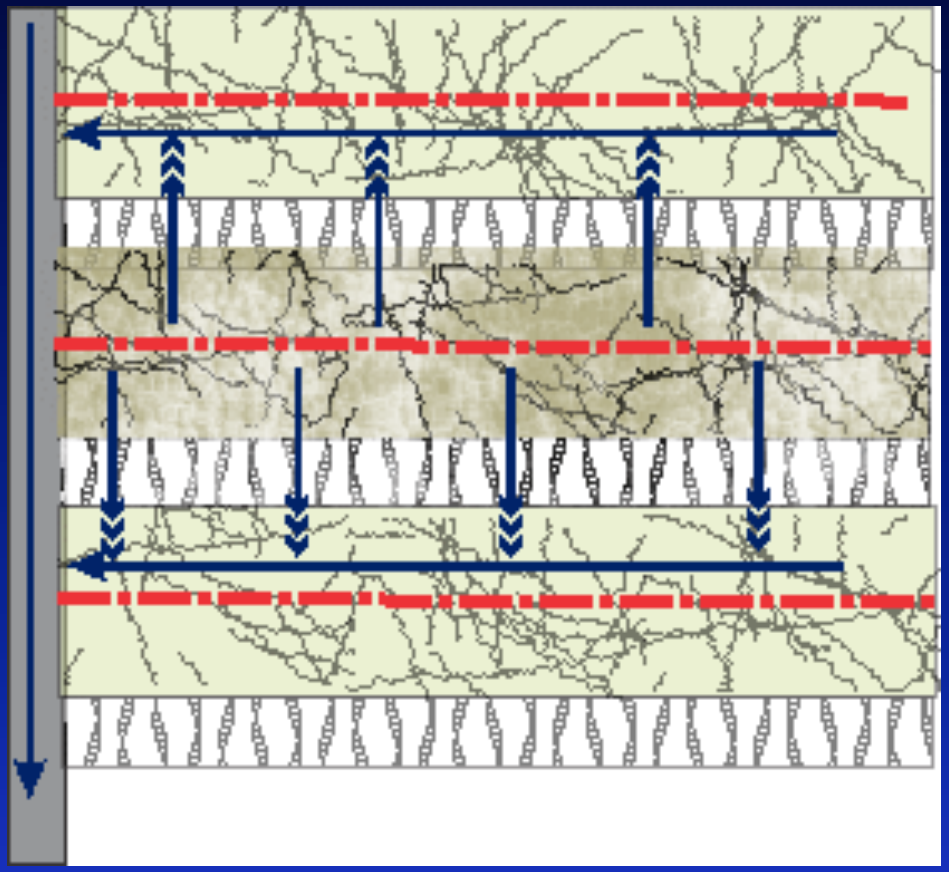


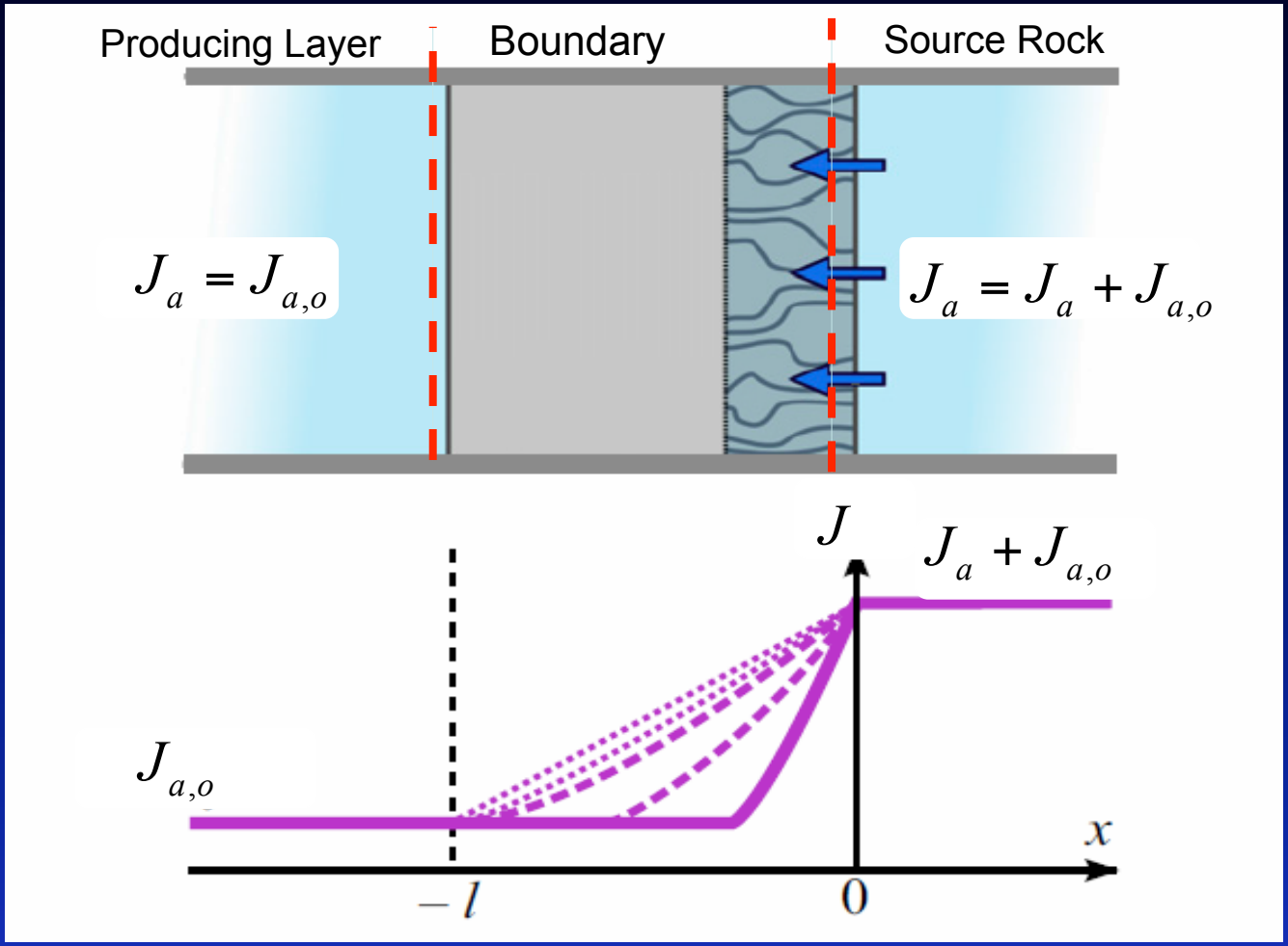
Modeling Approach

Alternating layers of source and producing rock
Identical source layers & identical producing layers



Modeling Approach

Flow Mechanisms



Modified from Monteiro, Rycroft and Barenblatt (2012)

Modeling Approach (Flow Mechanism)

Flow from Producing Layer to Fracture

Single Phase (Gas) Flow:

$$\frac{\partial\left(\phi c\rho\right)}{\partial t} = -\nabla\cdot\left(c\rho v_{Darcy} - \rho D\nabla c\right) + q$$

where

Single phase
CONVECTIVE FLUX :

$$J_{Darcy} = -\nabla\cdot\left(\frac{\rho}{\mu}k\nabla p\right) \quad \textbf{and} \quad v_{Darcy} = -\left(\frac{k}{\mu}\nabla p\right)$$

Single phase
DIFFUSIVE FLUX

$$J_{Fick} = \nabla\cdot\left(\rho D\nabla c\right)$$

(Knudsen diffusion/Slip flow :

$$J_a = J_{Convective} + J_{Diffusive}$$

Darcy flow may be a significant component of coupled flow

Modeling Approach (Flow Mechanism)

Flow from Source Boundary to Producing Layer

Single Phase Flow:

$$\frac{\partial\left(\phi c \rho\right)}{\partial t} = -\nabla \cdot \left(c \rho v_{Darcy} \right) + q$$

where

Single phase CONVECTIVE FLUX :

$$J_{Darcy} = -\nabla \cdot \left(\frac{\rho}{\mu} k \nabla p \right) \quad \textbf{and} \quad v_{Darcy} = -\left(\frac{k}{\mu} \nabla p \right)$$

$$J_a = J_{Convective}$$

Diffusive flux may be negligible

Modeling Approach (Flow Mechanism)

Flow from Source Rock to Boundary

Single Phase (Gas) Flow:

$$\frac{\partial\left(\phi c \rho\right)}{\partial t} = -\nabla \cdot \left(c \rho v_{Darcy} - \rho D \nabla c \right) + q$$

where

Single phase CONVECTIVE FLUX :

$$J_{Darcy} = -\nabla \cdot \left(\frac{\rho}{\mu} k \nabla p \right) \quad \textbf{and} \quad v_{Darcy} = -\left(\frac{k}{\mu} \nabla p \right)$$

Single phase DIFFUSIVE FLUX (Knudsen diffusion/Slip flow) :

$$J_{Fick} = \nabla \cdot \left(\rho D \nabla c \right)$$

$$J_a = J_{Convective} + J_{Diffusive}$$

Diffusive flow may be a significant component of coupled flow

Modeling Approach (Flow Mechanism)

Flow from Source Rock to Boundary & from Producing Layer to Fracture

Multi Phase Flow (Below Bubble Point):

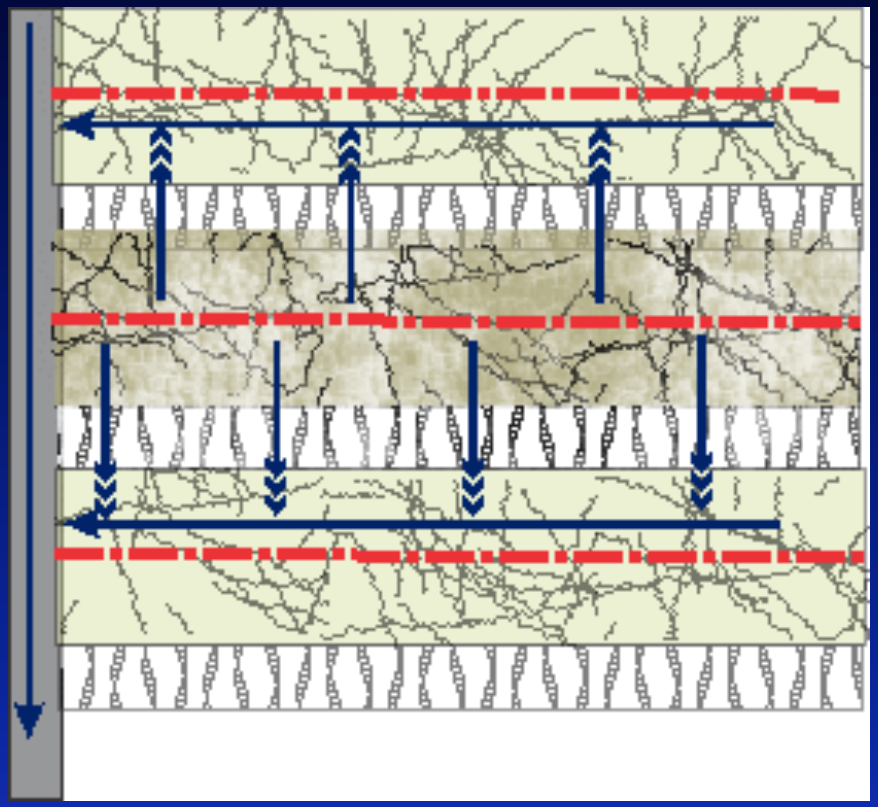
Above bubble point (single-phase oil), diffusive flow components are negligible

Below bubble flow, diffusive flux may include concentration driven and osmotic components

Single Phase Mathematical Model

Coupling of flows in four linear flow regions

- Linear flow from source rock to boundary layer
- Linear flow from boundary layer to producing layer
- Linear flow from producing layer to hydraulic fracture
- Linear flow in hydraulic fracture to horizontal well (with choking skin)



Planned Work

- Complete the derivation of the single-phase flow model
- Build and test the computational code
- Run sensitivity analyses to assess the relative contribution of each coupled flow
- Investigate the contribution of the source rock
- Develop a methodology to analyze and interpret production data
- Start planning multi-phase flow modeling

Thank you