Research Report

Fractal Formulation of Flow Toward Wells in Fractured Unconventional Reservoirs

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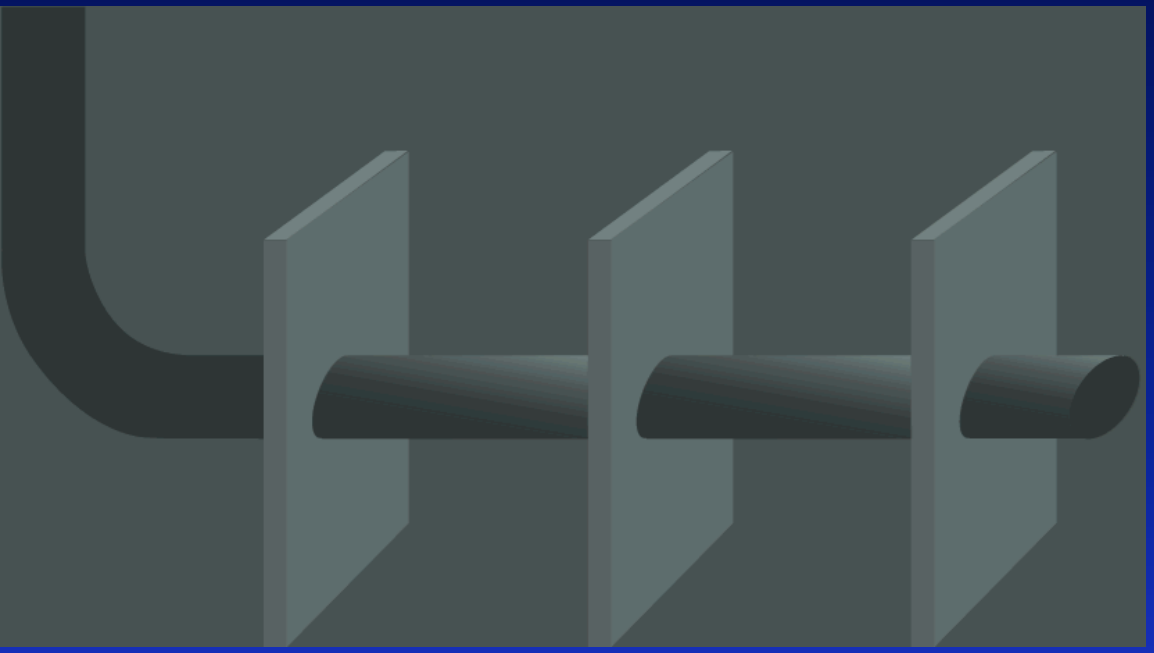
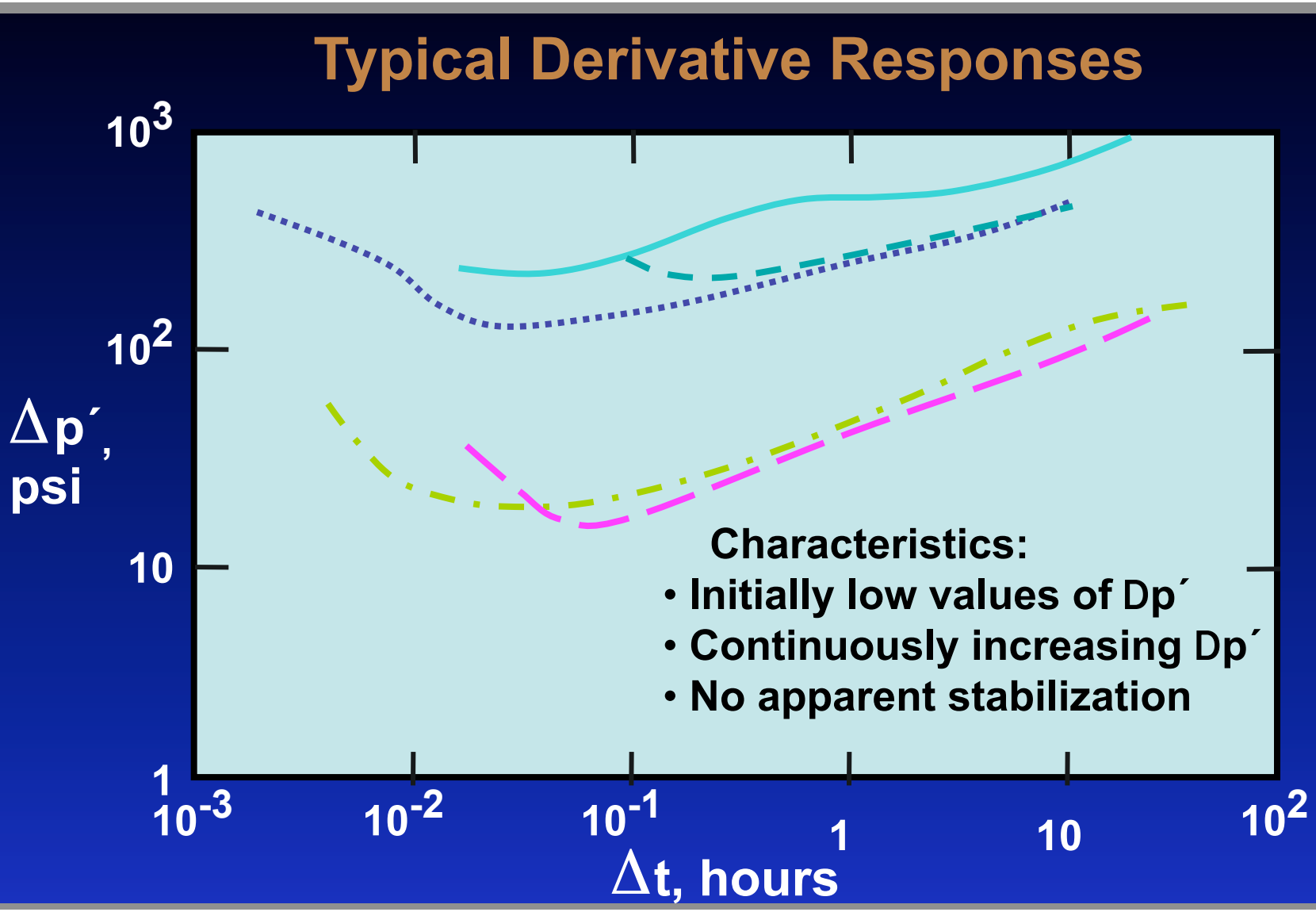
Shale



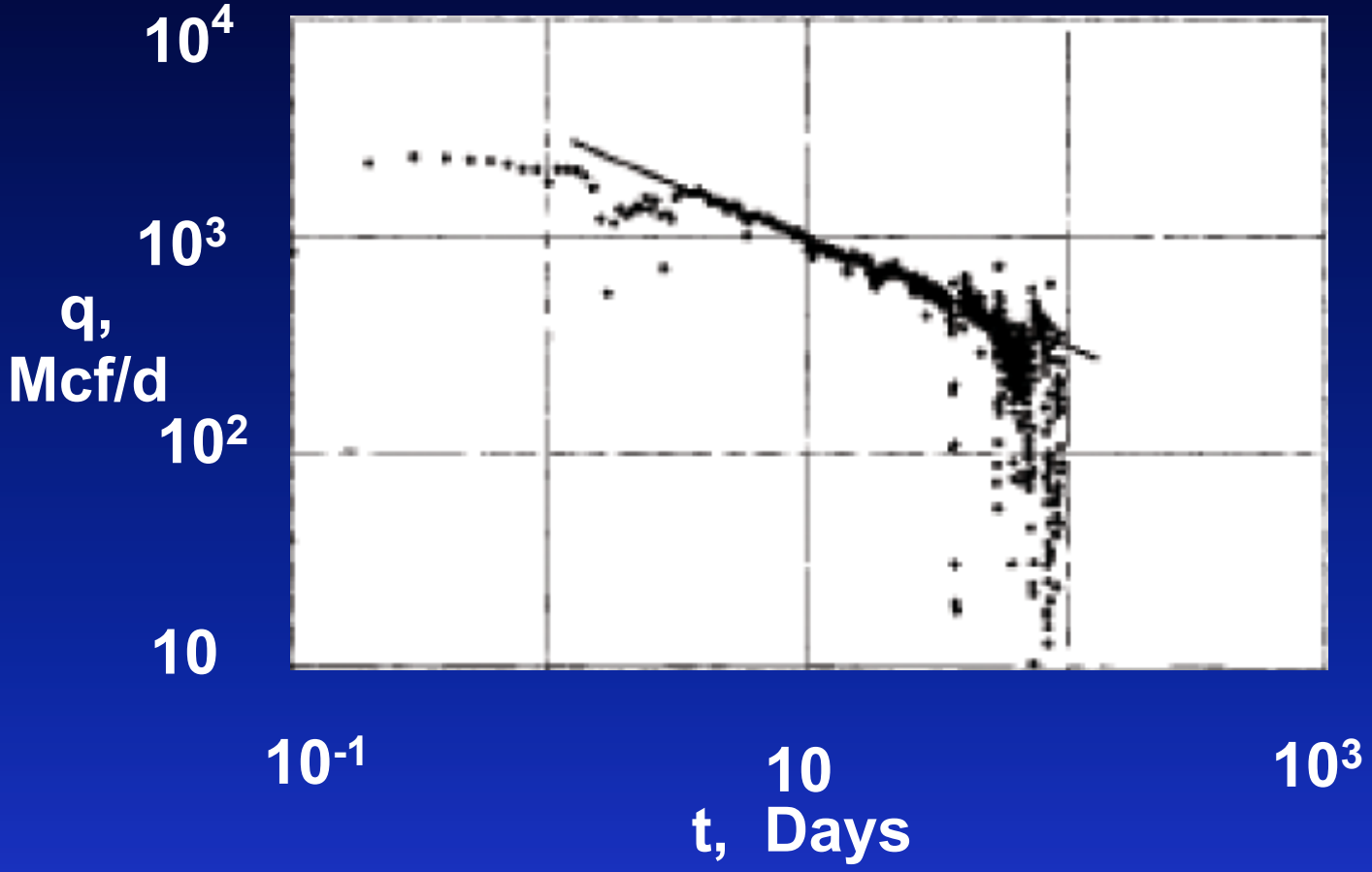
Motivation


Typical Derivative Responses
10^3
10^2
10
1
Δp´, psi
10^{-3}
10^{-2}
10^{-1}
1
10
10^2
Δt, hours
Characteristics:
• Initially low values of Dp´
• Continuously increasing Dp´
• No apparent stabilization

Rate Analysis

Linear Regime

After Bello & Wattenbarger



Fractal Reservoir Models

Principal Players

- **Yortsos *et al.* (1990-1995); radial flow**
- **Camacho *et al.* (2001; 2008) radial flow**
- **Beier (1990,1994) ; fractured wells**

Fractal Reservoir Models

Flow in Fractal Structures

- Speed of front , $r^2 \propto t^{2/d_w}$; $d_w = \theta + 2$
- Diffusivity, $\eta \propto r^{-\theta}$
- New parameter: d_f
- Permeability, $k(r) \propto r^{d_f - d - d_w + 2}$
- Porosity, $\phi(r) \propto r^{d_f - d}$

Application to Fractured Wells

Features

- Darcy's Law needs to be modified; many forms will exist depending on assumptions made
- Have to work with fractional derivatives, $\partial^{\nu} p / \partial t^{\nu}$
- Perhaps a method to handle 'fracture network' and also specialized mechanisms for diffusion in nanopores
- Over the past few years we have worked on fractured wells and horizontal wells produced through multiple fractures

Application to Fractured Wells

Fractured Well, Fractals, Laplace Space

For fractured wells, we show that must evaluate the integral given below (Raghavan and Chen, 2013):

$$\int_{x}^{\infty} \lambda^{w} K_{\nu}(\lambda)\, d\lambda$$

Application to Fractured Wells

Beier Solution through Laplace Transforms