[AV] Second White Specks Formation: New Concepts for Understanding Fractured Reservoirs*

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Abstract

The Upper Cretaceous Second White Specks Formation is a fractured, marine, interbedded shale, siltstone, and fine-grained sandstone. This unit is part of the Colorado Group (Alberta Group), which also includes the Cardium and Viking formations and was deposited in the Cretaceous Seaway during a relatively quiet tectonic period of the building of the western Canadian Cordillera. The Second White Specks has been characterized as a zone with numerous hydrocarbon shows, but to date it has not shown the repeatable success needed to establish a resource play.

Despite the lack of repeatability, there have been a few notable individual wells within the zone that have produced over one million barrels of liquid petroleum from vertical drill holes. In these cases the well appears to have intersected a regional natural fracture system that has delivered significant volumes of hydrocarbons. In resource plays there is an ongoing debate over the merits of matrix permeability versus the permeability of the natural fracture system. In the case of the Second White Specks Formation, the natural fracture system dominates the permeability system.

A paradox in the exploration/production endeavor is that wells are positioned and drilled to find hydrocarbon storage but are completed to maximize rate and deliverability. In this procedure the natural delivery system is ignored (natural fractures) in the belief that well stimulation and induced hydraulic fractures can replicate or improve upon the natural system. Flow from the rock is a complex interplay of varying fracture apertures, access to the hydrocarbon-generating system, development of elevated fluid pressures, fluid compatibility, and resistance to flow within the rock. Successful wells appear to access large natural fluid pathway systems such that the mega-fracture network connects effectively with the micro-fracture system.

Selected References

Clarke, H., L. Eisner, P. Styles and P. Turner, 2014, Felt seismicity associated with shale gas hydraulic fracturing: The first documented example in Europe: Geophysical Research Letters, v. 41/23, p. 8308-8314.
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Styles, P., I.Stimpson, R. Westood, S. Toon, L. Eisner, H. Clarke, and P. Turner, Seismicity induced by Shale Gas Hydraulic Stimulation: PreeseHall, Blackpool, United Kingdom. Website accessed August 10, 2015, http://www.seismo.ethz.ch/research/groups/schatzalp/Download/Styles.pdf.

Website

Department of Energy and Climate Change: https://gov.uk/oil-and-gas-uk-field-data. Website accessed August 10, 2015.

Second White Specks Formation

New concepts for understanding fractured reservoirs.

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June 2015

AAPG Playmakers' Forum

Shale Petroleum

AAPG

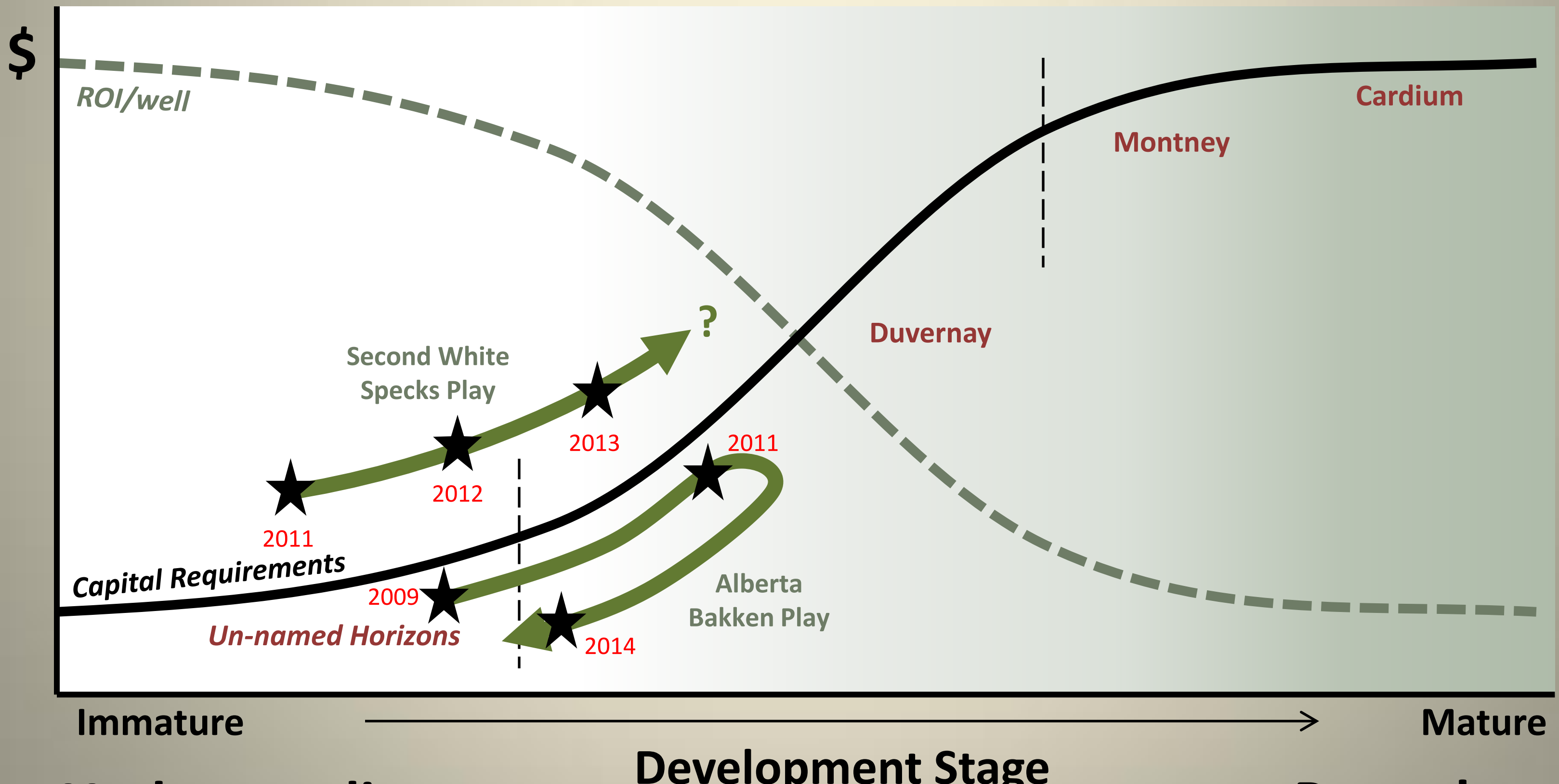
Canada's Energy Geoscientists cspg.org

Life Cycle of a Resource Play

Definition Mode
Early Entrant
Low Land Cost
Innovator

De-Risk Mode
Competitive
High Land Cost
Implement Technology

Manufacture Mode
Entry through Corporate Acquisition
Low Cost Operator
Continuous Improvement

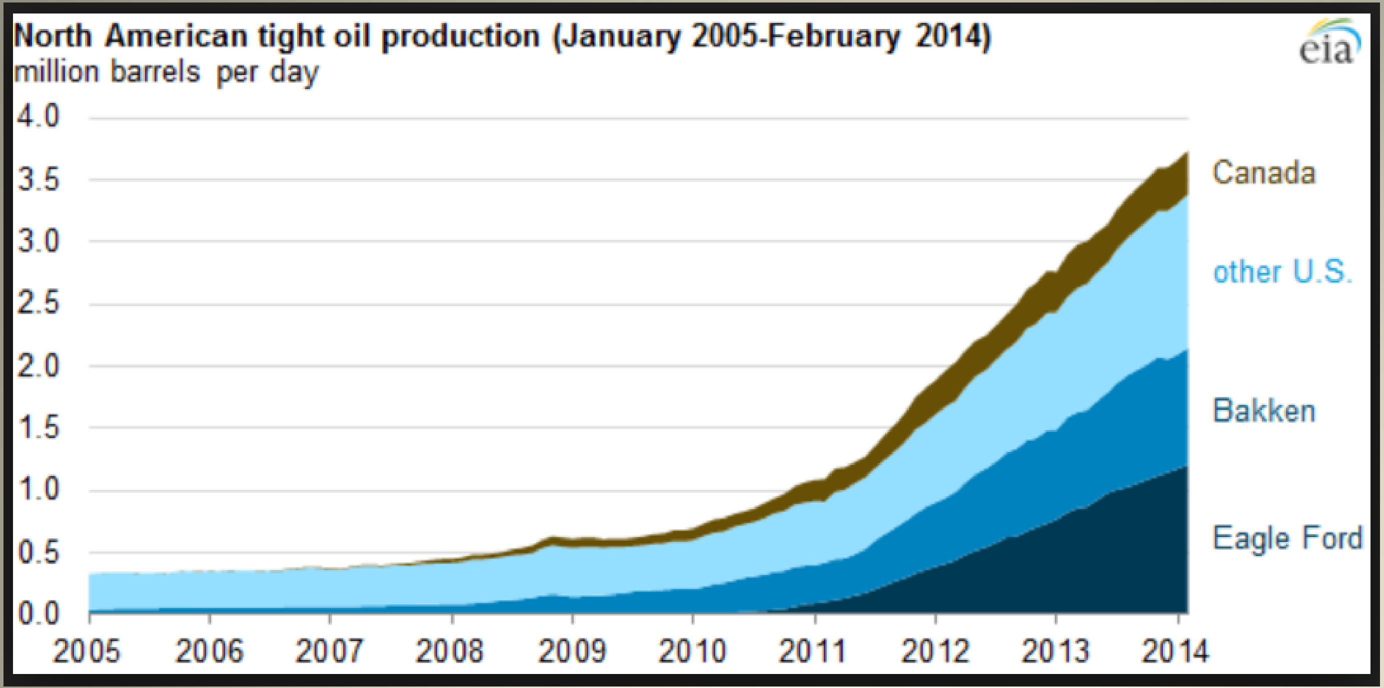


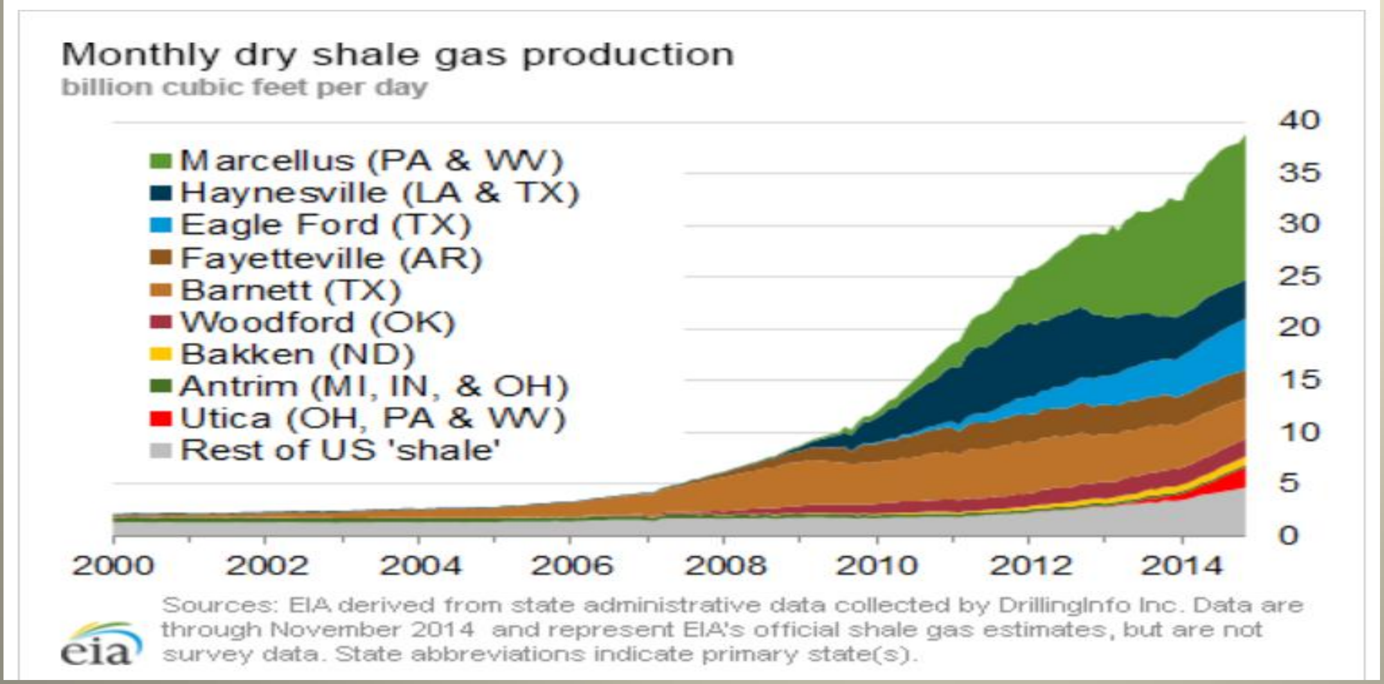
Understanding **Procedure**

The Production of Hydrocarbons from Fine-Grained Rock

A fundamental change in theory and practice

- Technical Challenges:
  - How do I know that my company is current with technology?
  - How do I know if my contractor is current?
  - Who is doing the latest research and are they a benefit to me or will they slow me down?
- Social Challenges:
  - What is a social license?
  - Is there a new regulatory system (Frac Procedures)?

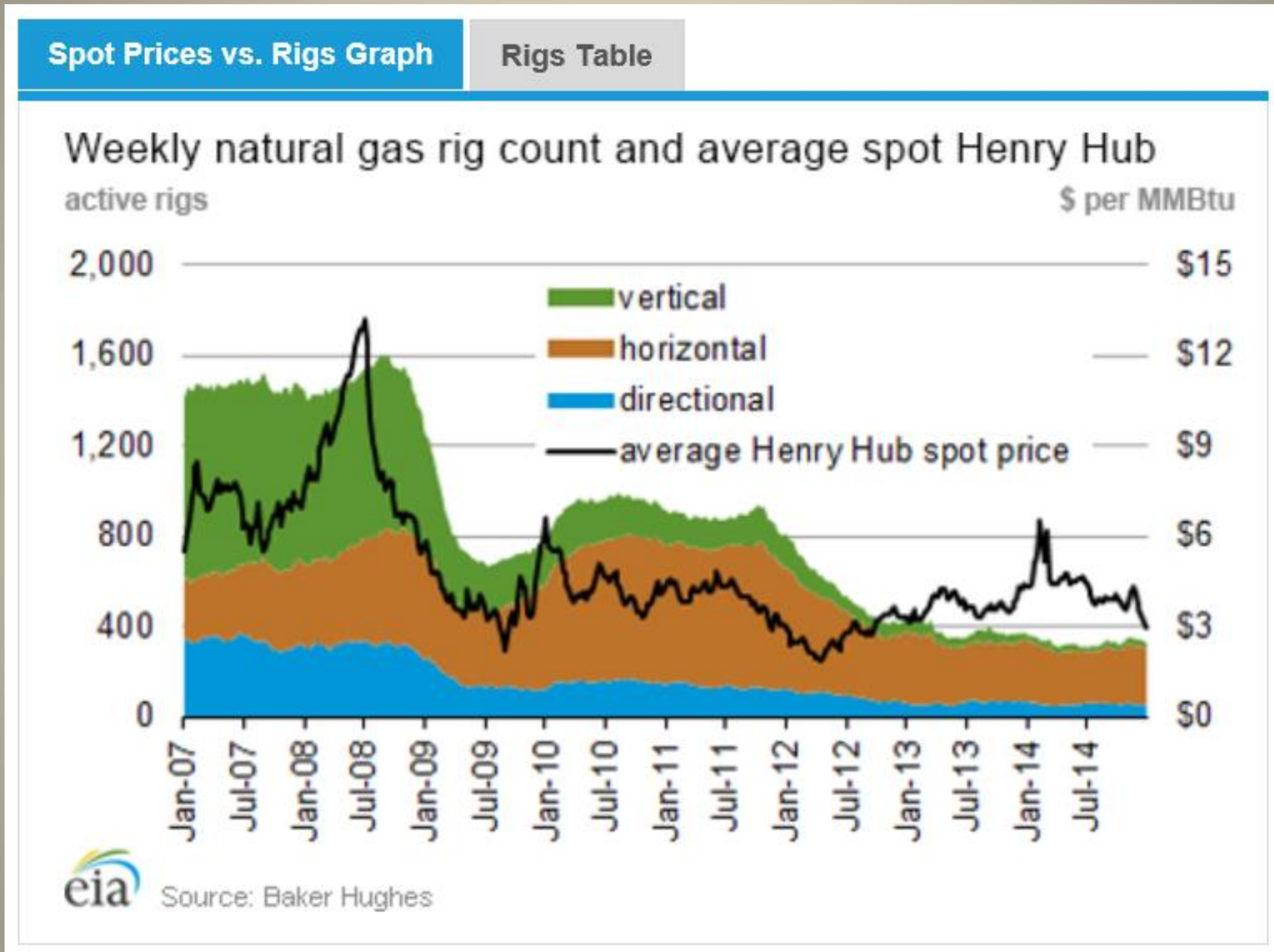




Commodity Prices

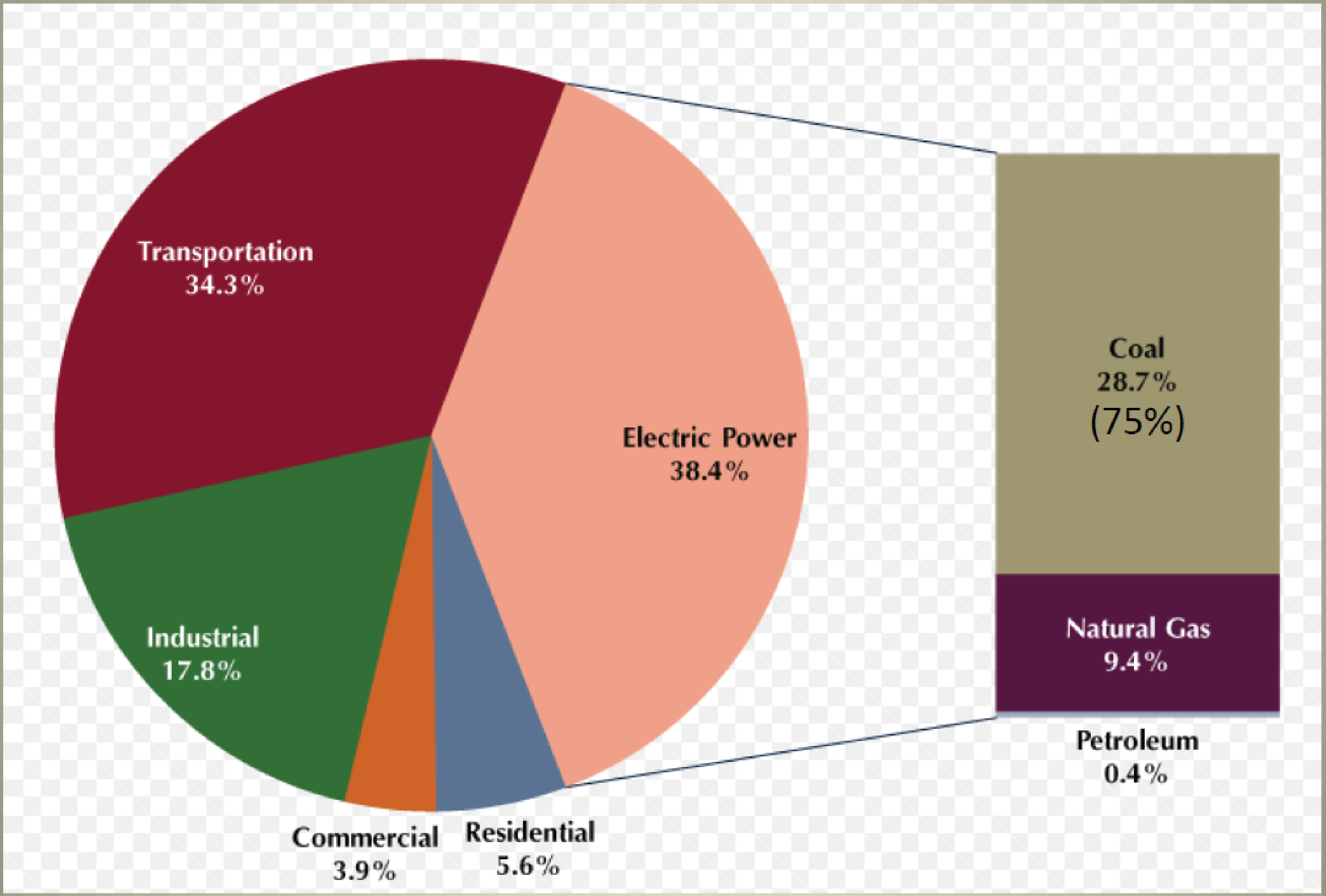
vs.

Time



Spot Prices vs. Rigs Graph
Rigs Table
Weekly natural gas rig count and average spot Henry Hub
active rigs
$ per MMBtu
2,000
1,600
1,200
800
400
0
$15
$12
$9
$6
$3
$0
vertical
horizontal
directional
average Henry Hub spot price
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13
Jul-13
Jan-14
Jul-14
eia
Source: Baker Hughes

United States Sources of Carbon Dioxide



The new technical order

Conventional Reservoirs

1. Porosity dictates reserves
2. Reserves define NAV
3. Highly competitive
4. Defined expl./dev. cycle
5. Small land position req'd.
6. Defined roles for staff
7. Dislocation to surface issues
8. Efficient drilling requires understanding

Unconventional Reservoirs

1. Porosity is poorly defined
2. Cash Flow define NPV
3. Collaborative amongst the companies
4. Expl. is not defined
5. Large land base req'd.
6. Integrated team
7. Surface issues are germane
8. Efficient drilling requires procedure

The Fundamental Question:

How do fluids move through the crust?

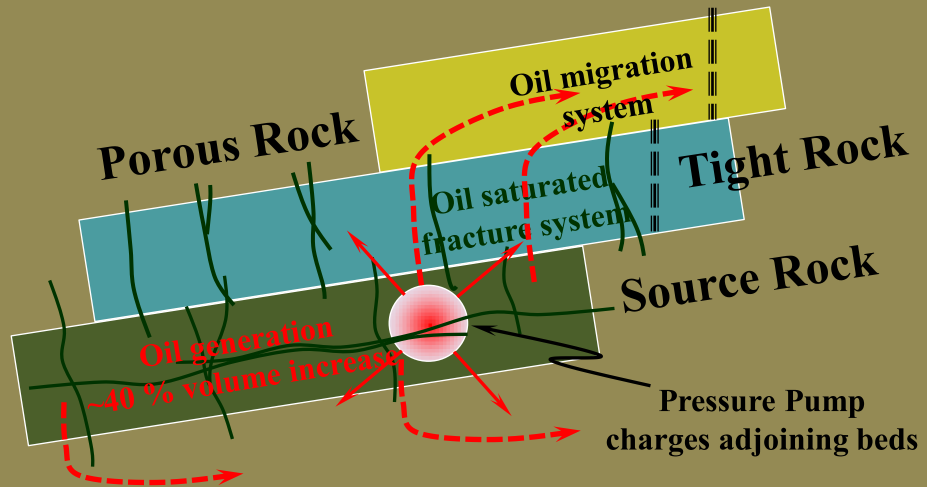
- Requires a pathway
- Requires increased Fluid Pressure

Nano-permeability

vs.

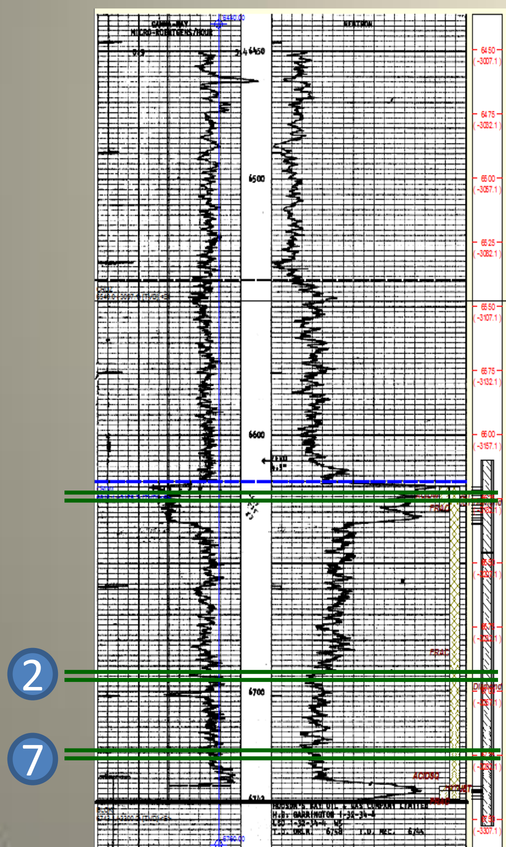
Fracture systems

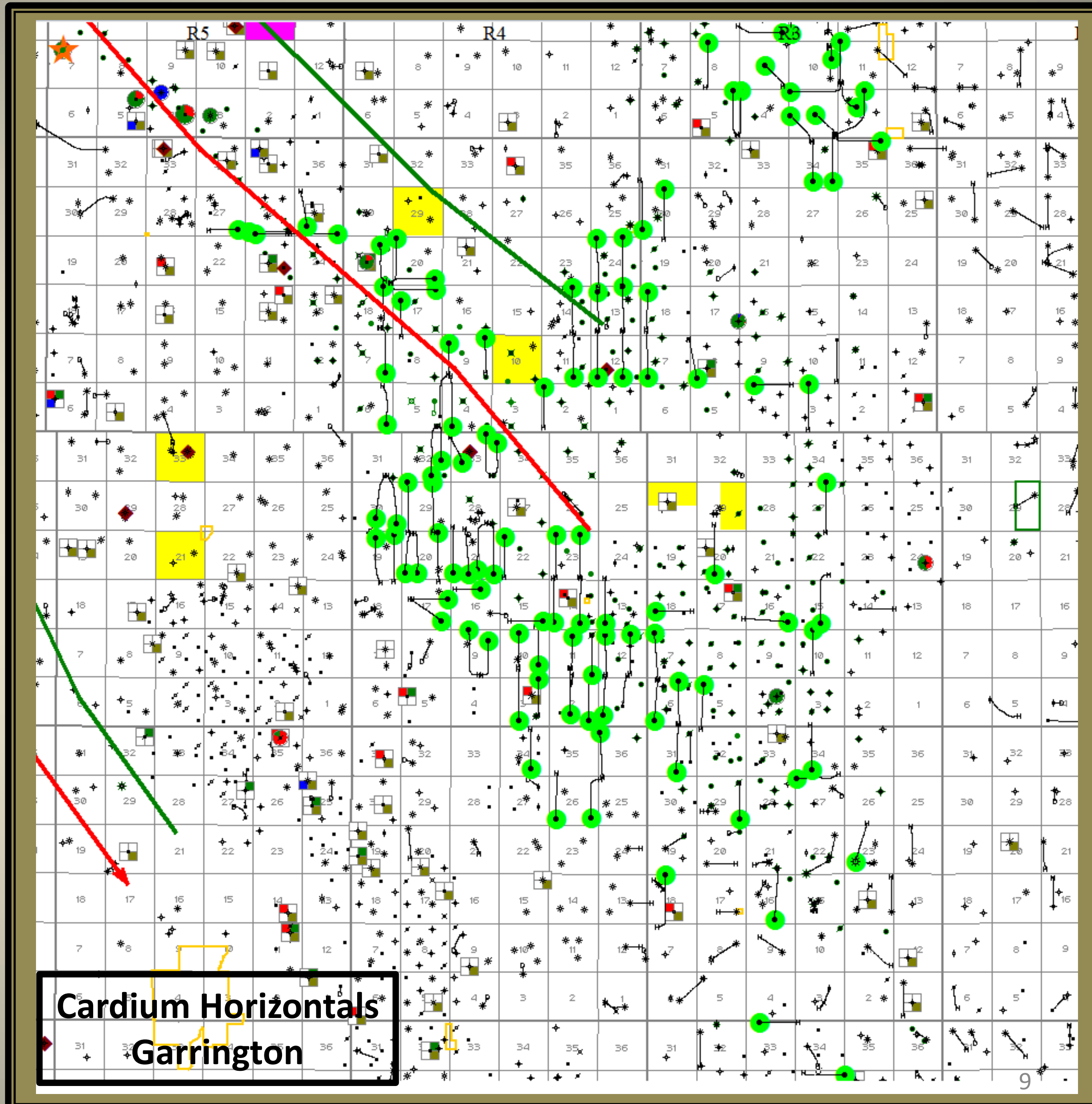
Buoyancy Forces are equal to the density contrast between the generated hydrocarbons and formation water. Generally these are not strong enough to overcome the frictional forces resisting flow (pore entry pressures).



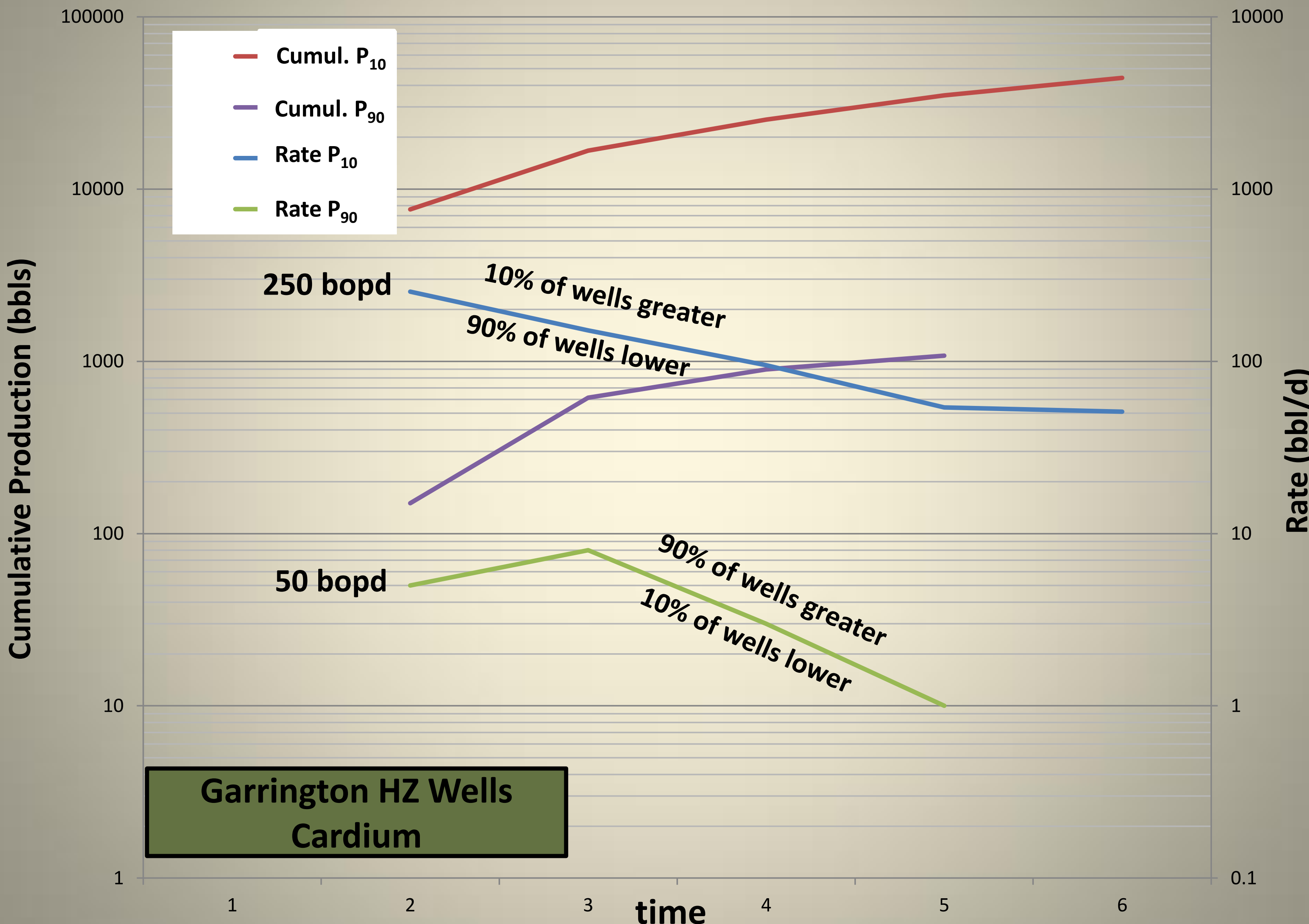
Cardium Horizontal Well Results (2012) Garrington

- ~120 wells
- 88 wells with reported deviation surveys
- 8 wells missed Cardium sandstone by more than 5 metres

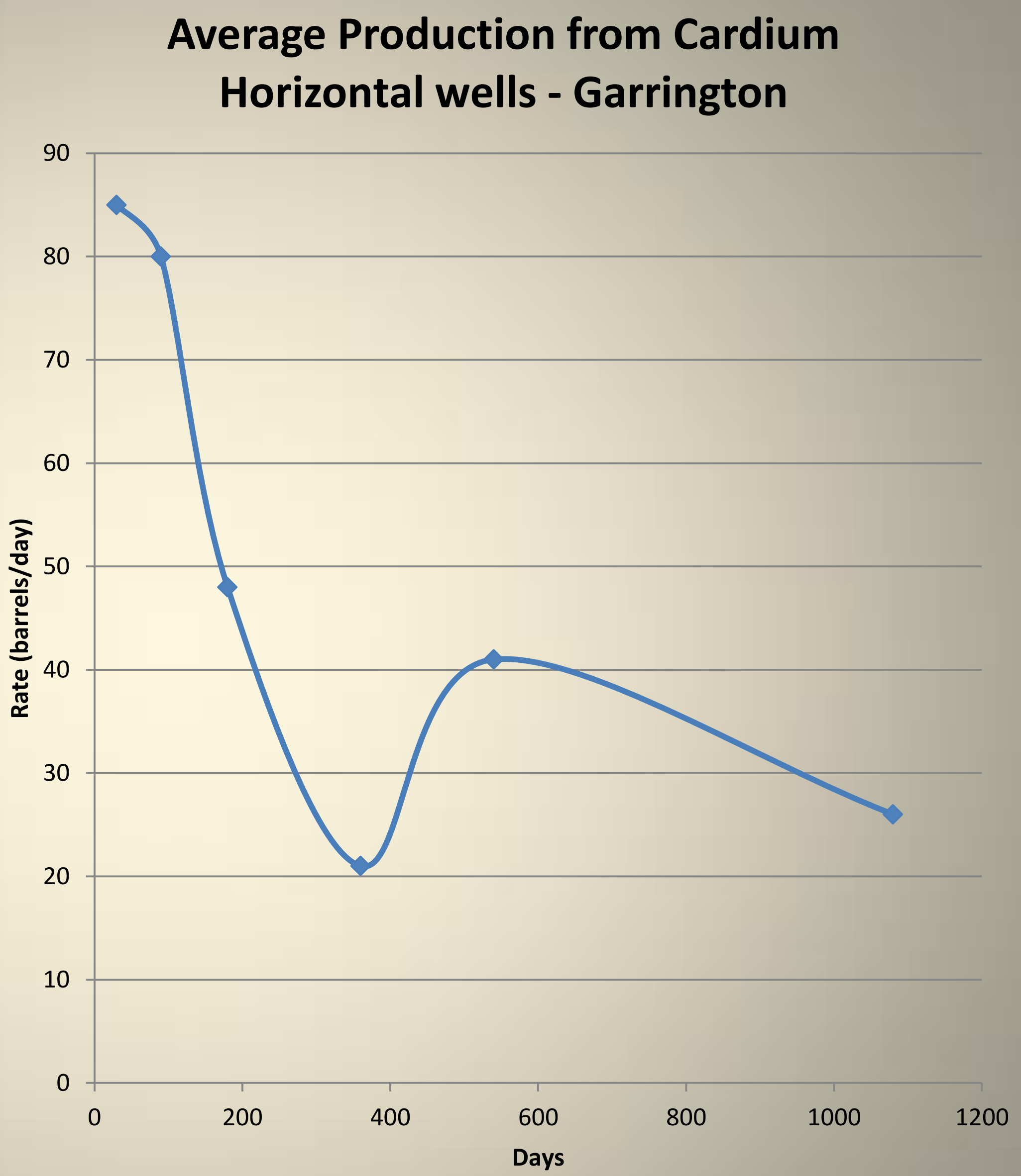




Production Data

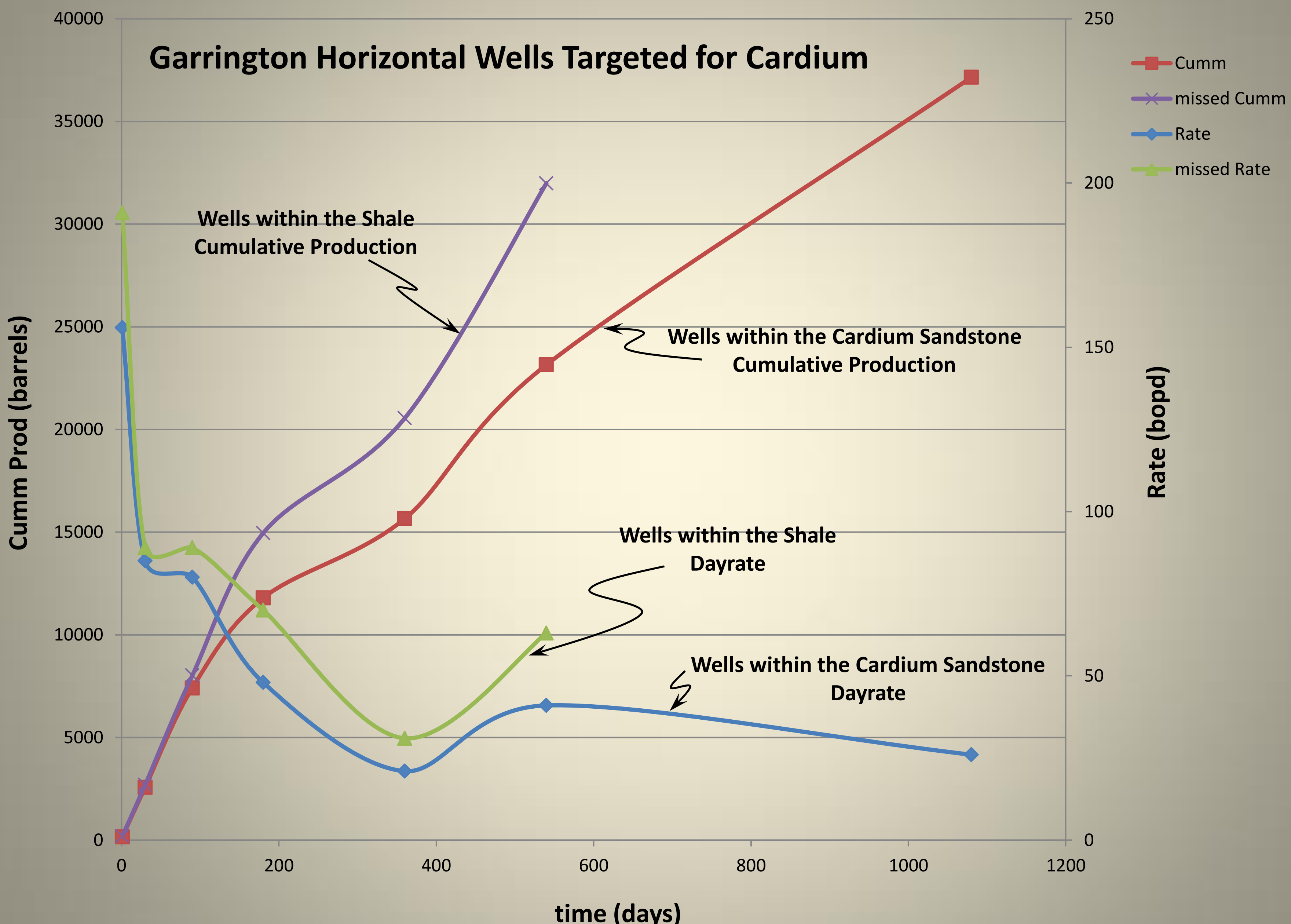


Averaged decline curve



Explanation:

- All horizontal wells in the Cardium from the Garrington Area
- IP(30), IP(90), IP(180), IP(360), IP(540), IP(1080)
- Back Calculate the average rate
- Use Arithmetic Average



Garrington Horizontal Wells Targeted for Cardium
Cumm
missed Cumm
Rate
missed Rate
Wells within the Shale
Cumulative Production
Wells within the Cardium Sandstone
Cumulative Production
Wells within the Shale
Dayrate
Wells within the Cardium Sandstone
Dayrate
Cumm Prod (barrels)
Rate (bopd)
time (days)
0
5000
10000
15000
20000
25000
30000
35000
40000
0
50
100
150
200
250
0
200
400
600
800
1000
1200

Linear Transport Laws

Ohms Law

$$I = \frac{V}{R}$$

Darcy's Law

$$Q = \frac{-kA}{\mu}\frac{(P_b - P_a)}{L}$$

Linear Transport Laws

Ohms Law

$$I = \frac{V}{R}$$

$$\text{Flow} = \frac{\text{Driving Force}}{\text{Friction}}$$

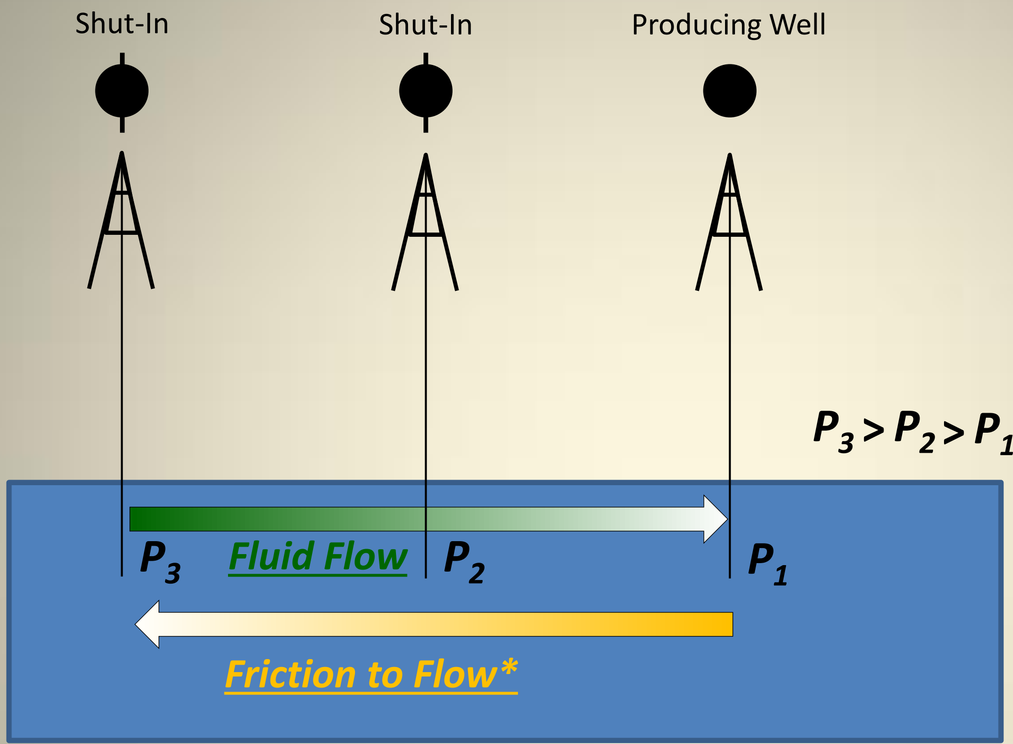
Darcy's Law

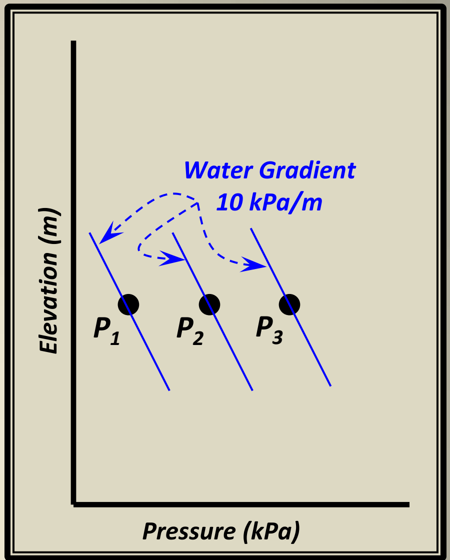
Friction

Driving Force

$$Q = \frac{-kA}{\mu}\frac{(P_b - P_a)}{L}$$

Flow

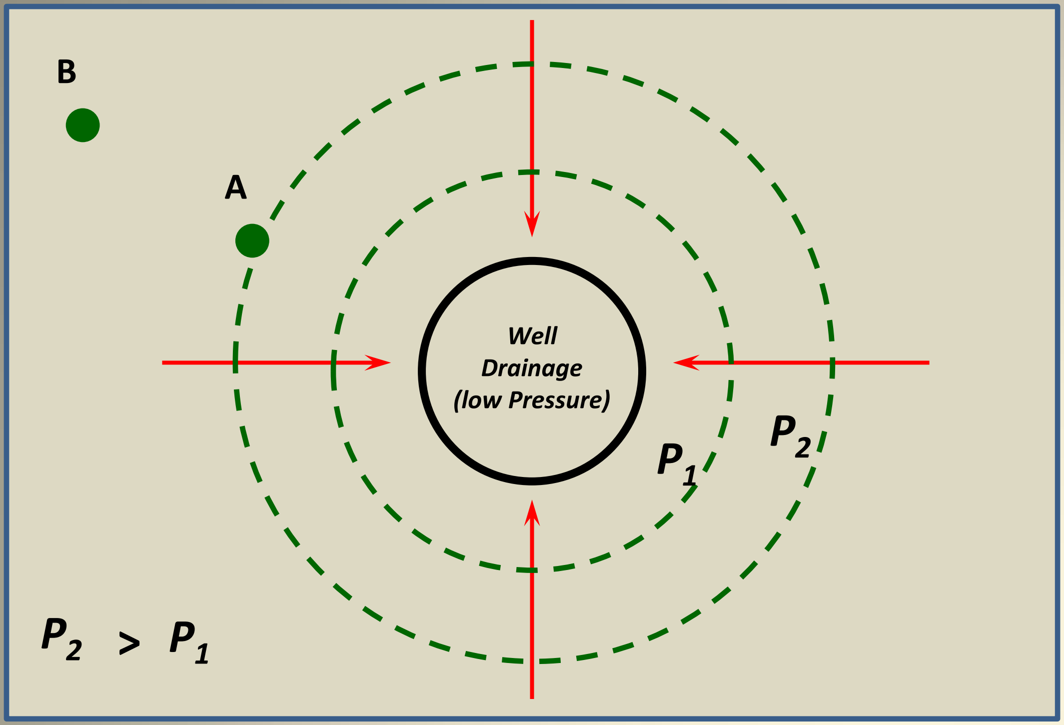




* System will not equilibrate to common water gradient due to friction

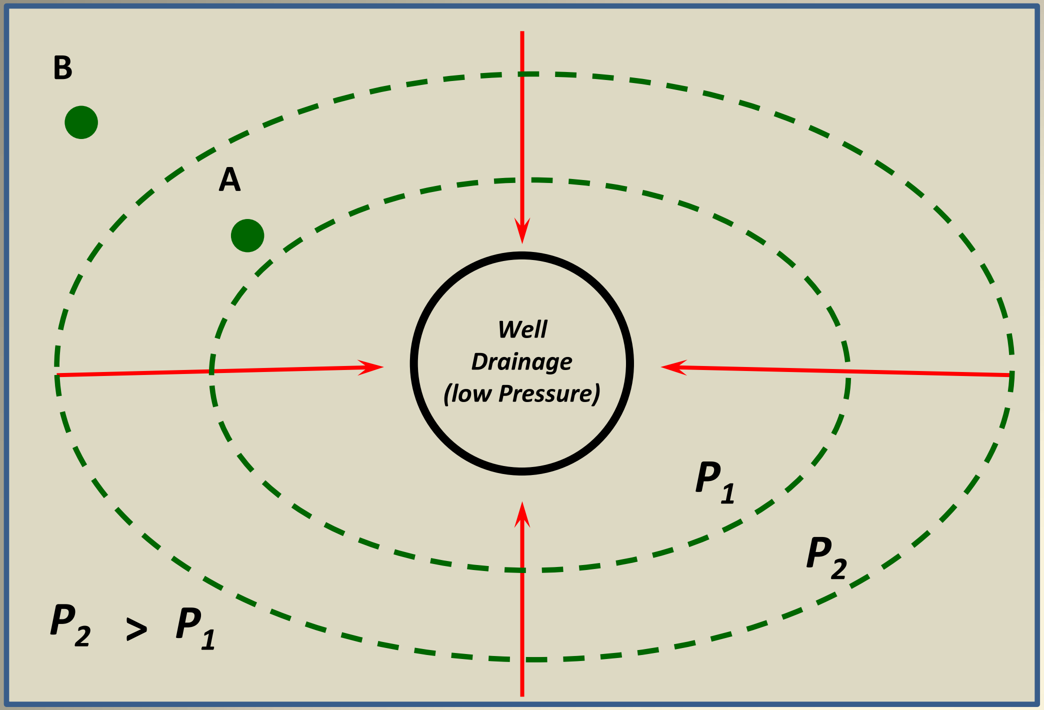
$$\vec{Q} = \frac{-\vec{k}A}{\mu}\frac{(P_b - P_a)}{L}$$

Flow in a Homogeneous Isotropic Reservoir



Radial Flow:

- Particle A will reach the well bore before particle B
- Pressure Front radiates from the well bore as a function of the radius of the well bore
- Drainage is along straight lines towards the well bore

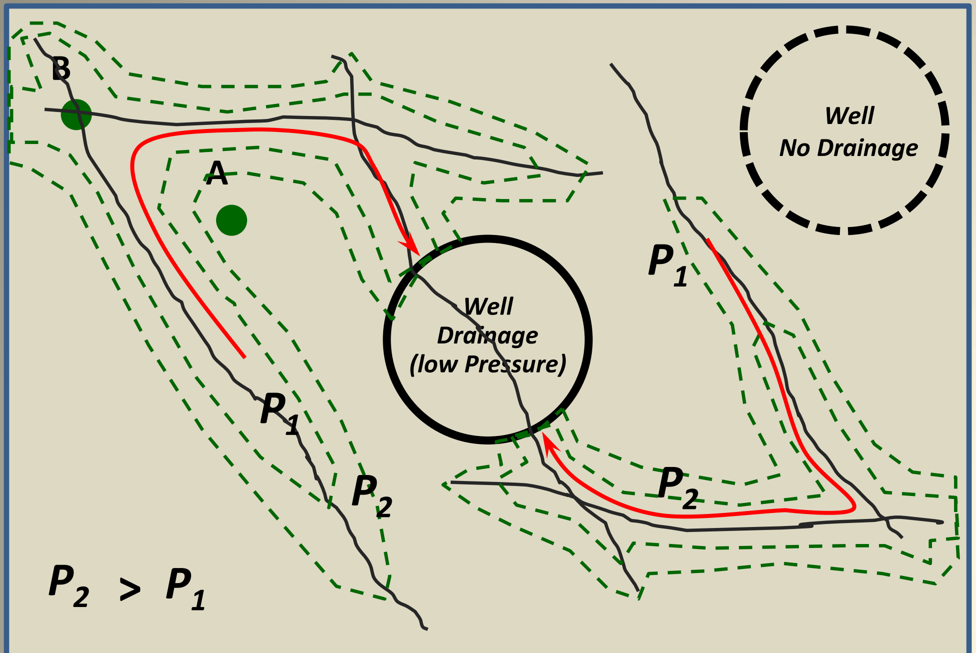


Flow in a Two Porosity (permeability) system

Elliptical Flow:

- Particle A will reach the well bore before particle B
- Pressure Front radiates from the well bore as a function of the radius of the well bore and the difference in permeability between k_{hmax} and k_{hmin}
- Drainage is along lines perpendicular to the pressure front creating smooth curve drainage trajectory to the well bore

Flow along Fractures

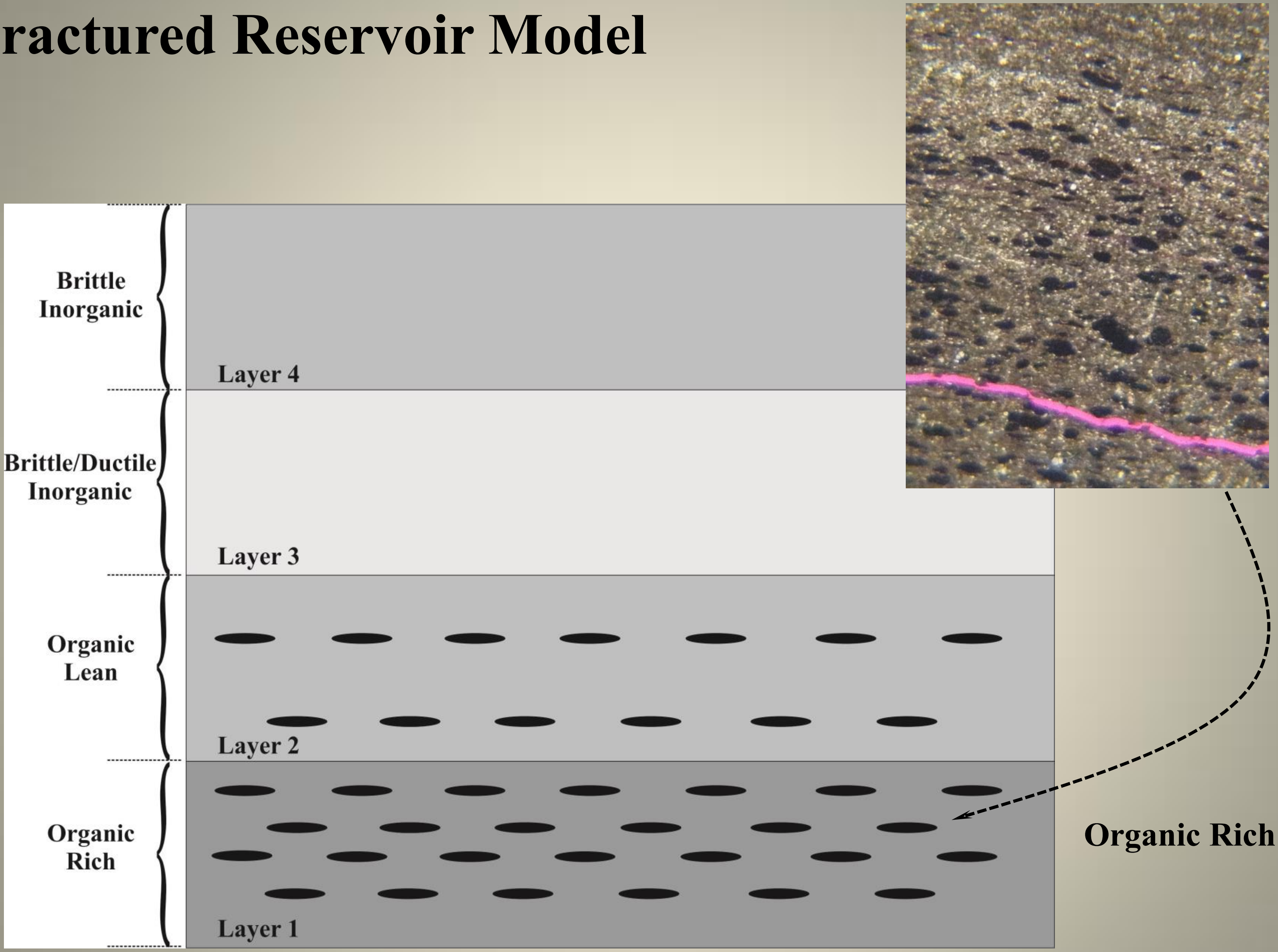


Fracture Flow:

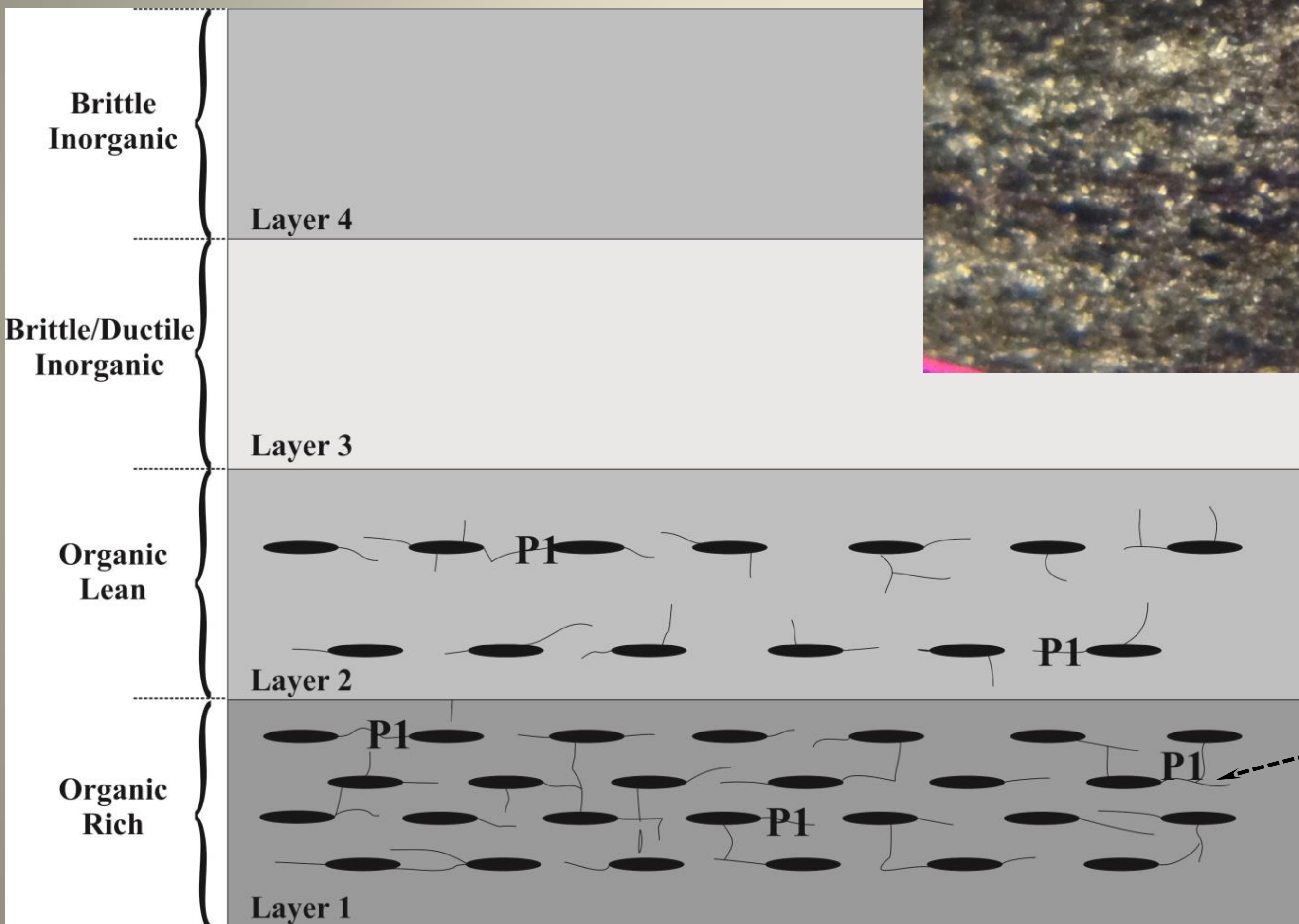
- Particle B will reach the well bore before particle A
- Pressure Front radiates from the fractures and is a complex relationship between the matrix permeability and the fracture permeability
- Drainage is along tortuous paths in the reservoir and distance is difficult to determine
- A well not connected to fractures likely will not have flow

How does a Shale Reservoir work?

Fractured Reservoir Model

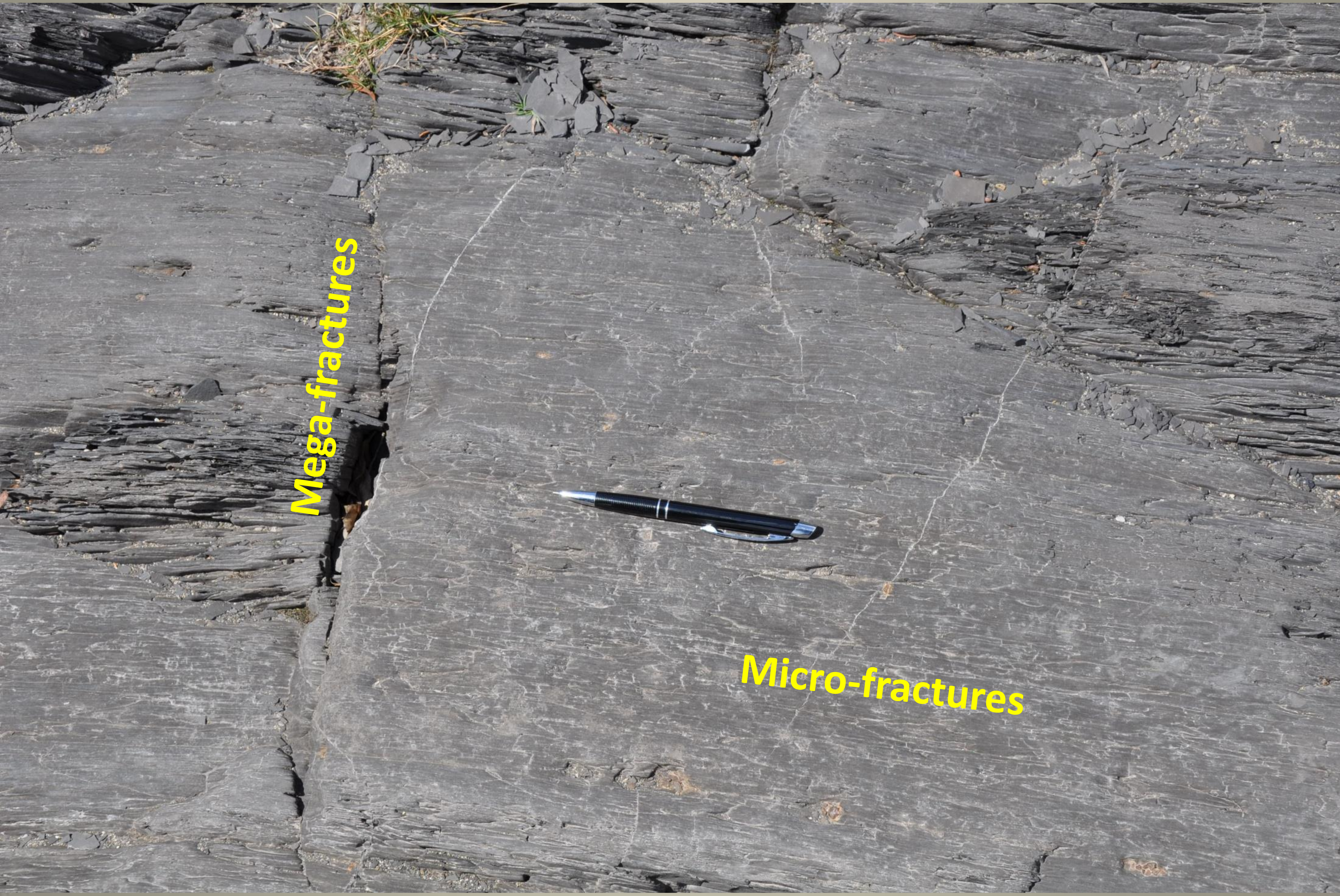


Fractured Reservoir Model

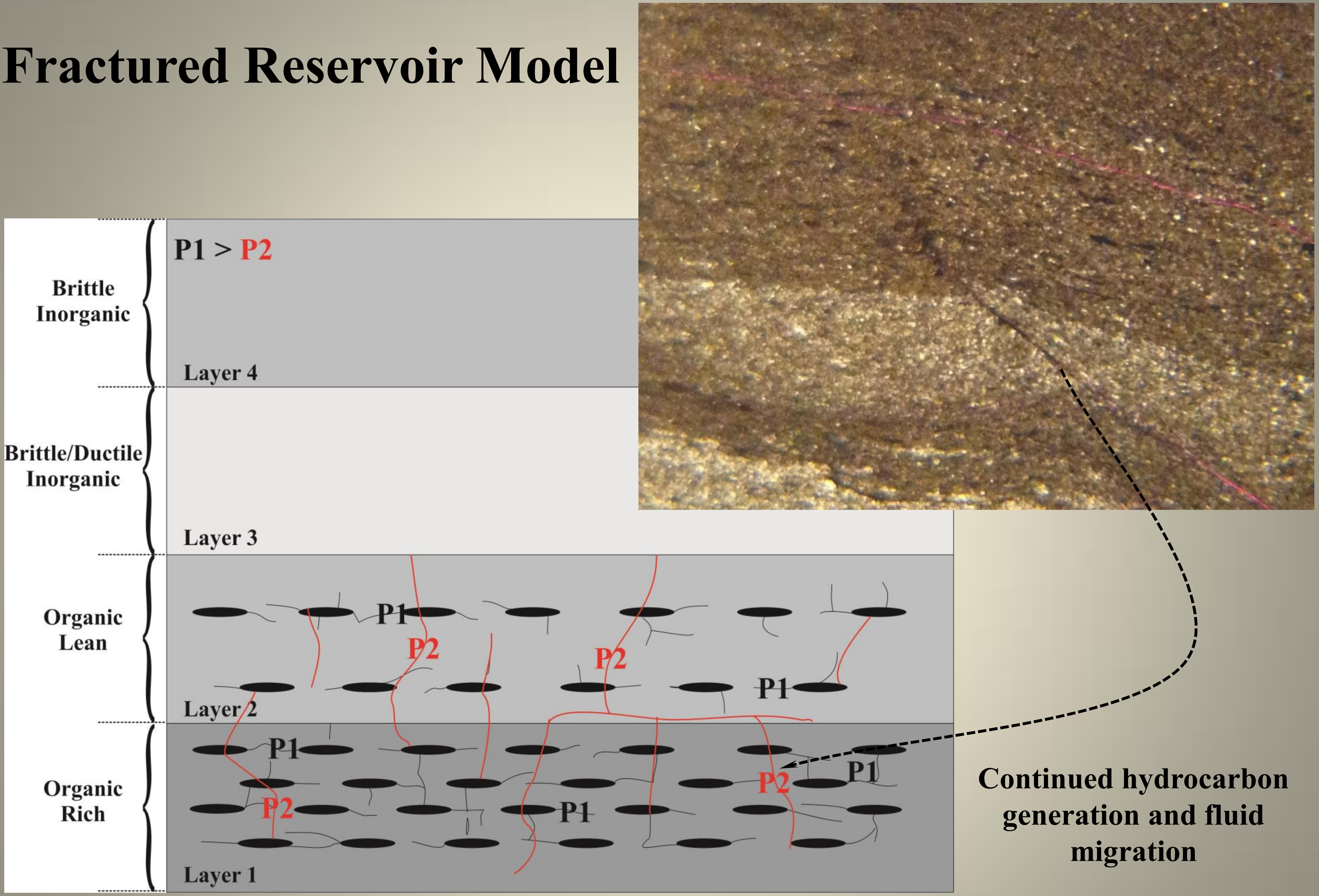


Hydrocarbon generation and micro-fracture development

Second White Specks – Highwood River



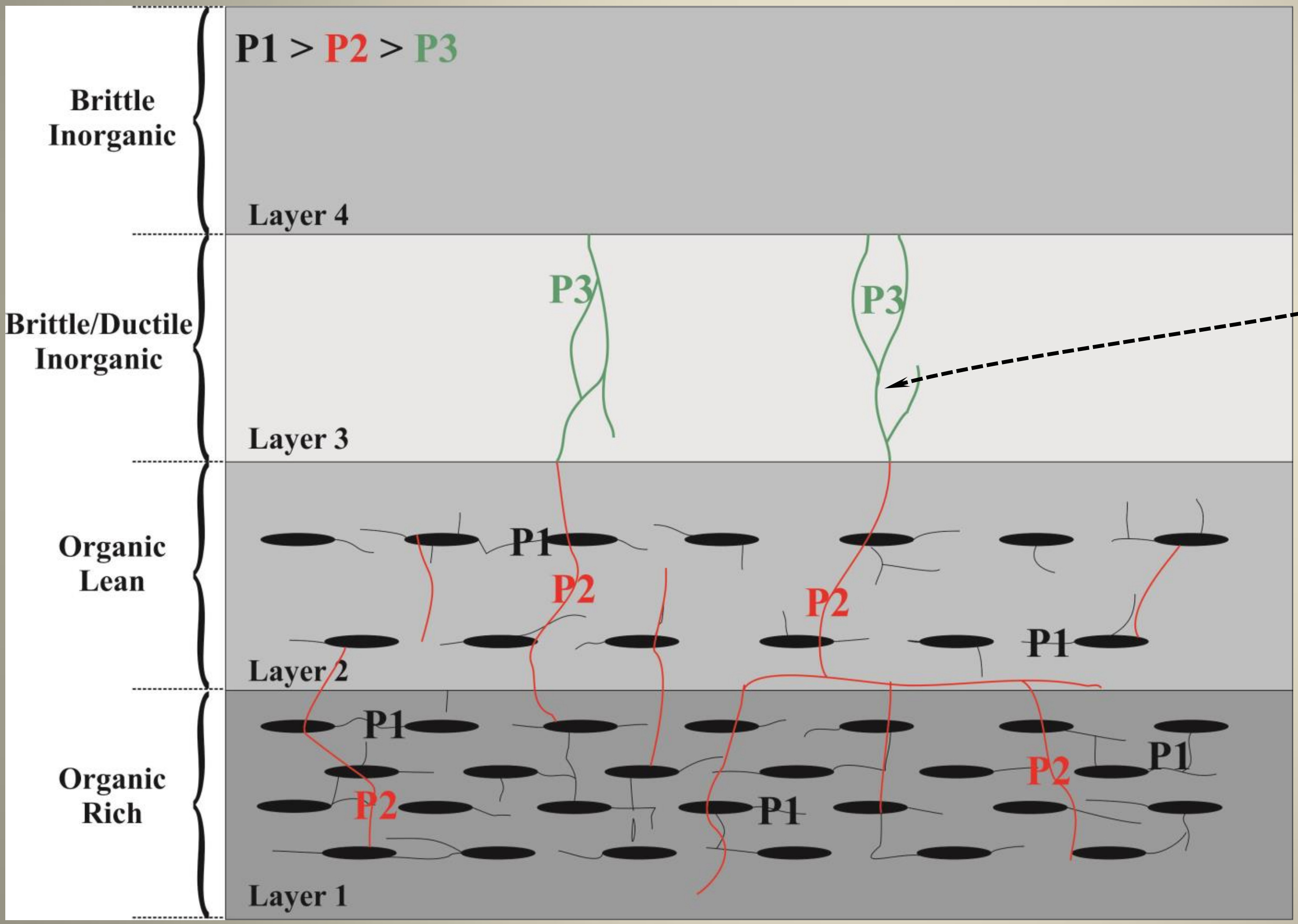
Fractured Reservoir Model



Continued hydrocarbon generation and fluid migration

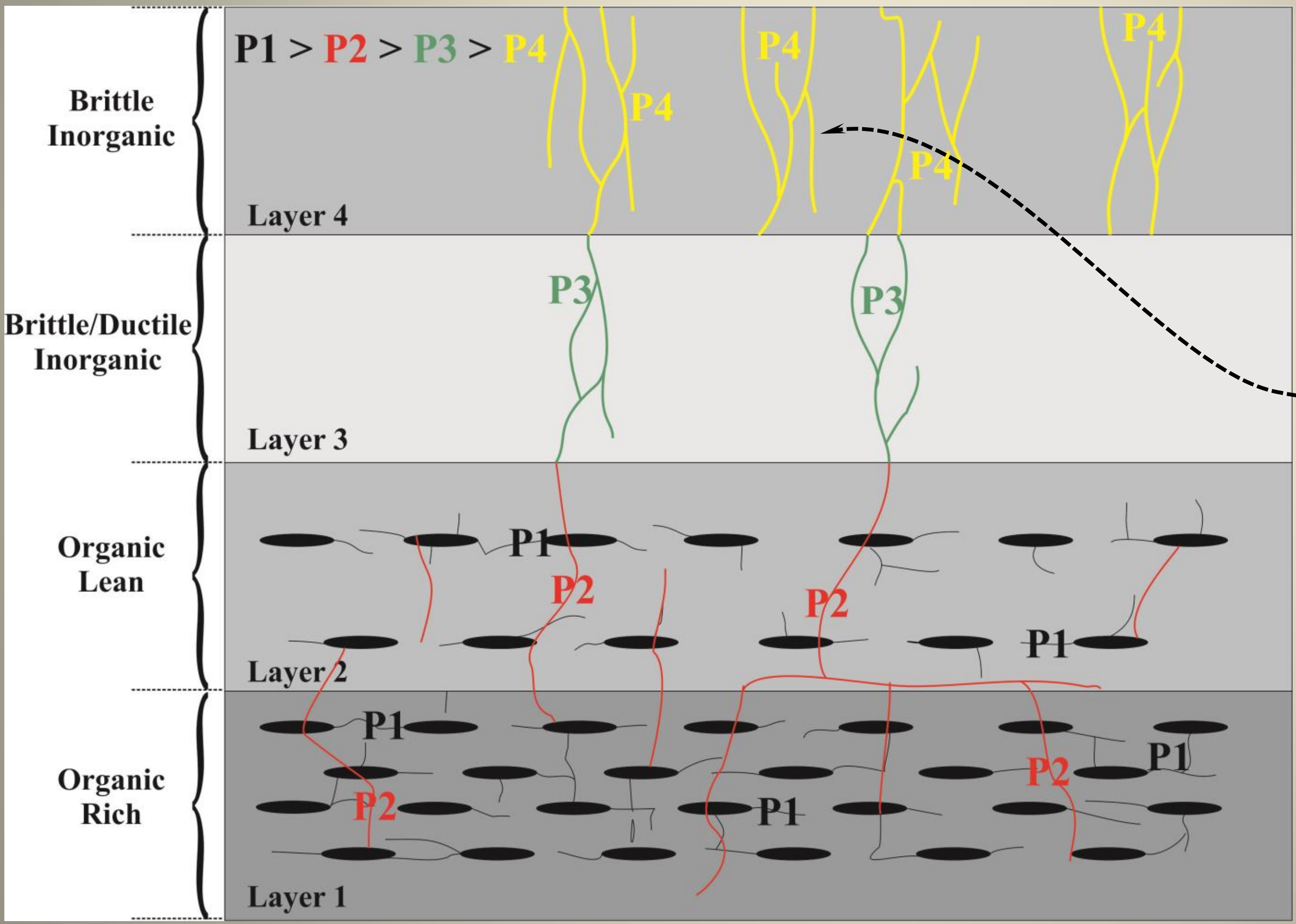
Second White Specks (Upper Cretaceous)

Fractured Reservoir Model



Continued hydrocarbon generation and fluid migration
Vertical migration into meso-fractures

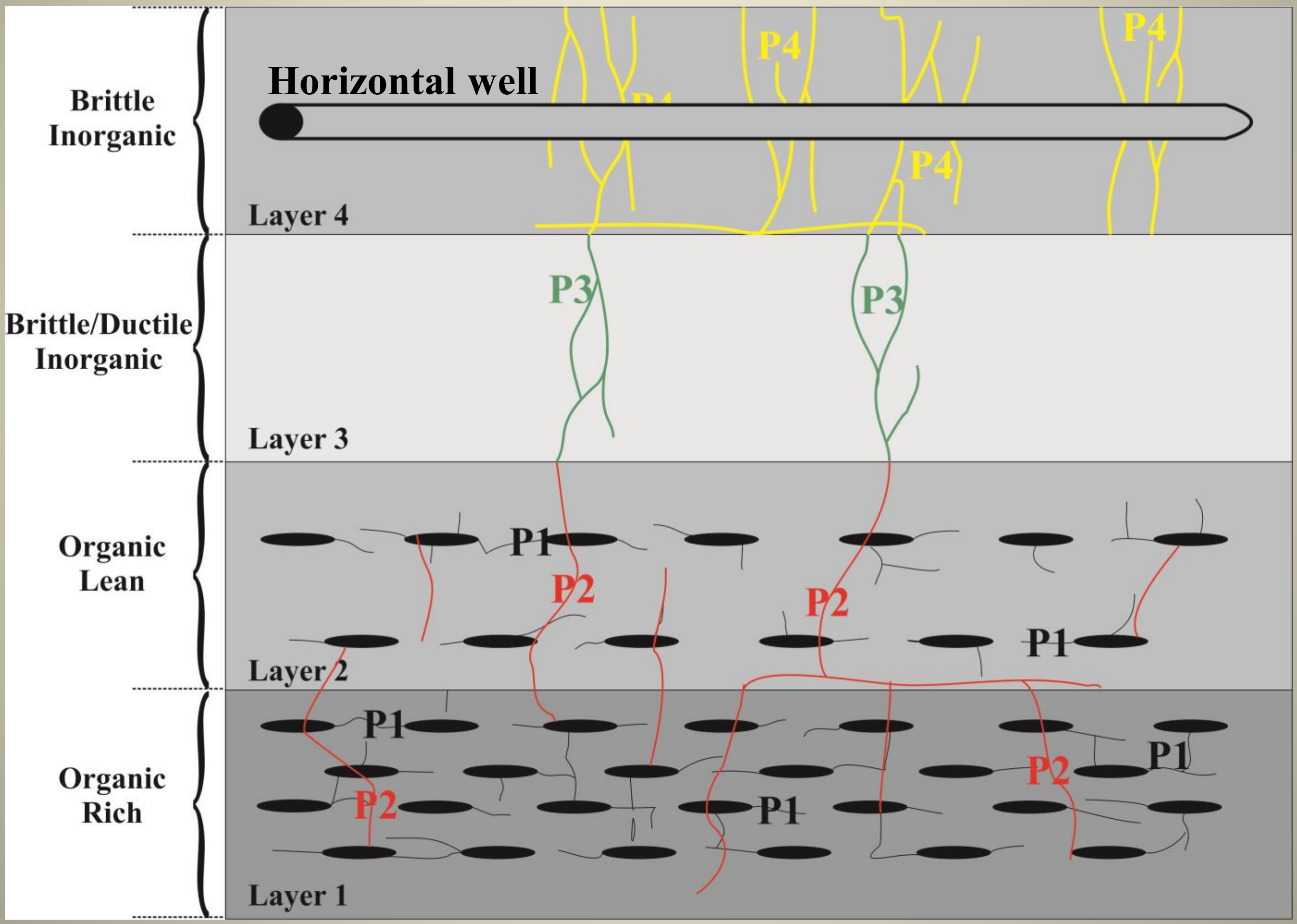
Fractured Reservoir Model



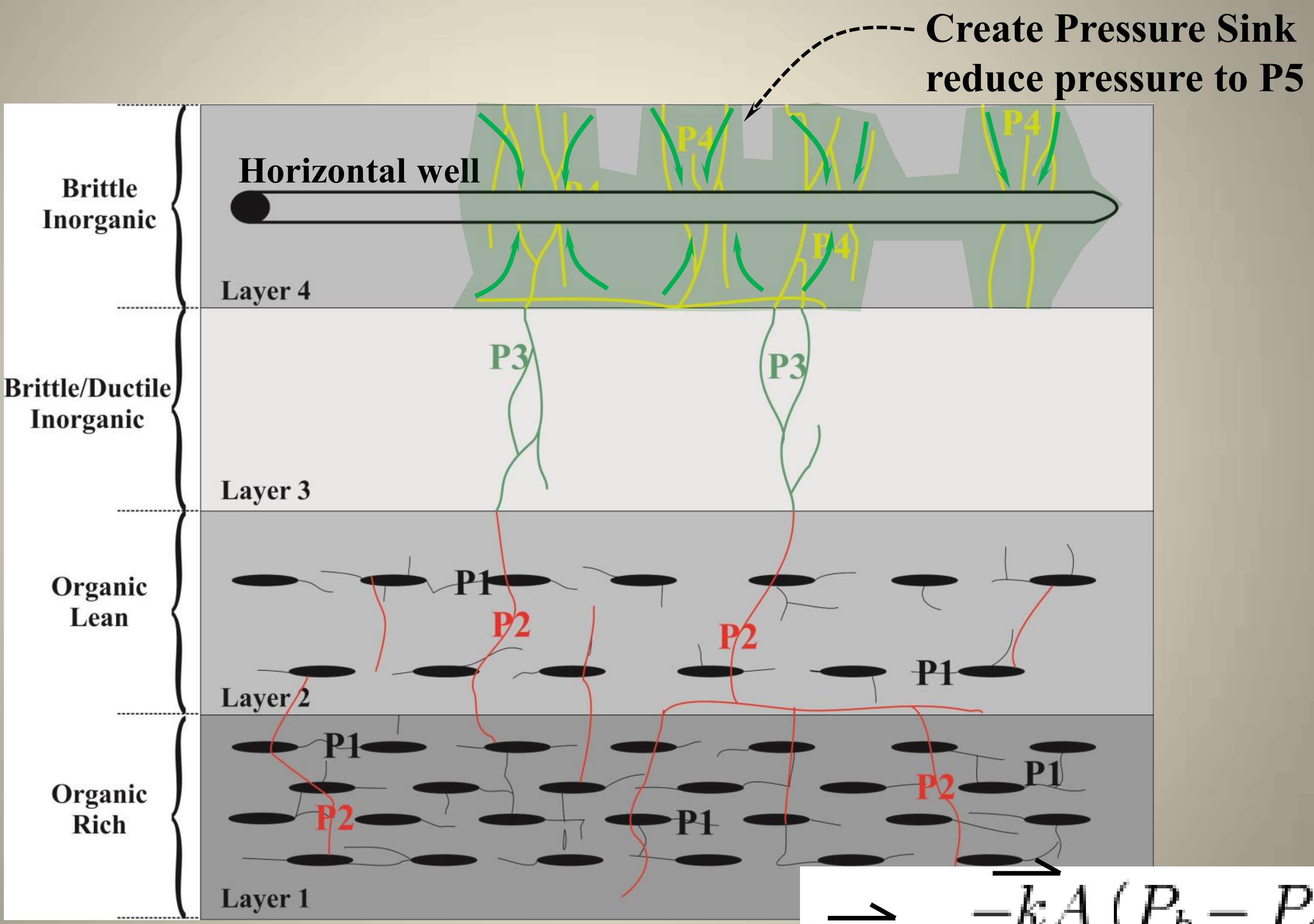
Continued hydrocarbon generation and fluid migration
More Brittle Zones form macro-fractures

Second White Specks – Highwood River

Fractured Reservoir Model

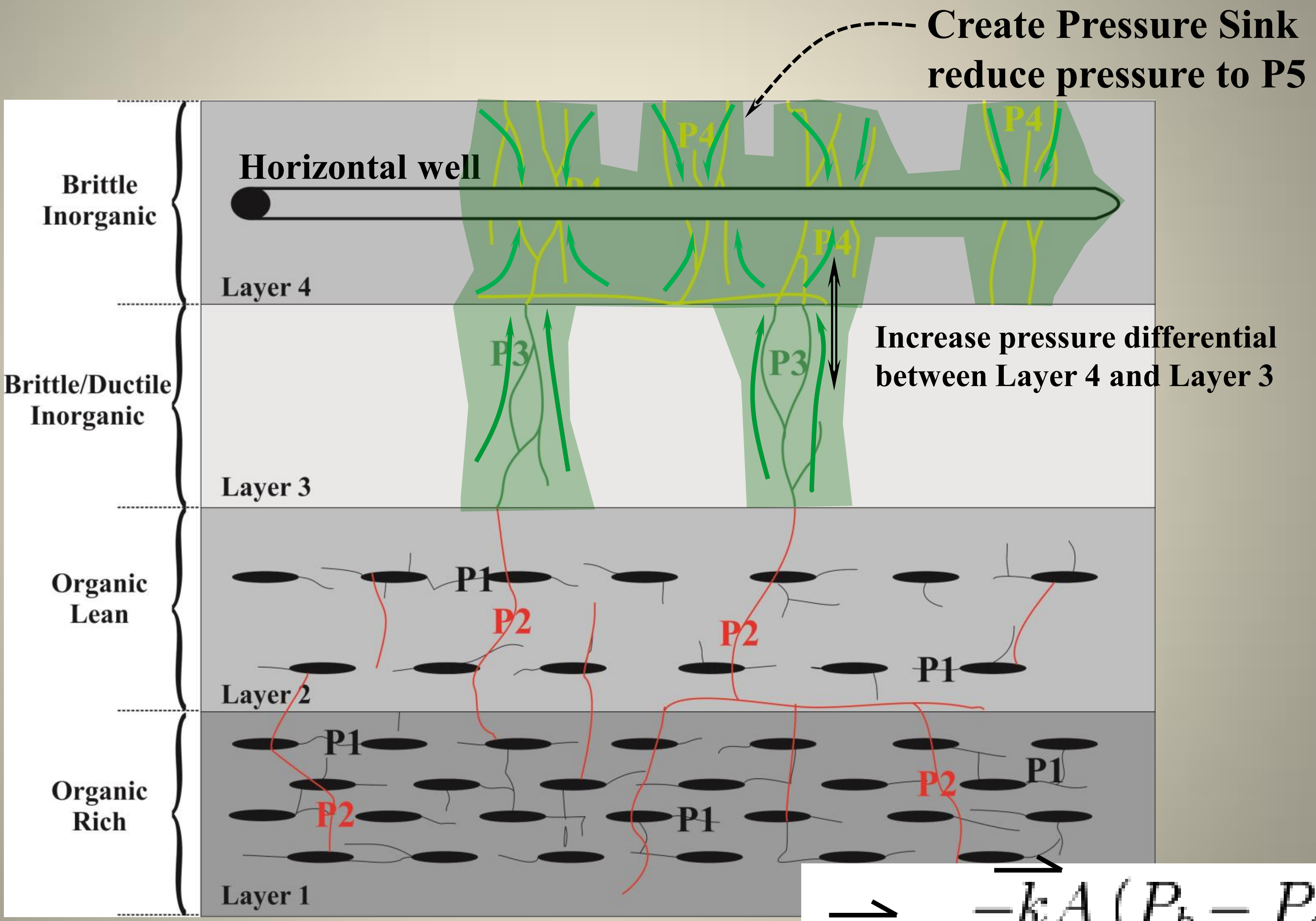


Fractured Reservoir Model



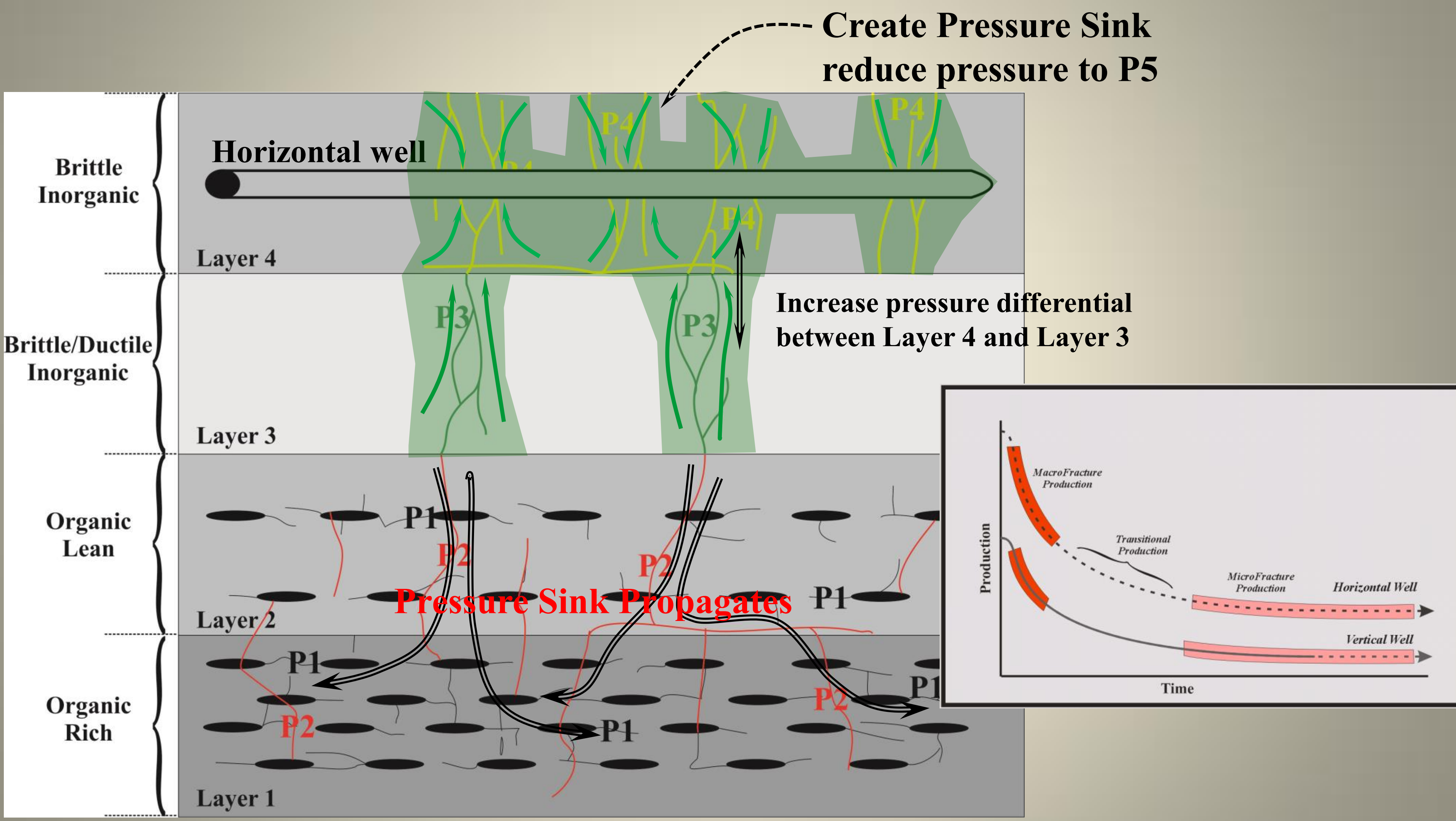
$$\overrightarrow{Q} = \frac{-kA}{\mu}\frac{(P_b - P_a)}{L}$$

Fractured Reservoir Model

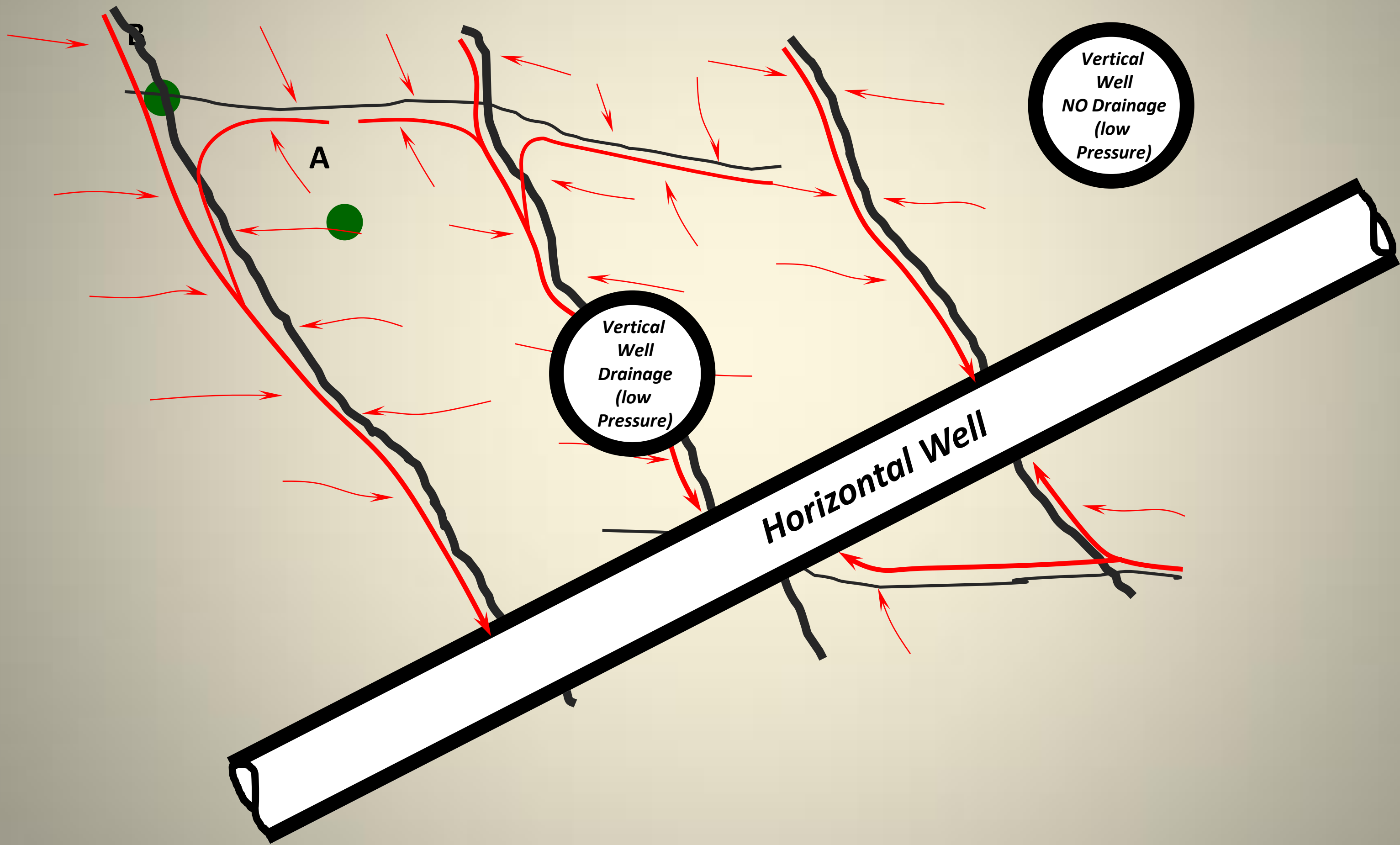


$$\overrightarrow{Q} = \frac{-kA}{\mu}\frac{(P_b - P_a)}{L}$$

Fractured Reservoir Model

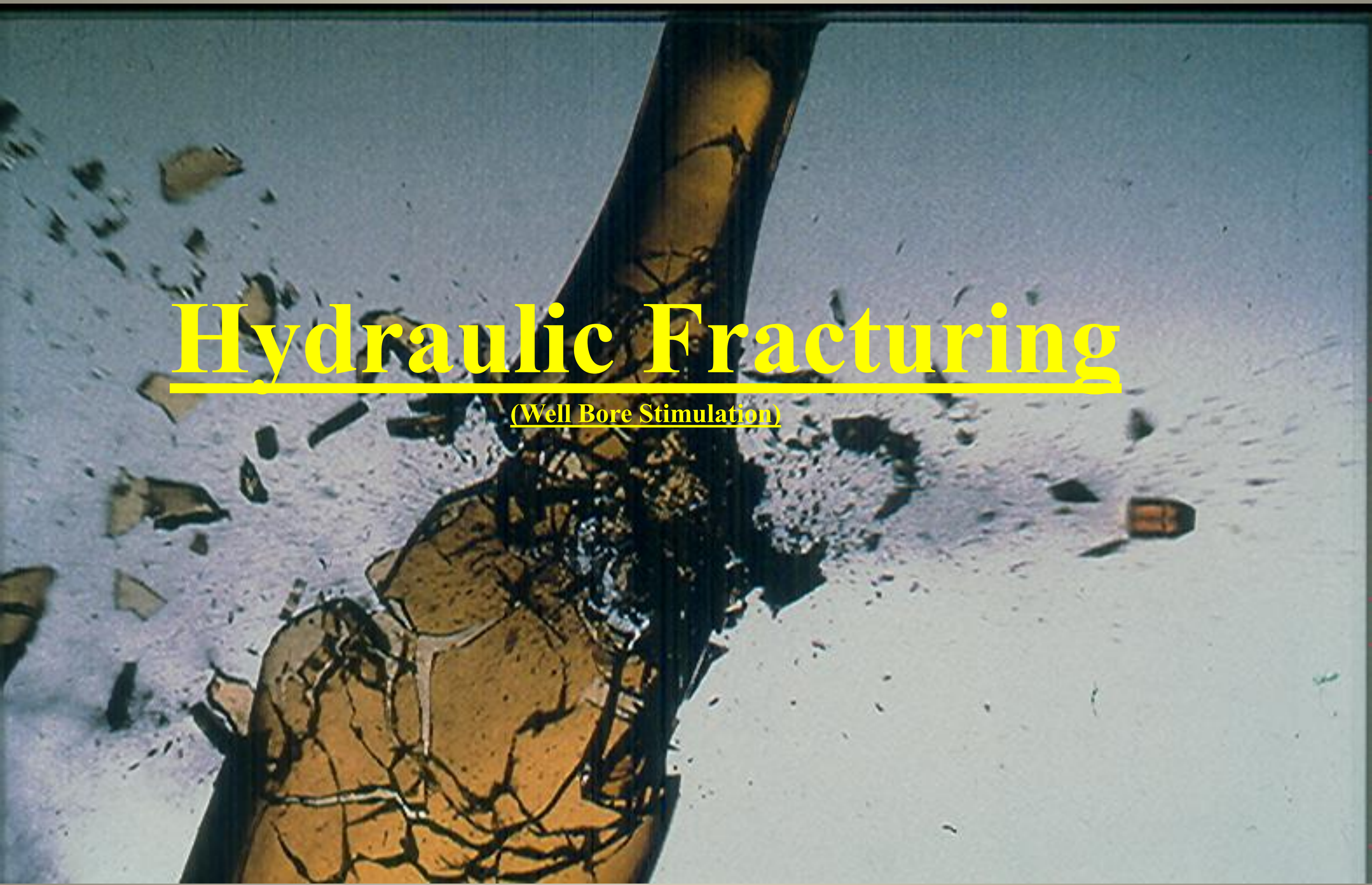


$$\overrightarrow{Q} = \frac{-\overrightarrow{k}A}{\mu}\frac{(P_b - P_a)}{L}$$



Conceptual View of a Fractured Reservoir

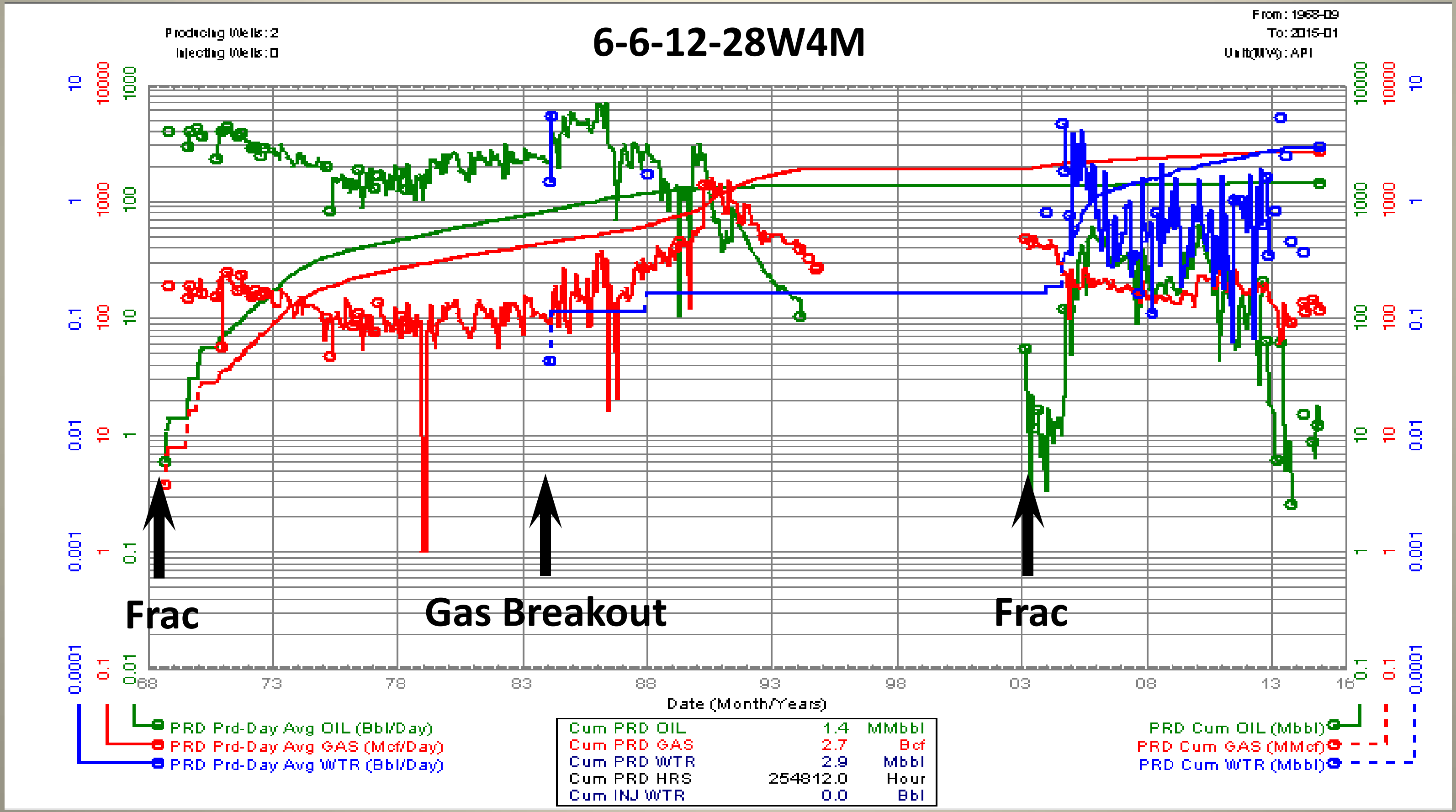
Plan View



Hydraulic Fracturing

(Well Bore Stimulation)

The Role of Proppant



Issues

1. Ground water protection
2. Water use
3. Airborne Emissions
4. Use of a variety of industrial chemicals
5. Industrial Impact
   - Site fluid storage and containment
   - Trucking
   - Noise
6. Induced Seismicity

Problems

- Pavillion, WY, 2010 – EPA detect petroleum in drinking water (liability not determined)
- Leroy Twp, PN, 2011 – Operational failure led to surface spill
- Mamm Ck, CO, 2006-2011 – frac fluid migrated to ground water – faulty design
- Grande Prairie, AB, 2011 – frac fluid contamination of ground water – faulty operation
- Blackpool, UK, - earthquake linked to frac operation
- Horn River, BC – earthquake linked to Frac operation

Induced seismicity – Blackpool, UK

- Cuadrilla Resources conducts multistage hydraulic frac: April, 2011
- Induced a series of microseismic events with the largest at M=2.3
- UK Government responds to public complaint and puts Moratorium on hydraulic fracturing
- Moratorium lifted in 2014
- Lancashire has 40,000 signatures asking to reject Cuadrilla's application to hydraulically fracture stimulate its well
- A motion to call a moratorium on "Fracking" was rejected in the House of Commons 308 votes to 52 votes

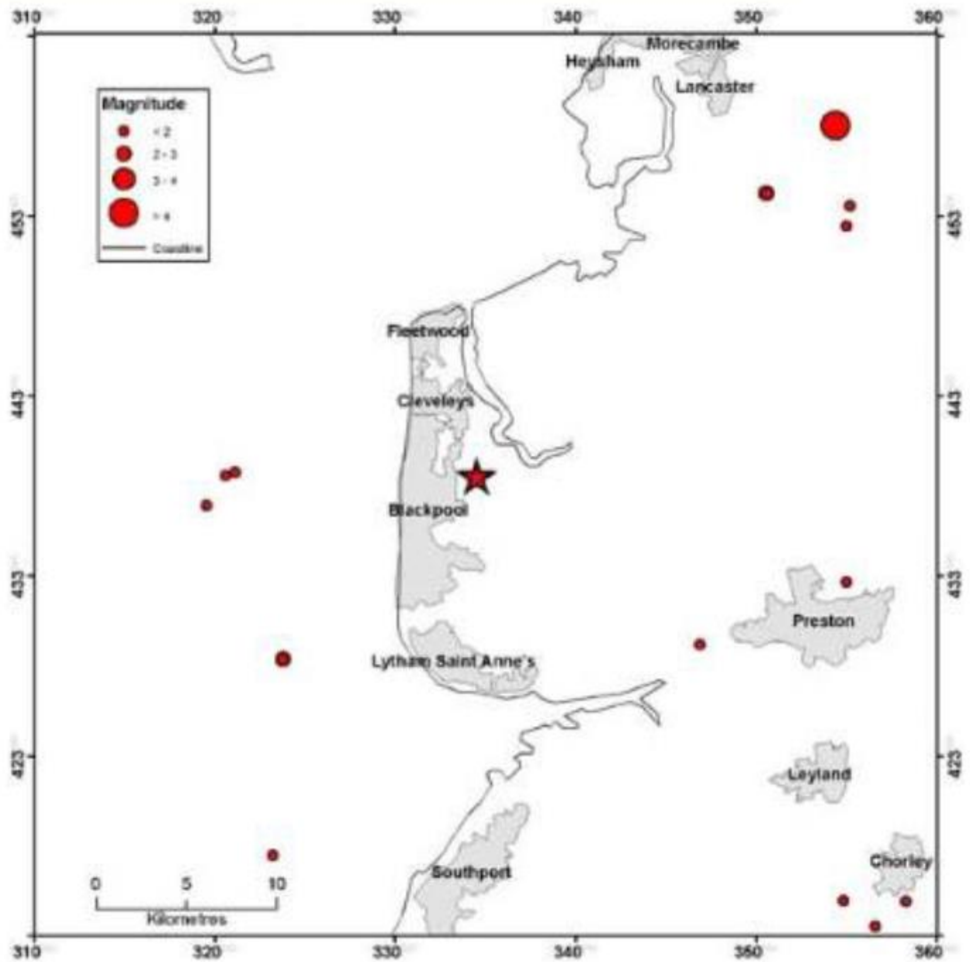
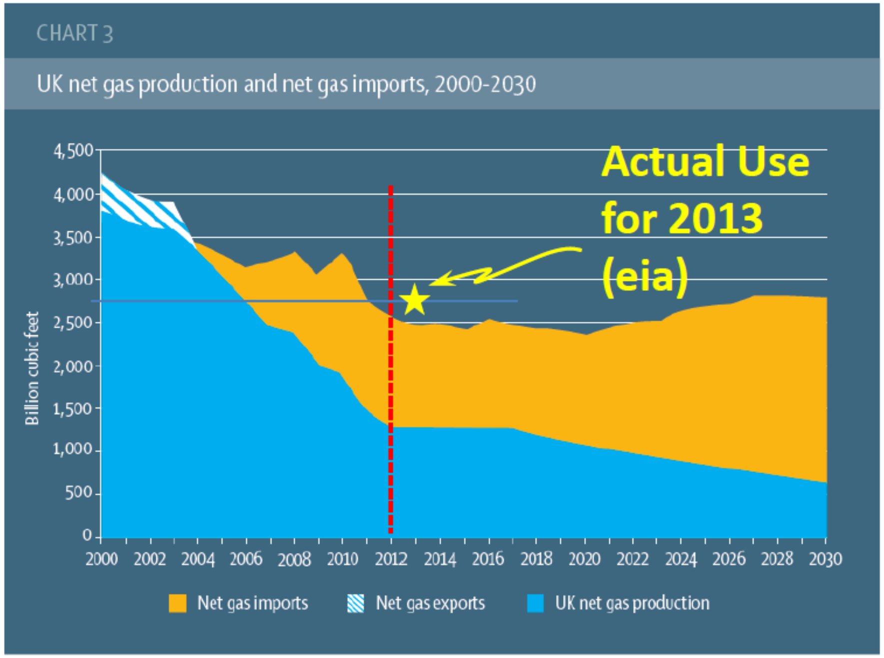


Figure 5. Seismic activity in a 50 km square centred on the epicentre of the magnitude 2.3 earthquake.

Situation in the United Kingdom

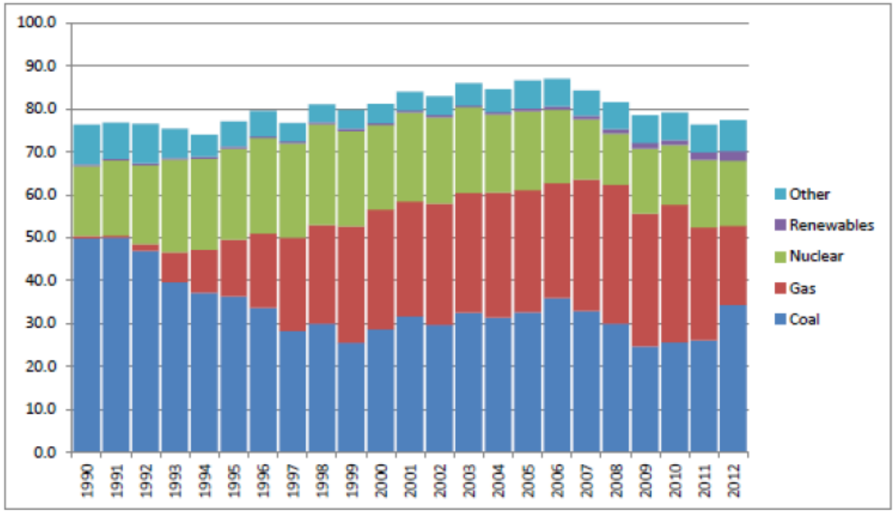
(a cautionary tale)

35% of all energy consumed in the UK is from Natural Gas

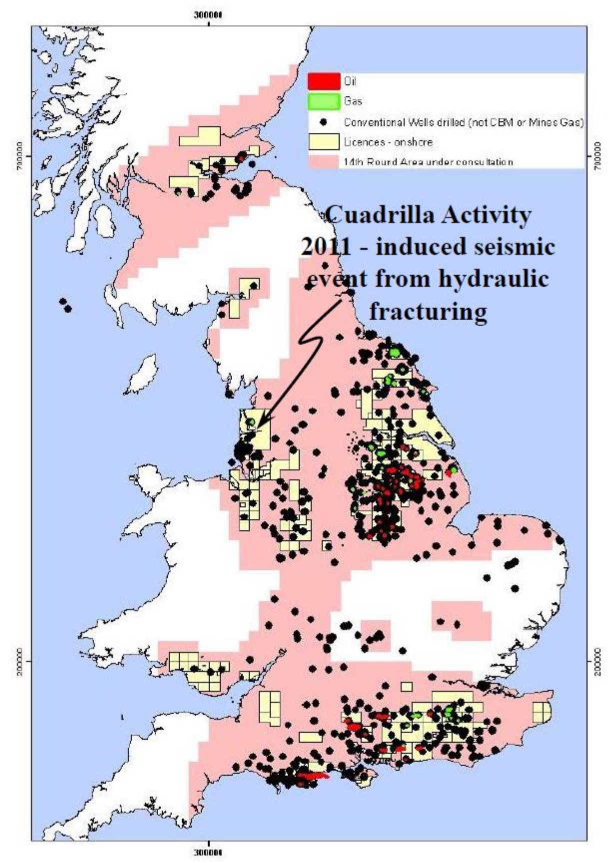


Source: Department of Energy and Climate Change, Production projections, extracted 15 March 2013 https://www.gov.uk/oil-and-gas-uk-field-data. NB: Figures given in billion cubic metres are converted to billion cubic feet.

Figure 5: Fuel mix for UK electricity generation, 1990-2012 (Mtoe)



Source: Digest of United Kingdom Energy Statistics, Table 5.1.1 Fuel input for electricity generation, 1970 to 2012



Demand for Affordable Energy
Advancing Technology
and the
Nature of Trial and Error

The Social Contract
And the Public's
Level of Scientific Literacy
Cost of Mistakes