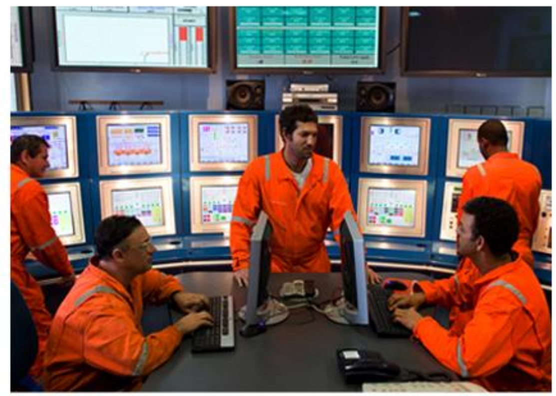
Well Completion and Hydraulic Fracturing Methodology Explained



Kevin Rice

AAEE Workshop – May 14th, 2012

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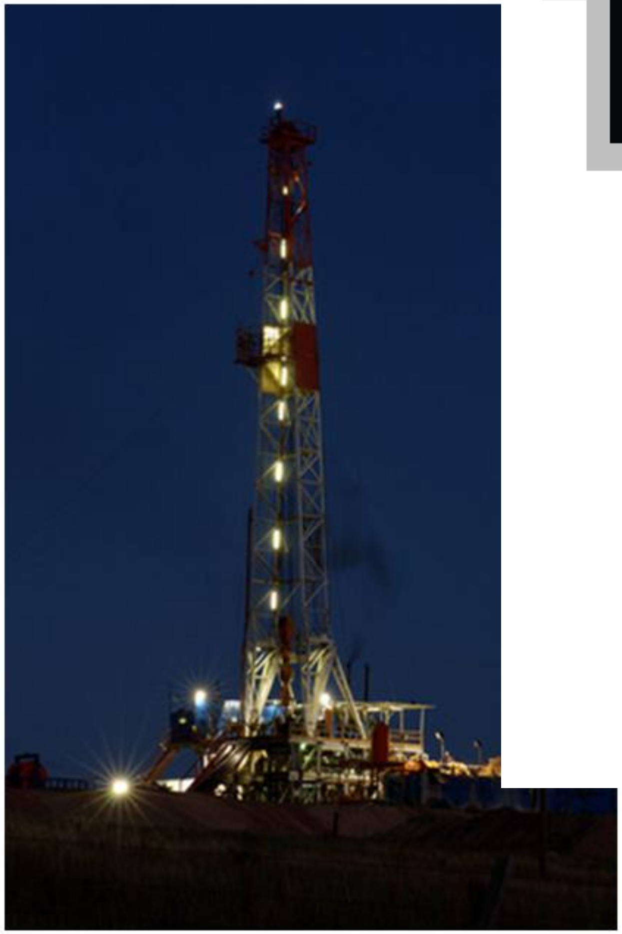
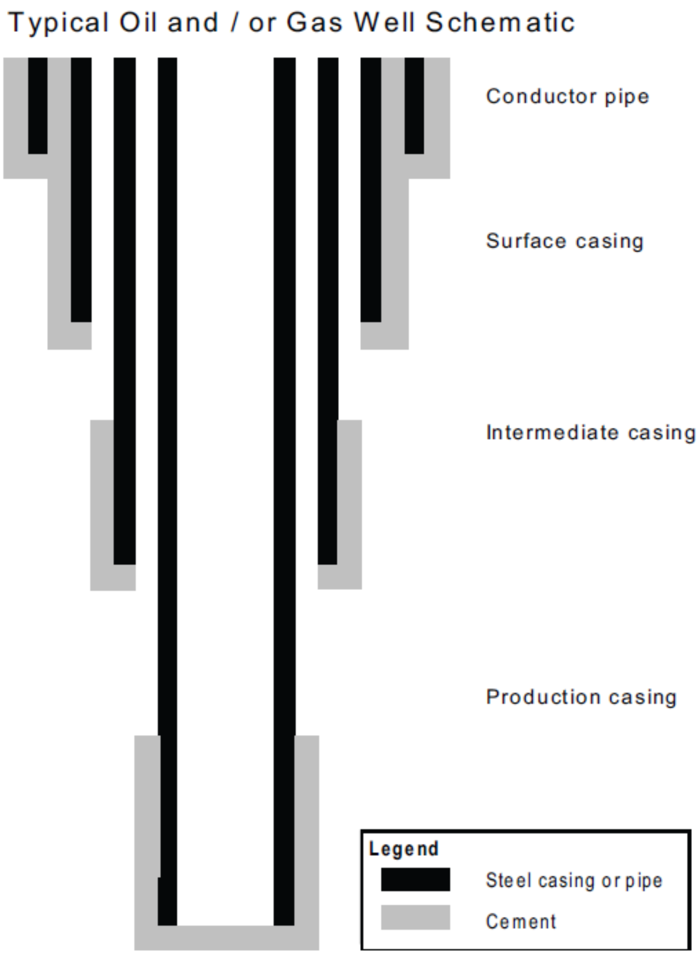
Well Construction Process

- Drilling
- Completion
  - Cementing
  - Perforating
- Hydraulic Fracturing
  - Conventional
  - Unconventional





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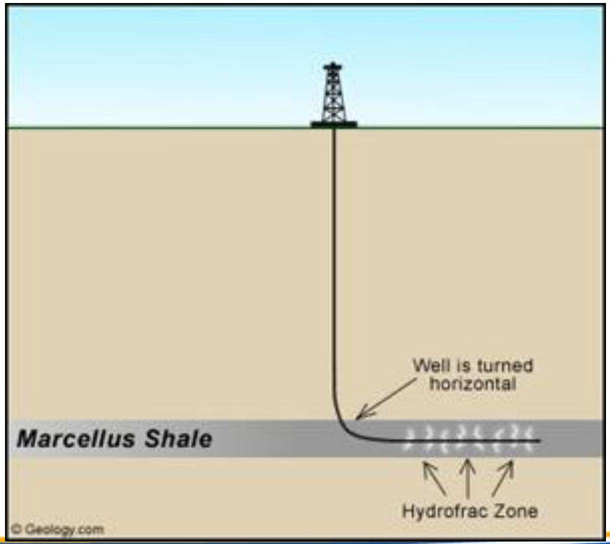
Drilling – general statistics for US Land

- Depths up to 35,000 ft., vertically
- Almost 65,000 new wells in the US 2011
- US land-based rig count at the end of April 2012
  - 613 Gas (31%)
  - 1328 Oil (69%)
- Less than two weeks to drill a new well

Drilling Process

- Drilling Rig
  - Controls the downward force on the bit
  - Supports the drill string or casing as new joints are added
- Vertical Drilling
  - Power comes from the rotatory platform on surface
- Horizontal Drilling
  - MWD (Measurement While Drilling)
  - LWD (Logging While Drilling)
  - Downhole drill motors



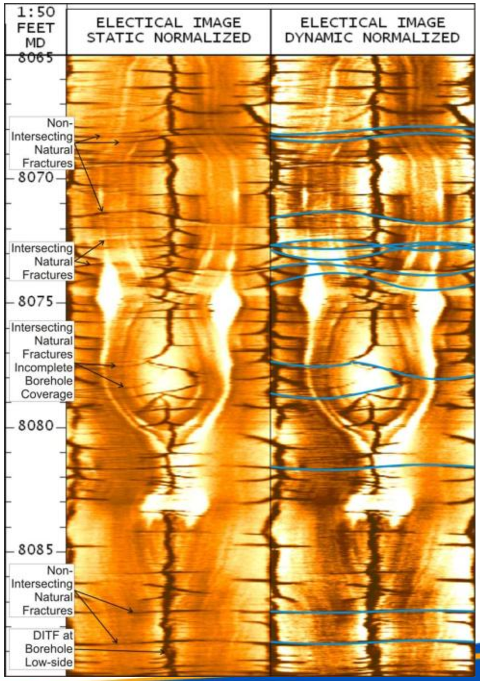


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Photo Courtesy Brad Cole – Geology.com

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Drilling Fluids (Muds)

- Circulated down the drill stem and up the annulus
- Jetted to high flow rates at the bit
- Key functions:
  - Control formation pressures
  - Remove cuttings
  - Lubricate the bit
  - Control leak-off
- Muds are recirculated and periodically reconditioned

Cementing Principles

- Provide a permanent bond between the casing and the formation
- Performed in stages to provide wellbore stability and isolate zones
- Cement is pumped down the inside of the casing and up the annular space
- Key steps include:
  - Ensure bonding by both chemical and mechanical techniques
  - Centralize the casing in the open hole

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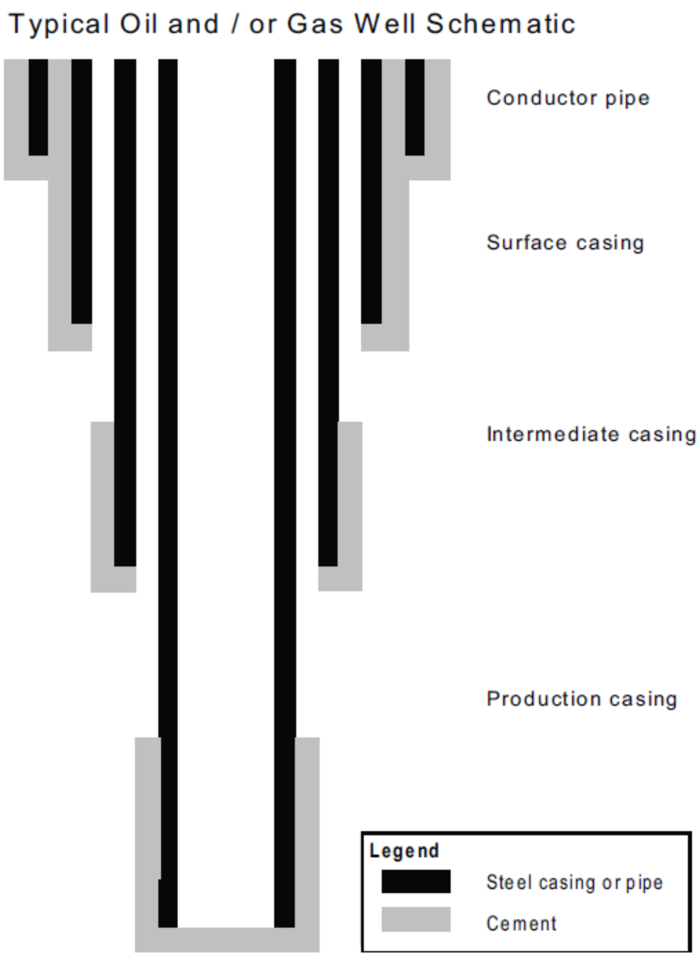
Cementing Stages

Generally consists of four components:

- Conductor casing
  - Less than 100 ft
  - Isolate shallow groundwater
- Surface casing
  - Surface to 5,500 ft, typical
  - Isolate groundwater aquifers
  - Marcellus typically less than 500 ft
- Intermediate casing
  - Surface to 16,000 ft, typical
  - Isolate subsurface formations
- Production casing
  - Surface to 20,000 ft or deeper
  - Isolate production zone from other formations
  - Contain hydraulic fracturing, production strings, etc.



Cementing Measurements

Prior to Placement

- Thickening Time – Cement placement
- Compressive Strength – Casing support
- Gel Strength – Resistance to reservoir fluids
- Viscosity – Flow requirements
- Fluid Loss – Water lost to the formation

During Placement

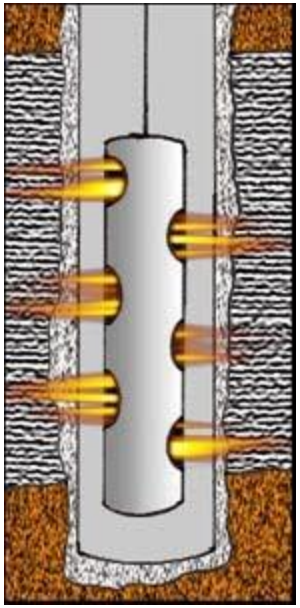
- Density – Control pressures
- Rate and Pressure – Compare to expectations

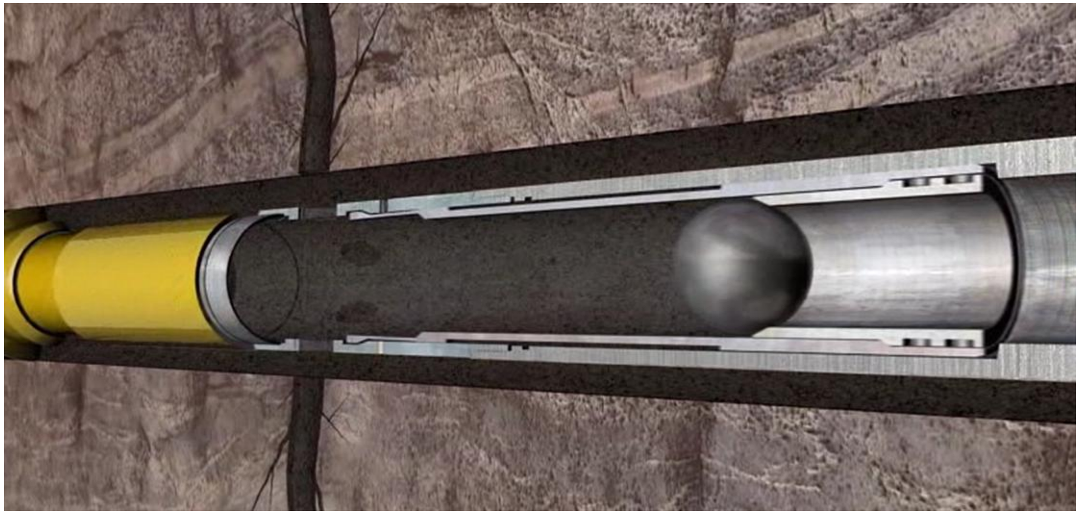
After Placement

- Positive or Negative Pressure Test – Cement integrity
- Cement Bond Log – Cement integrity

Completion Tools

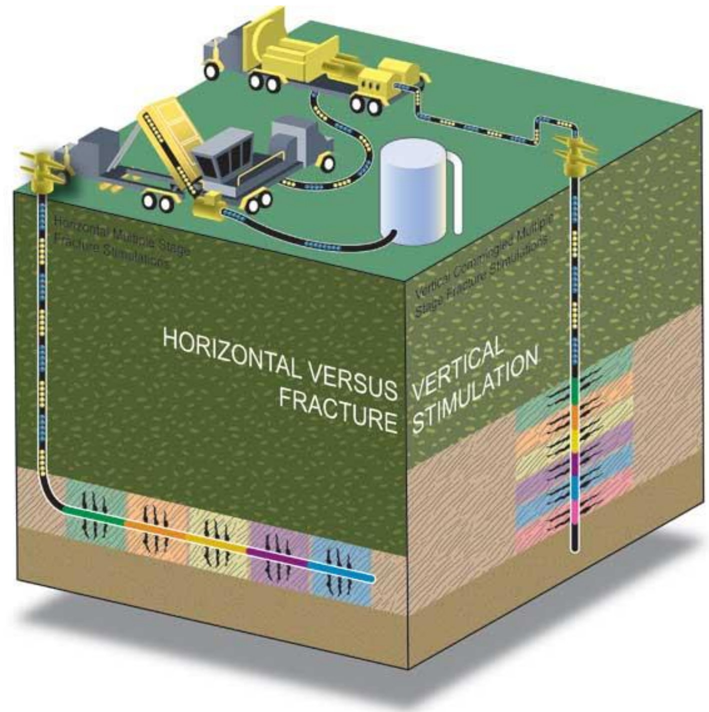
- Perforating
  - Punctures casing to create flow path
  - Isolates zone with packer or fill
- Sliding Sleeve
  - Isolates and accesses openings in one process





Hydraulic Fracturing Process
Conventional Oil and Gas

- Initiate a fracture by pressuring fluids to the breakdown pressure of the formation
- Pump fluid into the fracture to create width & length
- Add sand or other proppant to be transported into the fracture
- Reduce the pressure and allowing the fracture to close
- Flow the fluid back out of the fracture while the proppant stays in place



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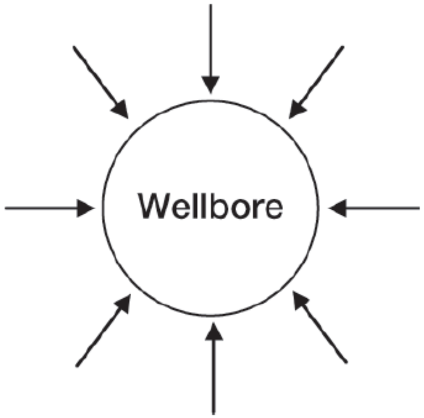
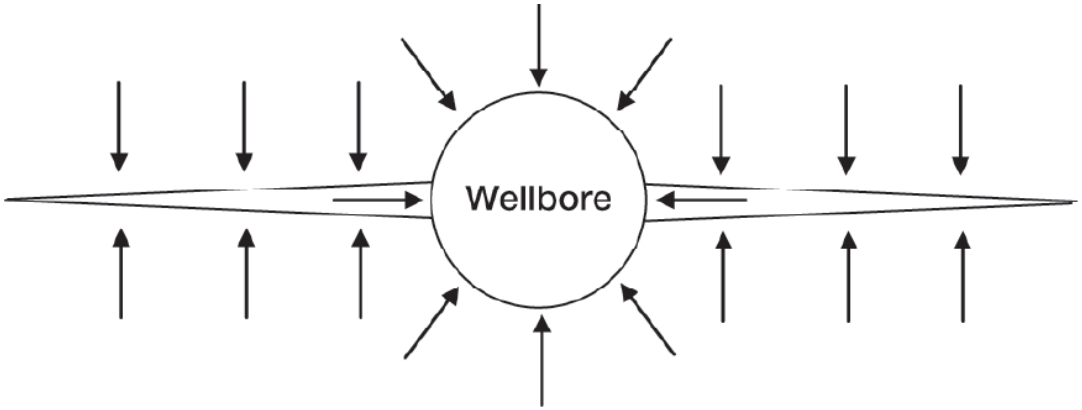
Why Fracture?

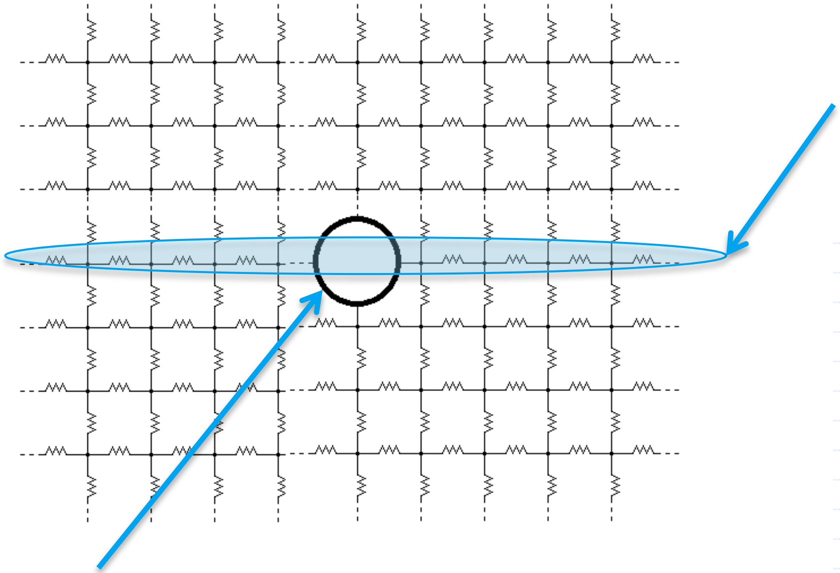


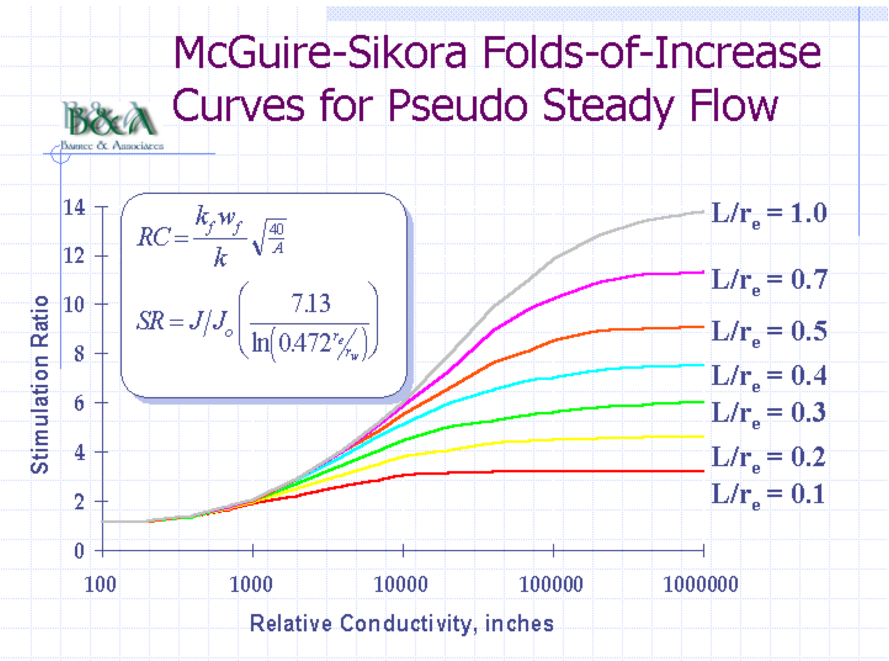
Radial Flow – Flow converges



Linear Flow – No converging

Production Increase



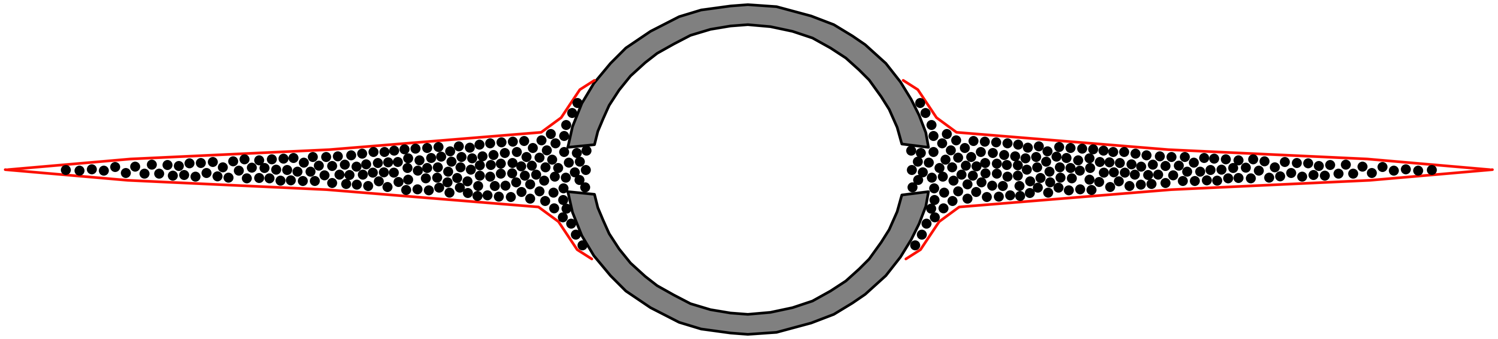


In 1960 experiments were conducted by McGuire and Sikora with an electrical resistance grid to simulate the reservoir production increases by fracturing

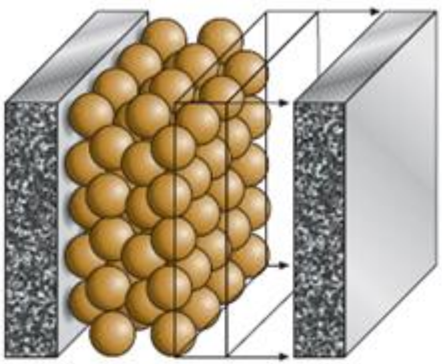
Production increases with length and width of fracture

Fracturing Proppants

Fractures are created, then held open
with a proppant, creating a conductive path



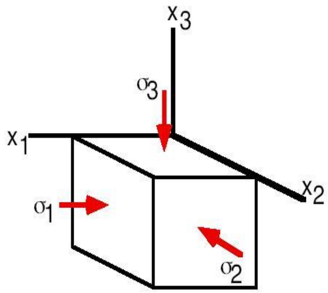
Sand



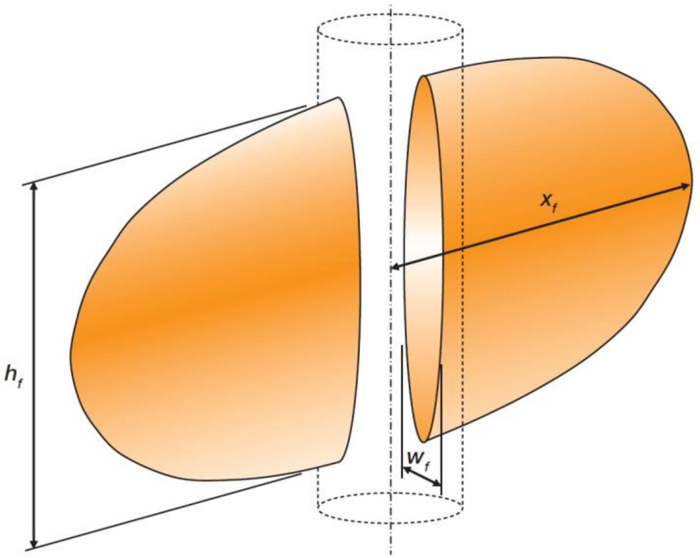
Ceramic

Fracture Mechanics

- Fracture Initiation
  - Exceed breakdown pressure
- Fracture Growth
  - Circular initial growth, Height = Length
  - Direction based on formation stress



Frac Height: 50 to 200 feet

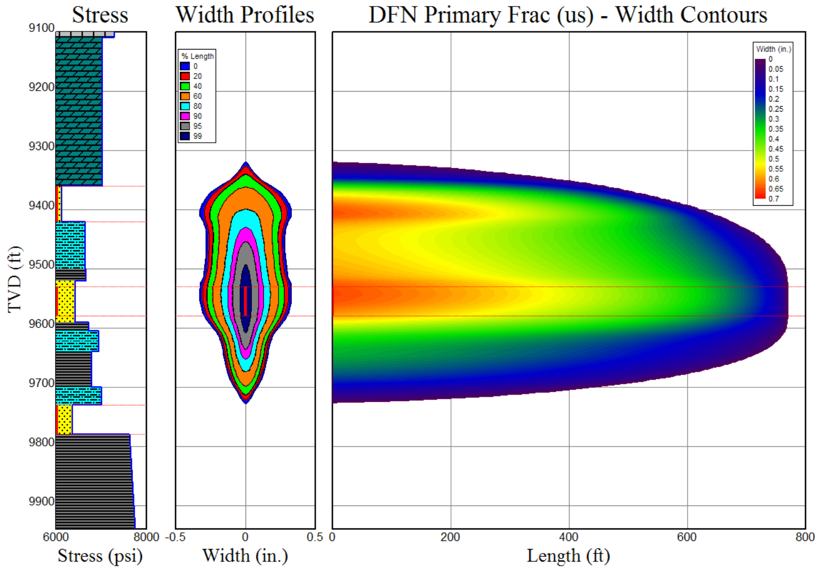


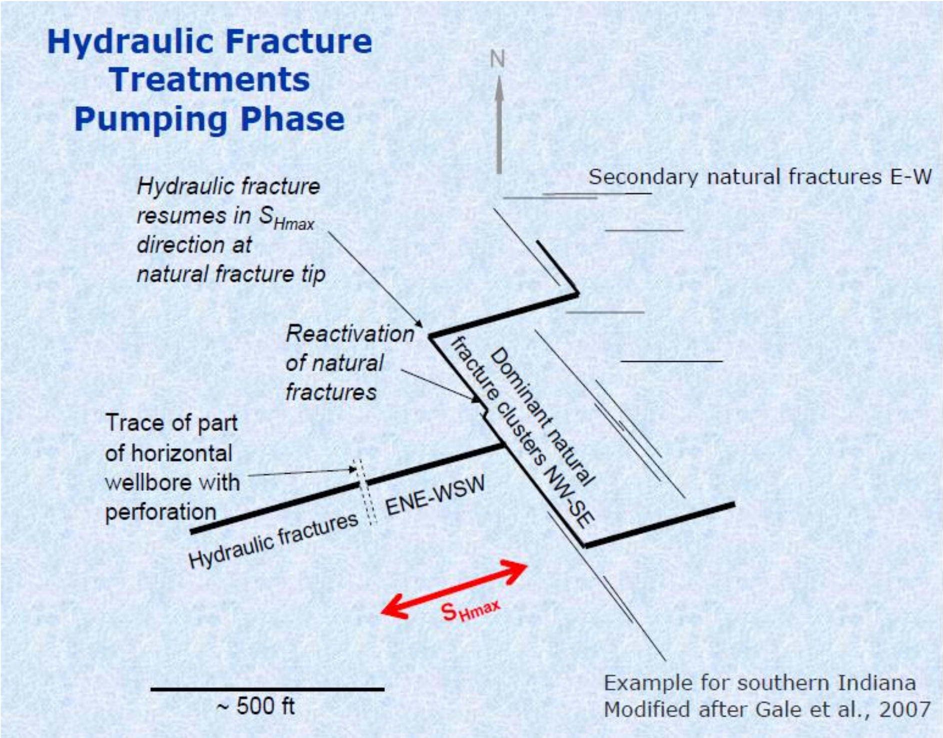
Frac Length: 500 to 1500 feet

Frac Width: ½ inch

Fracture Growth

Shape and Containment





Intersection with natural fractures

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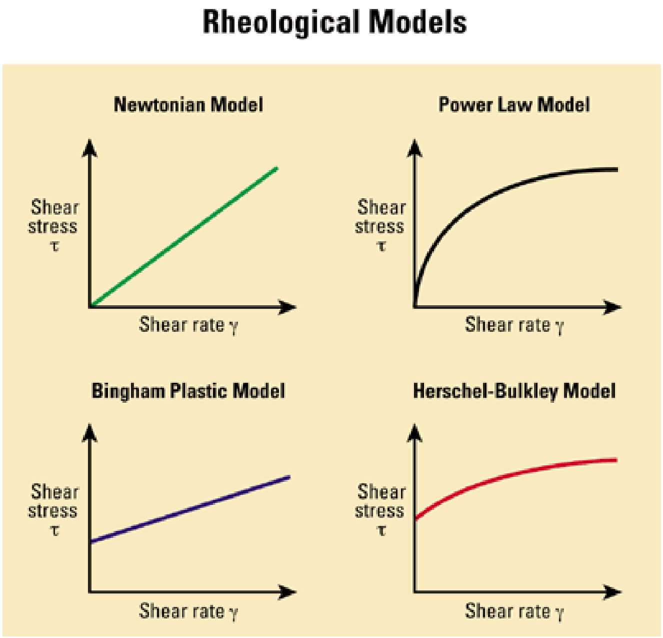
Hydraulic Fracturing Fluid Properties

- Low pumping friction (low viscosity)
- Create fracture width (low to high viscosity)
- Transport proppant (high viscosity)
- Control leak off



Fracturing Matrix

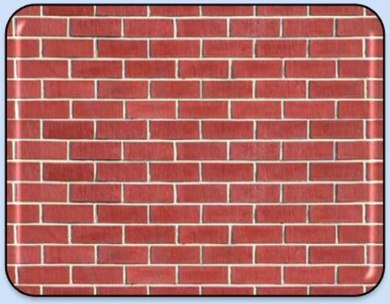
Fracturing Categories

Conventional

1000 to 0.5 md
Sandstone

Fracturing used to stimulate production

Tight Gas



0.5 to 0.001 md
Brick, Concrete

Fracturing required for production

Unconventional

0.001 to 0.000001 md
Granite, Shale

Fracturing required for production

Horizontal Drilling required for production

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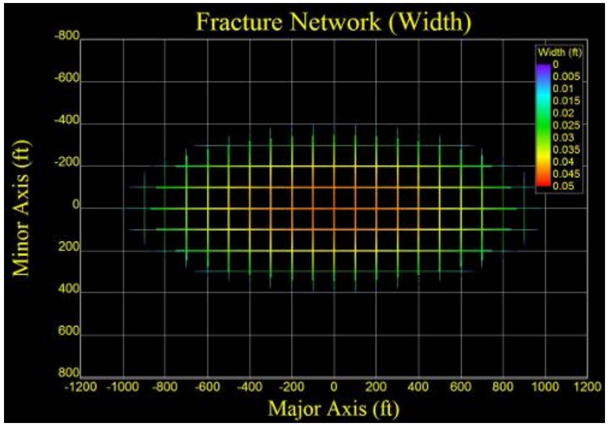
Unconventional (Shale) Fracturing

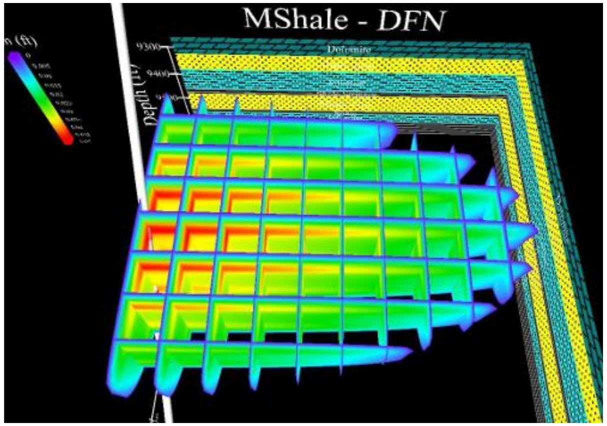
- What is shale?
  - Mudstone, siltstone, shale stone
  - Source rock for nearby oil and gas bearing formations
  - Very fine grain size, extremely low permeability
  - Tends to be highly fractured
- Natural gas resides
  - Within the natural fractures
  - Adsorbed on the surface
  - Within the porosity
- How do we fracture shale?

Shale outcropping

Shale Fracturing

- No longer about just fracture width and length – now we build a network of new and existing fractures
- The goal is Stimulated Reservoir Volume (SRV)
- Requires horizontal drilling, multistage fracturing and a fracture network





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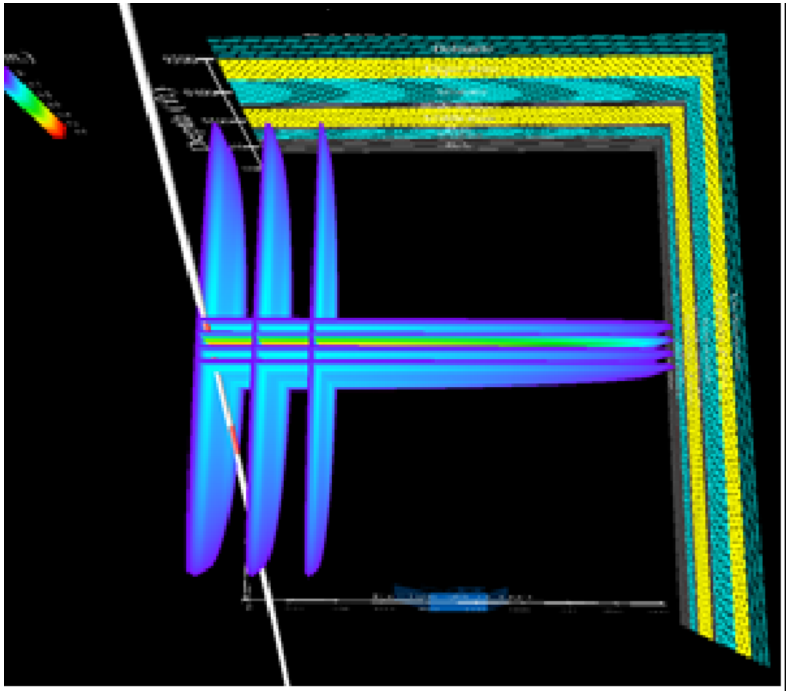
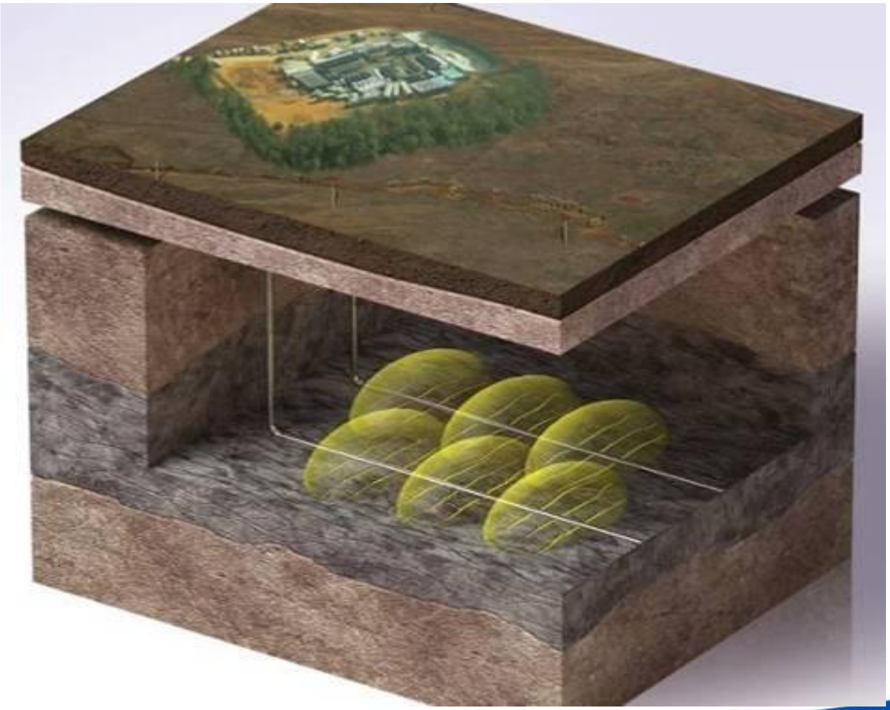
Fracturing Network

- Currently developing and evaluating different techniques to alter the near wellbore stress field and promote more secondary fractures
- The average number of stages per well in 2011 was 16+

Clustering method



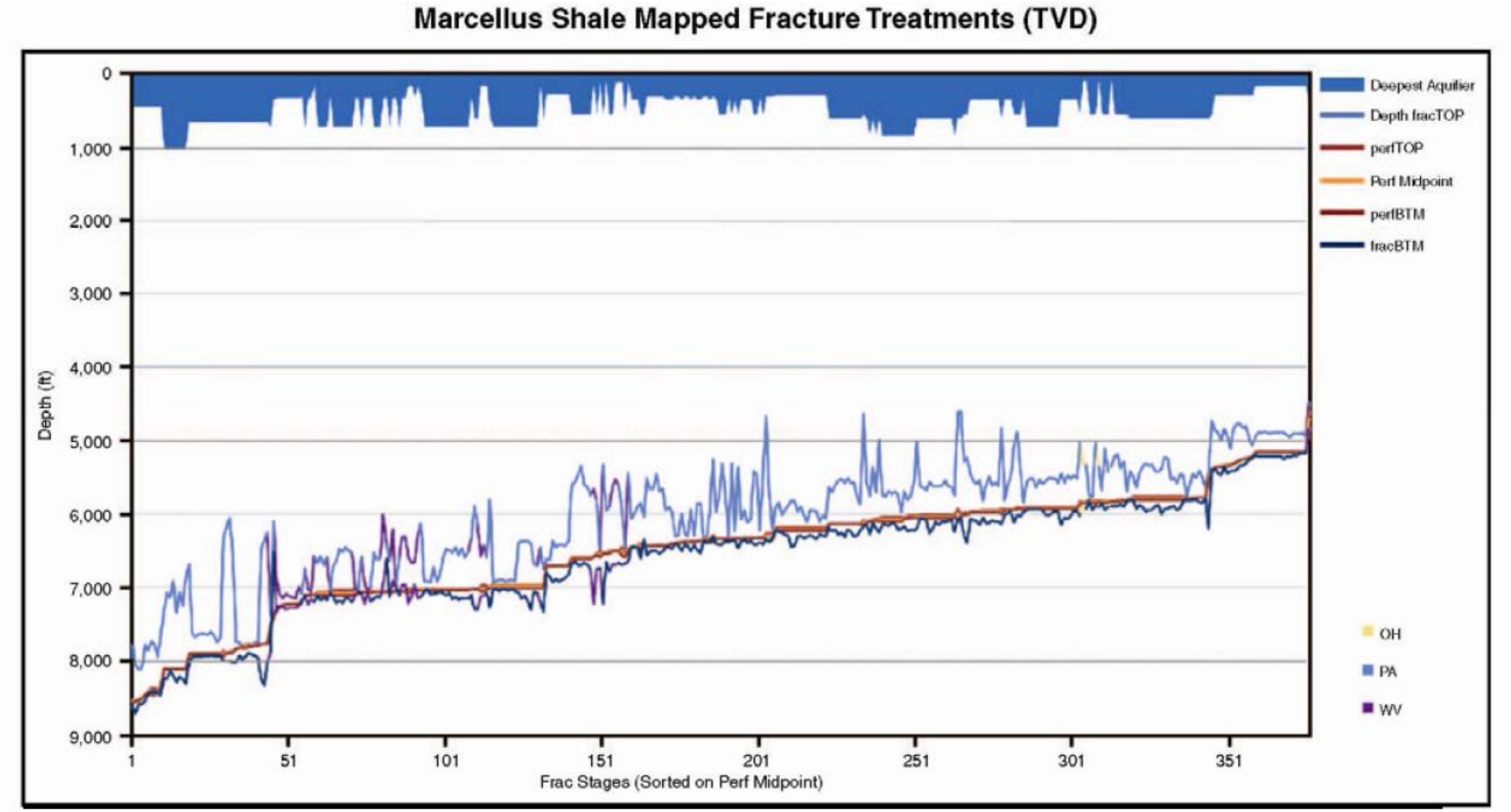
Alternating clusters in adjacent wells



Summary:

- Hydraulic fracturing is necessary to develop shale gas but it is not a standalone process
- The key developments to successfully produce from shale formations include:
  - Measurement while drilling
  - Logging while drilling
  - Downhole drilling motors
  - Multistage completions tools
  - Fracture network techniques

Fracture Height Growth in Marcellus



From SPE 152596 Hydraulic Fracturing 101 by George King, Feb 2012

