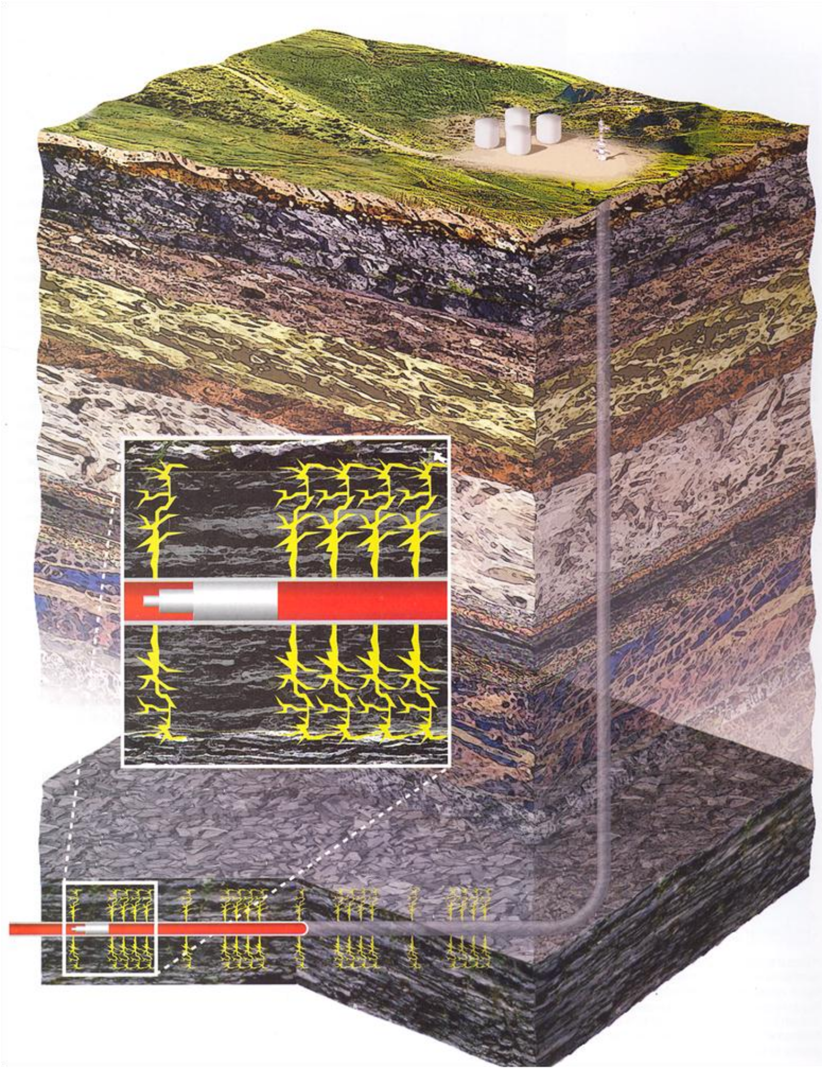
DRILLING
&
FRACING

For Montana Bureau of Mines & Geology
July 31, 2012

Objective of Oil and Gas Wells



The mineral owner and the mineral leasee (i.e. the operator) want a money-making producing oil/gas well with

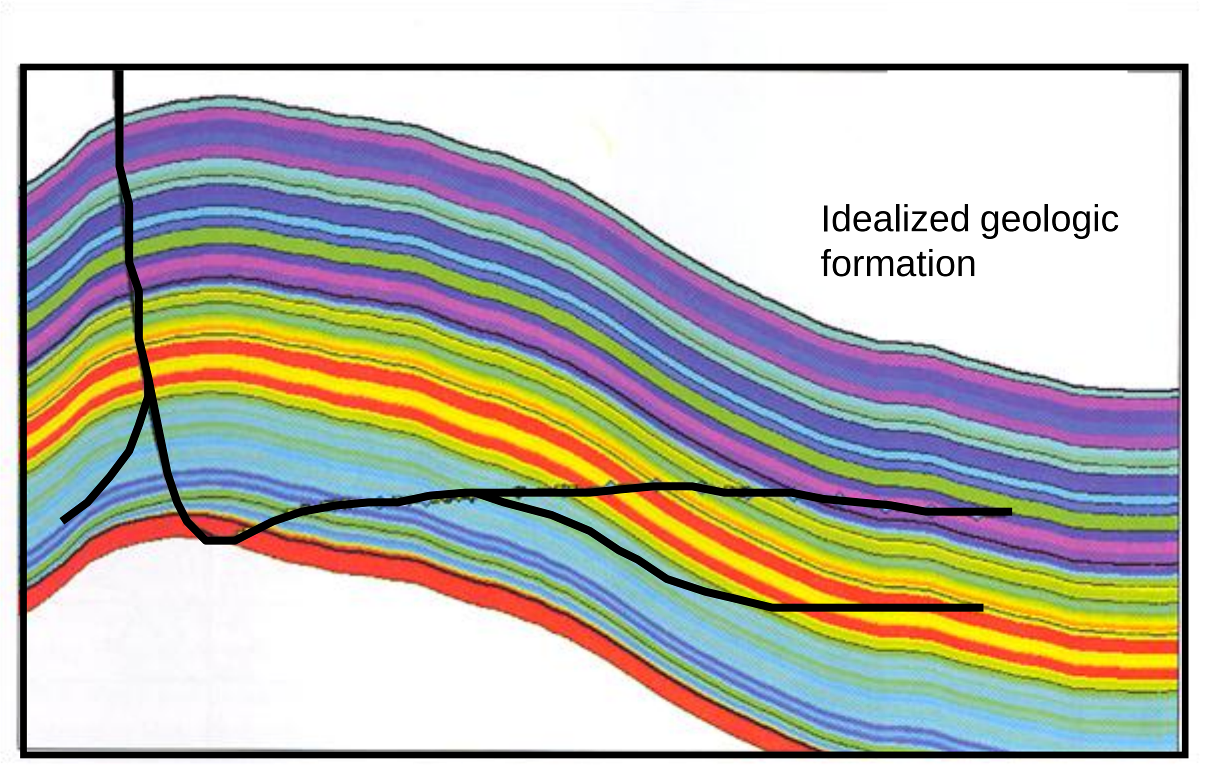
- A minimum disturbance of the land,
- A lack of bother to the surface owner and nearby residents, and
- No contamination of surface soil and freshwater aquifers

Large Land Drilling Rig

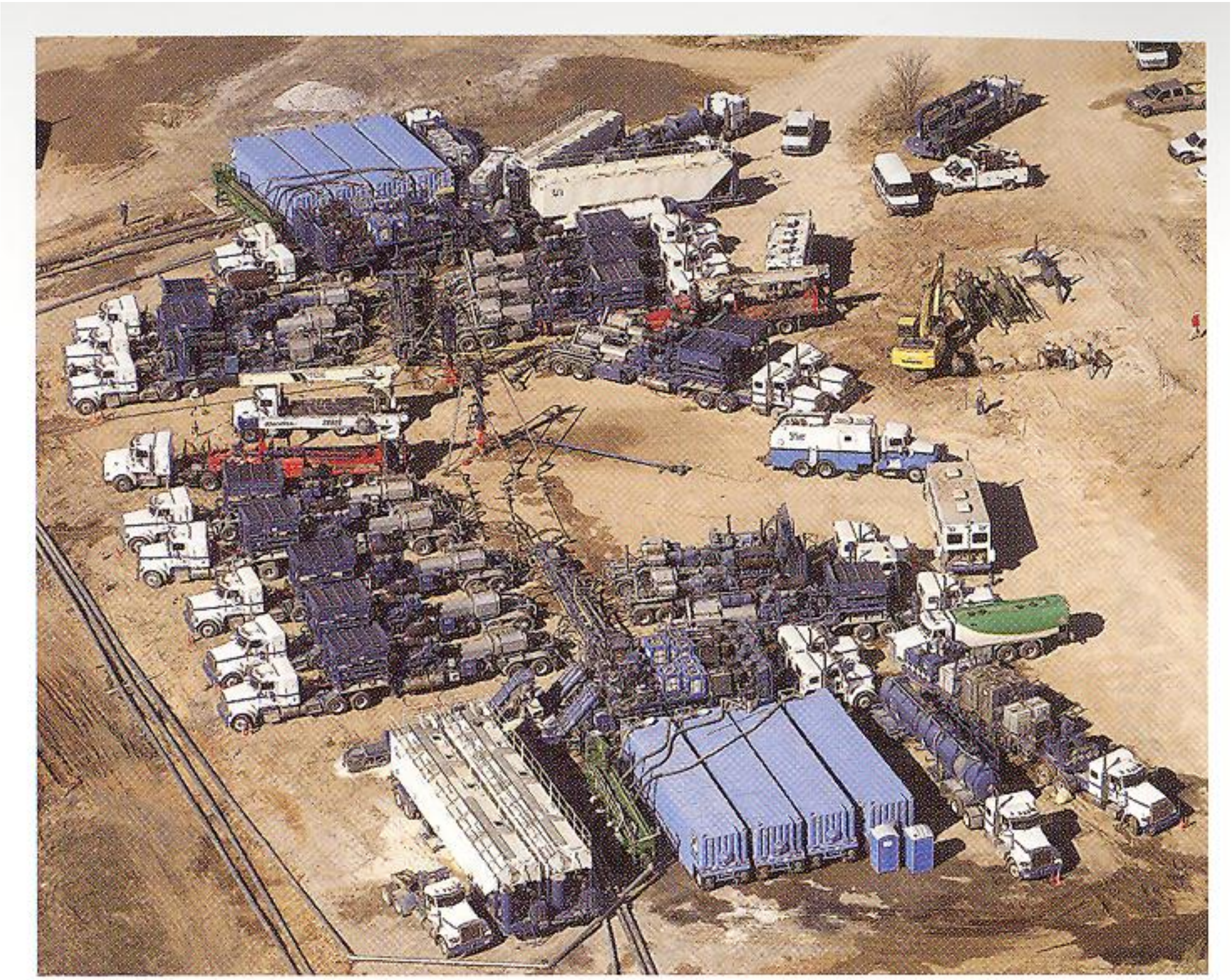
Land Based Drilling Rig

Multi-Lateral Horizontal Well

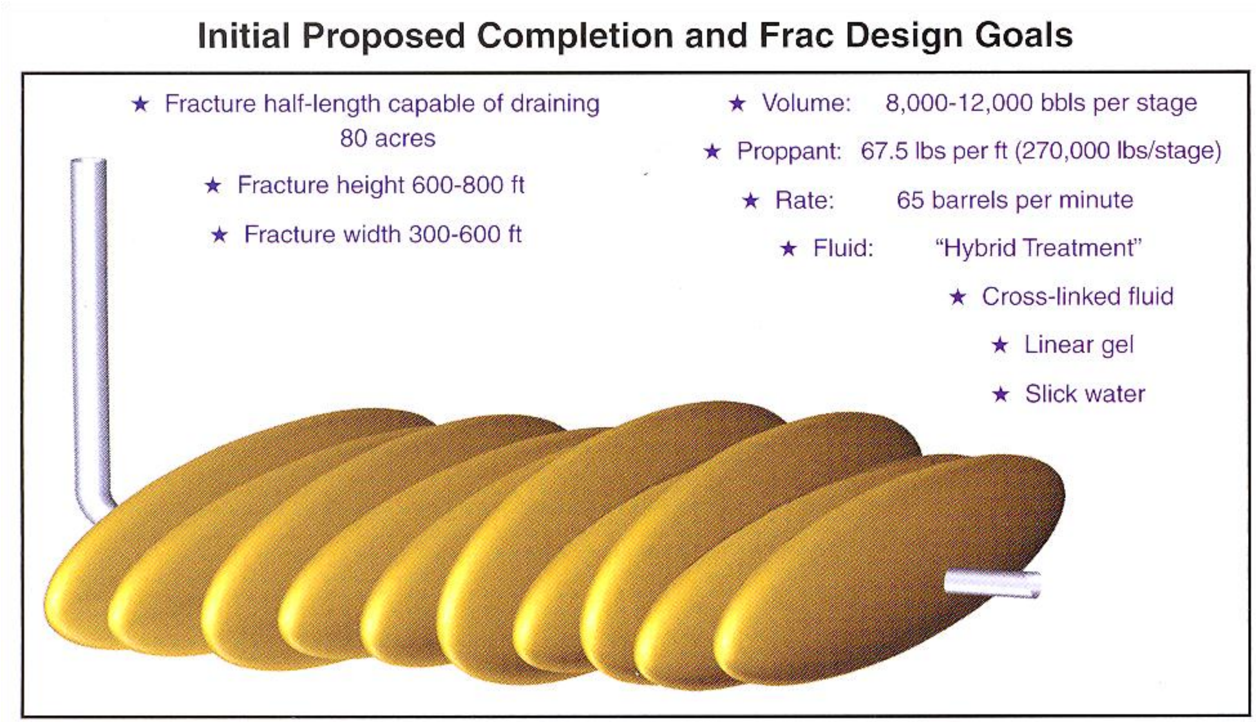
Laterals can be drilled in practically any direction to great lengths



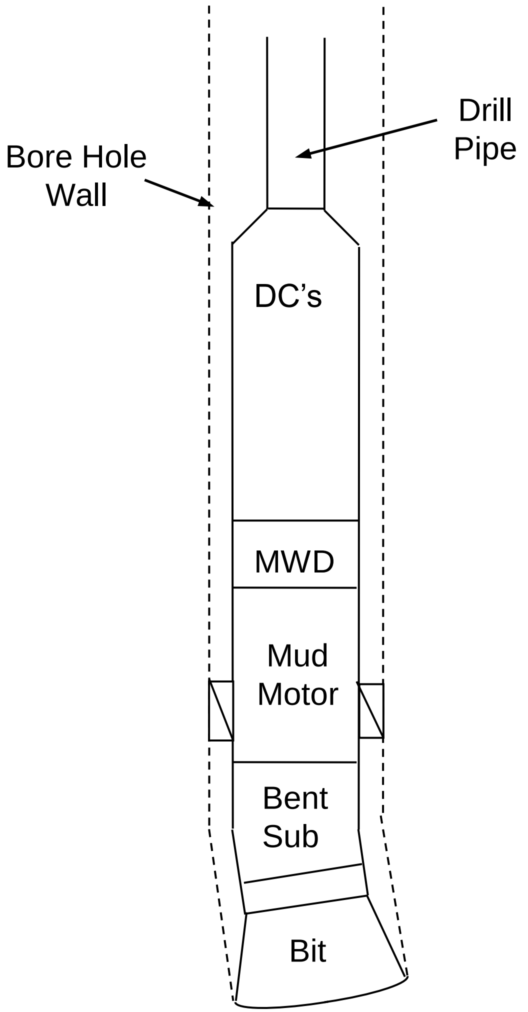
Fracing Equipment



Idealized Completion of a Horizontal Well

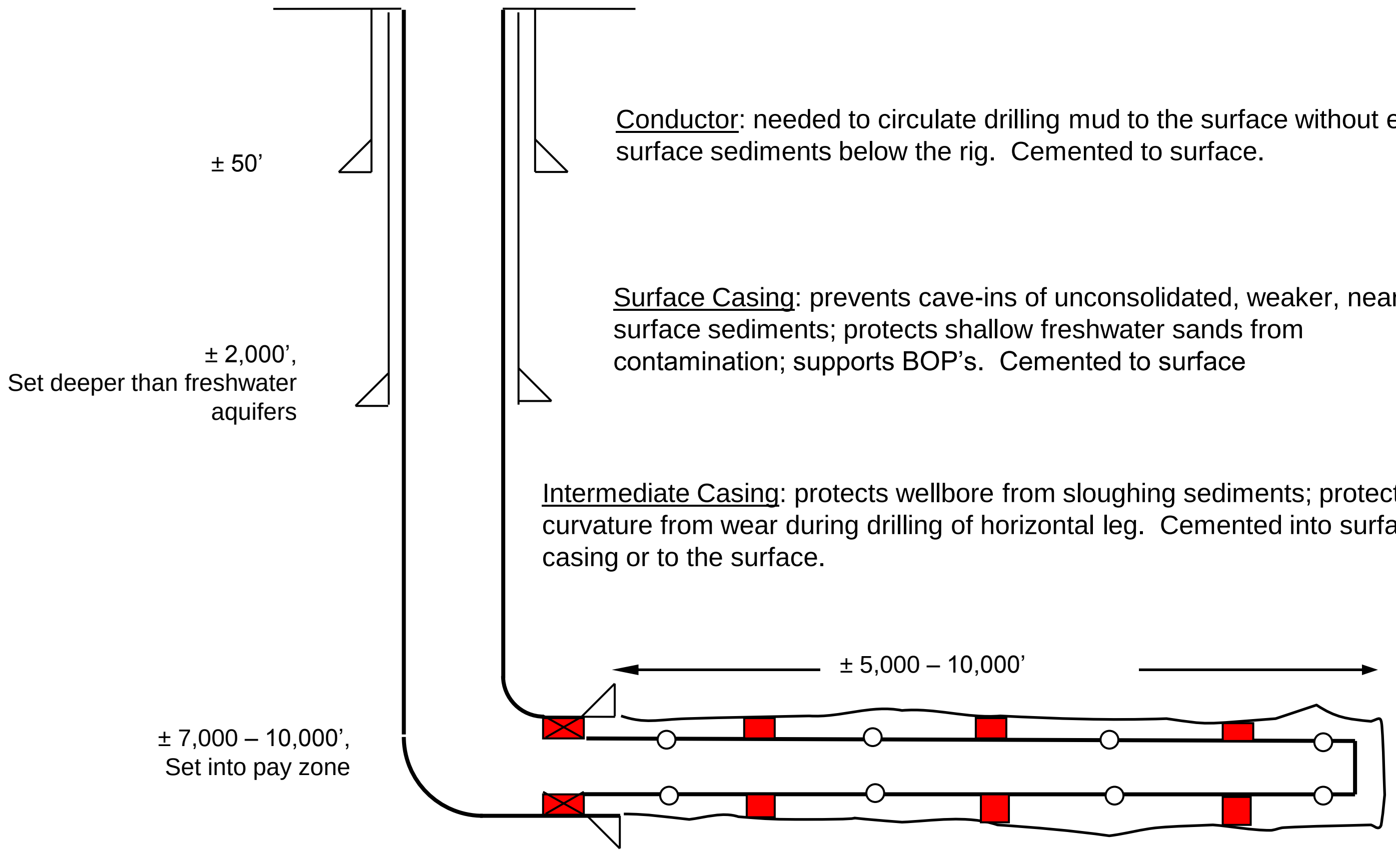


Bottomhole Assembly for Drilling Directional Hole



1. For drilling straight ahead; rotate bit with motor and drill pipe simultaneously.
2. For drilling directionally; orient bit along desired azimuth and rotate with motor only.

Casing & Cement



Conductor: needed to circulate drilling mud to the surface without eroding surface sediments below the rig. Cemented to surface.

Surface Casing: prevents cave-ins of unconsolidated, weaker, near-surface sediments; protects shallow freshwater sands from contamination; supports BOP’s. Cemented to surface

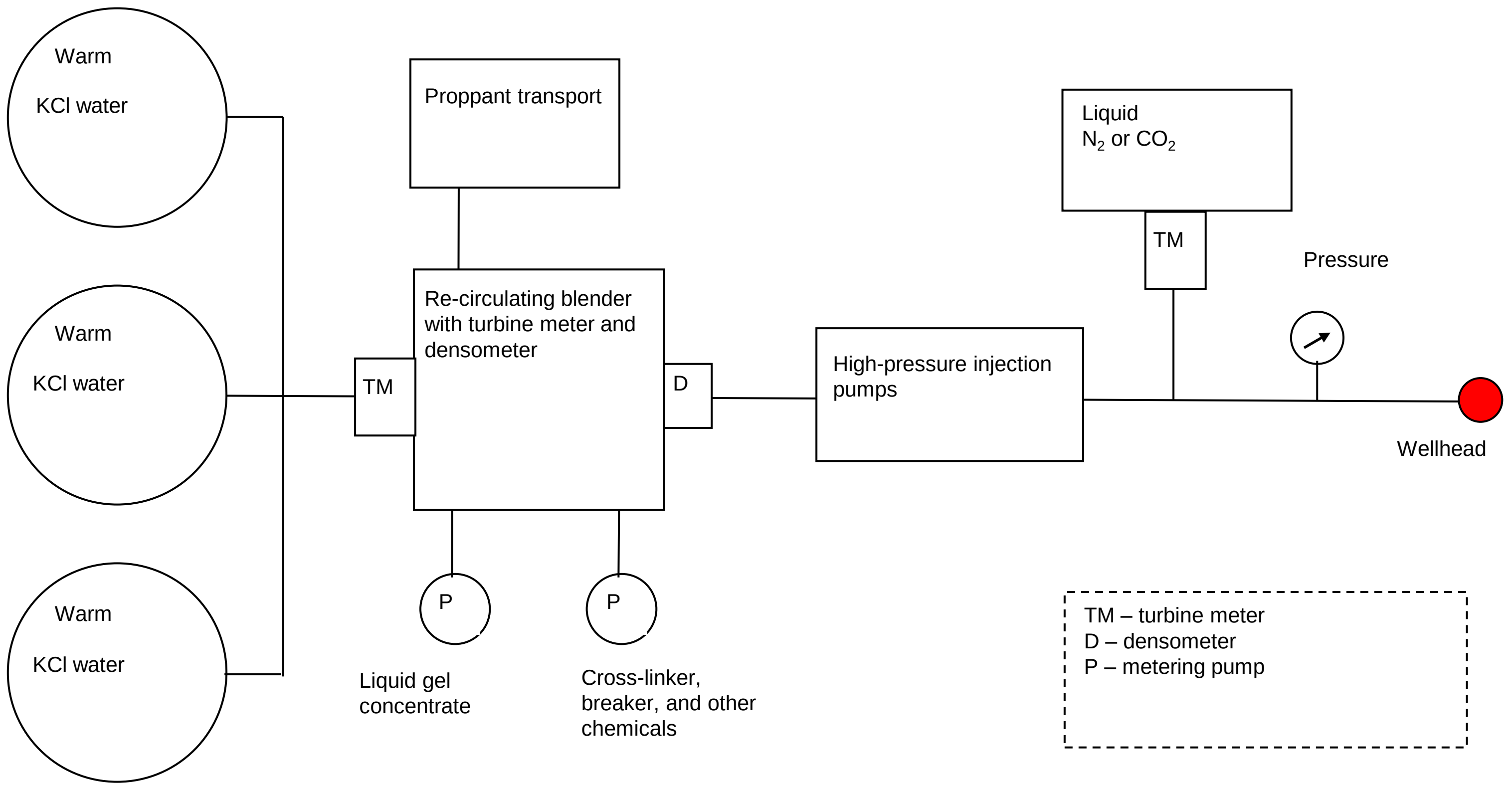
Intermediate Casing: protects wellbore from sloughing sediments; protects curvature from wear during drilling of horizontal leg. Cemented into surface casing or to the surface.

Liner with external casing packers: protects wellbore from sloughing sediments; perforated for hydraulic fracturing and production. Annulus isolated from open hole with packers and liner hanger. No cement.

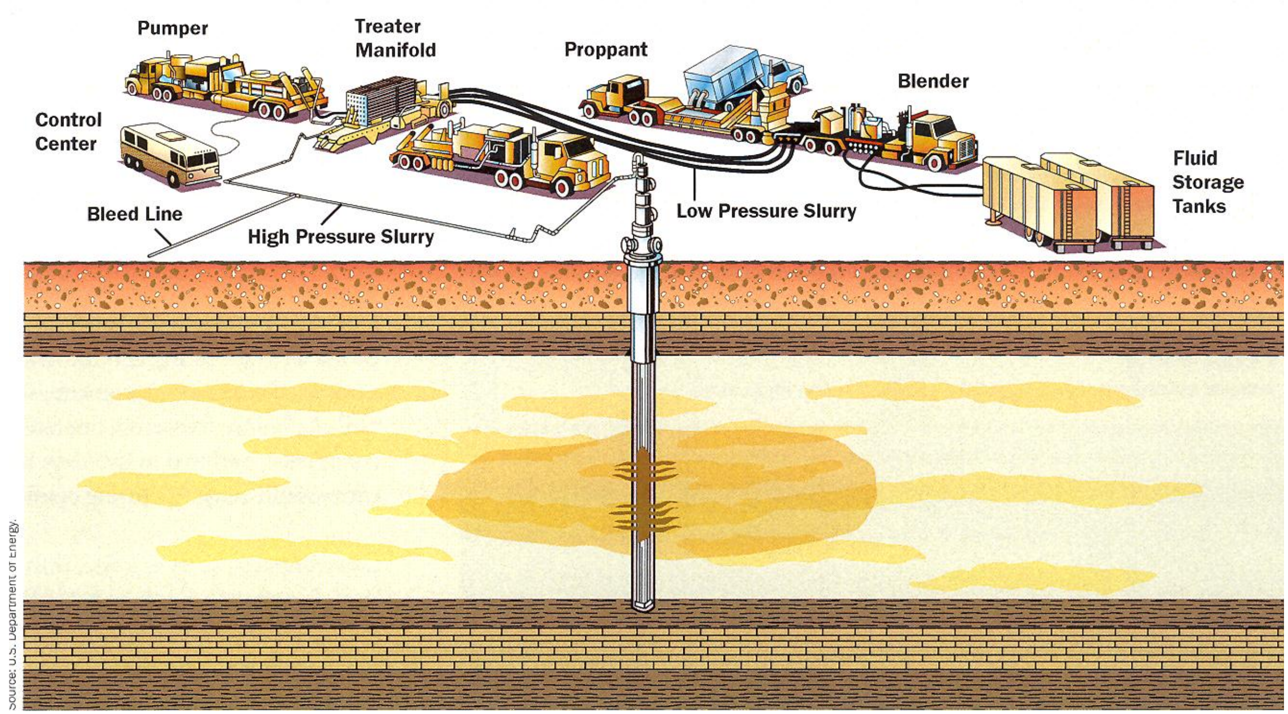
What is Hydraulic Fracturing?

- One method of stimulating oil & gas well productivity.
- A manufactured fracture placed in the pay zone using hydraulic energy.
- Hydraulic energy is transferred to the formation through a water-based fracturing fluid, causing a crack to appear and propagate.
- Proppant (small sand or ceramic beads) is carried by frac fluid (most common is viscosified water) into the open crack as the fracture is lengthened horizontally and vertically.
- The beads provide a permeable bed in the fracture that 1) withstands compressive earth stress acting to close the fracture and 2) transmits the produced fluids to the wellbore.

Equipment Schematic



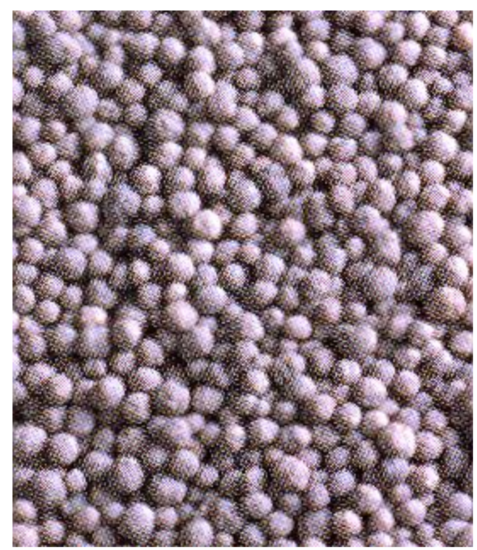
Fracing Equipment



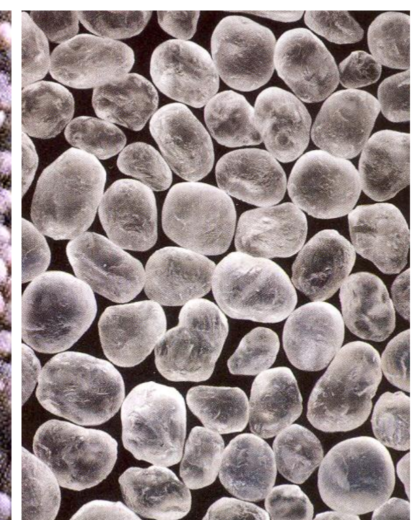
Proppant

Healed propped fracture.

Resin coated sand

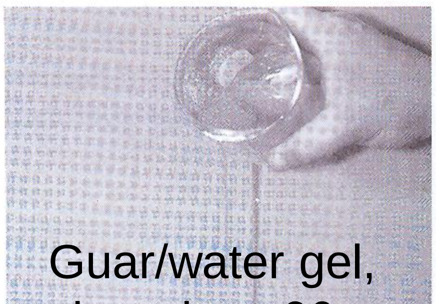


Ceramic prop

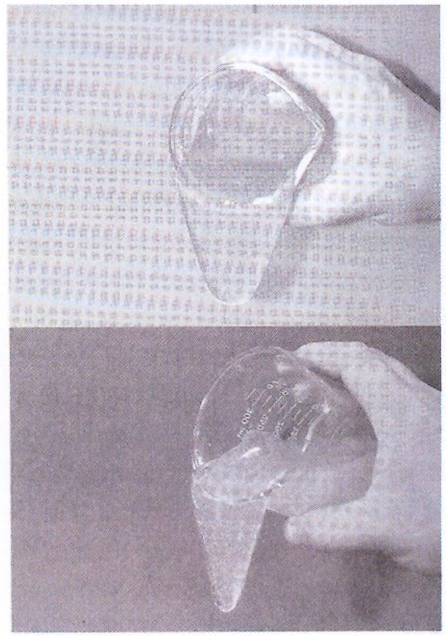


Natural frac sand

Fracturing Fluid



Guar/water gel, viscosity ≈ 30 cp



Cross-linked guar/water gel, viscosity ≈ 300 cp

Purpose of a fracturing fluid

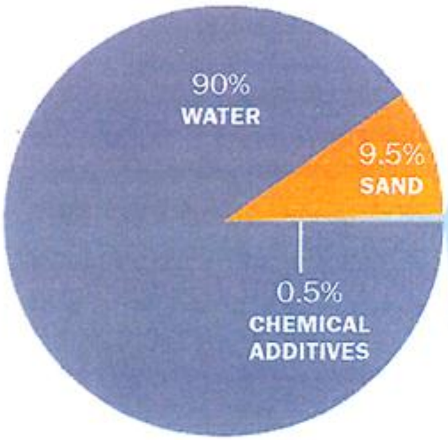
- Hydraulically "wedge-open" a crack to initiate and extend the fracture.
- Transport and distribute the proppant along the fracture.

Desirable Properties

- Stable viscosity and gel strength under reservoir temperature.
- Low fluid loss.
- Low friction.
- Compatible with formation rock and fluids; i.e. not damaging.
- Low cost.

Fracturing Fluid Ingredients

Typical Shale Fracturing Mixture Makeup

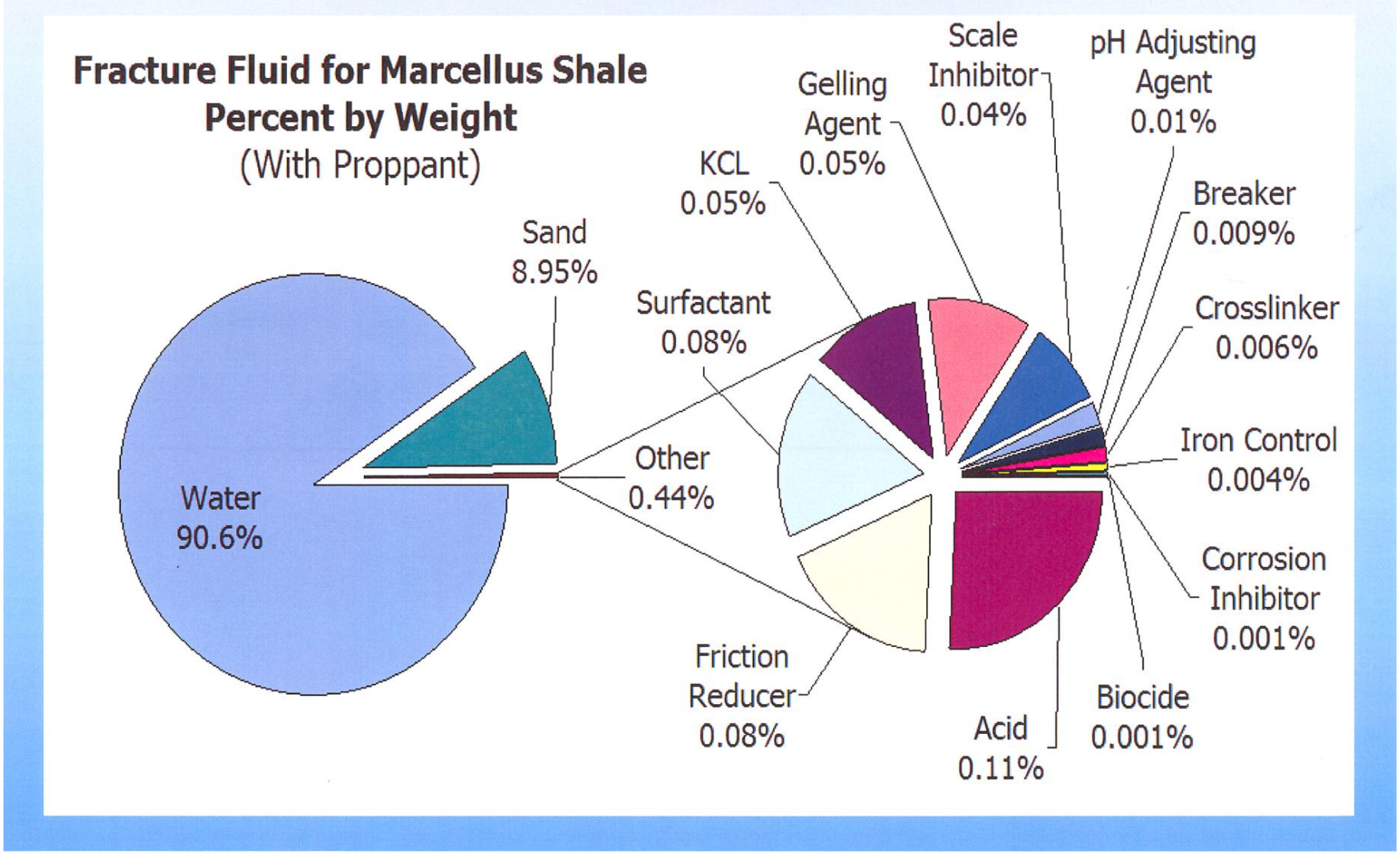


Typical Chemical Additives Used in Frac Water

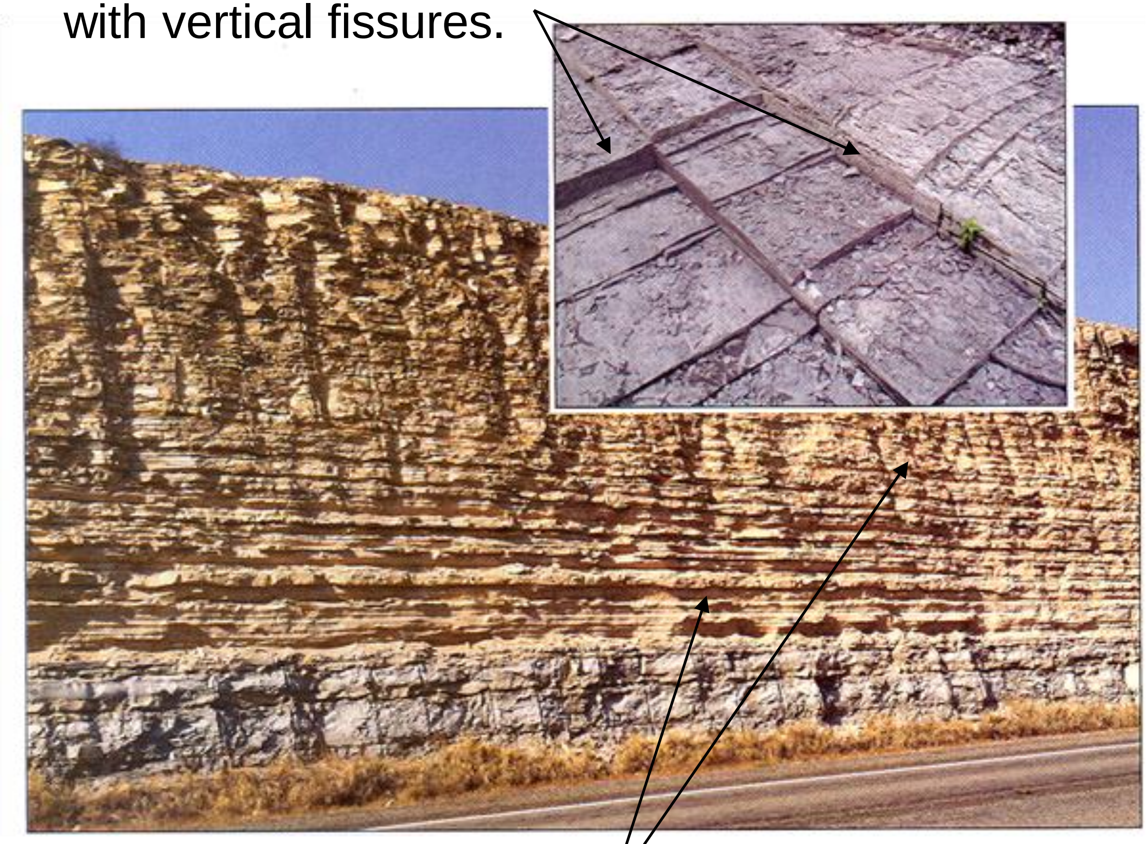
Compound	Purpose	Common application
Acids	Helps dissolve minerals and initiate fissure in rock (pre-fracture)	Swimming pool cleaner
Sodium Chloride	Allows a delayed breakdown of the gel polymer chains	Table salt
Polyacrylamide	Minimizes the friction between fluid and pipe	Water treatment, soil conditioner
Ethylene Glycol	Prevents scale deposits in the pipe	Automotive anti-freeze, deicing agent, household cleaners
Borate Salts	Maintains fluid viscosity as temperature increases	Laundry detergent, hand soap, cosmetics
Sodium/Potassium Carbonate	Maintains effectiveness of other components, such as crosslinkers	Washing soda, detergent, soap, water softener, glass, ceramics
Glutaraldehyde	Eliminates bacteria in the water	Disinfectant, sterilization of medical and dental equipment
Guar Gum	Thickens the water to suspend the sand	Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces
Citric Acid	Prevents precipitation of metal oxides	Food additive; food and beverages; lemon juice
Isopropanol	Used to increase the viscosity of the fracture fluid	Glass cleaner, antiperspirant, hair coloring

Source: DOE, GWPC: Modern Gas Shale Development in the United States: A Primer (2009).

Fracturing Fluid Ingredients



Examples of Reservoir Rocks Being Fractured

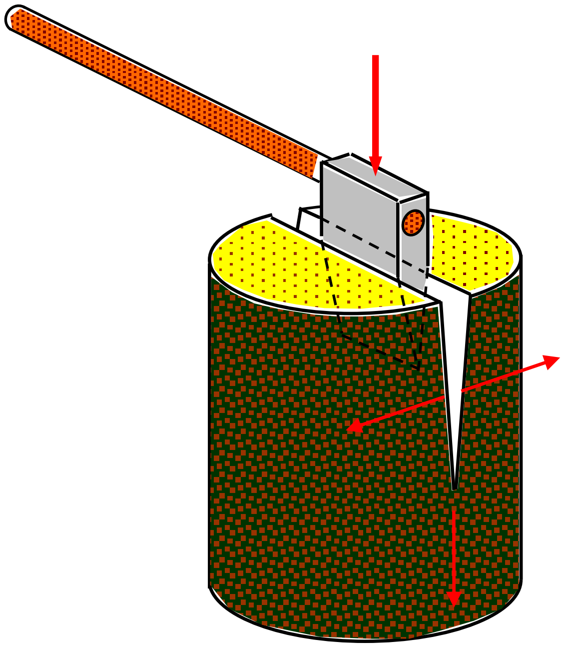


Producible formations with matrix blocks that have ultra-low permeability are surrounded by nearly impermeable fissures.

Hydraulic fracturing props open a few of a natural fissures, creating passageways for reservoir fluids to flow into the wellbore.

Visualization of the Hydraulic Rock Cracking Process

Similarity with Spitting a Log

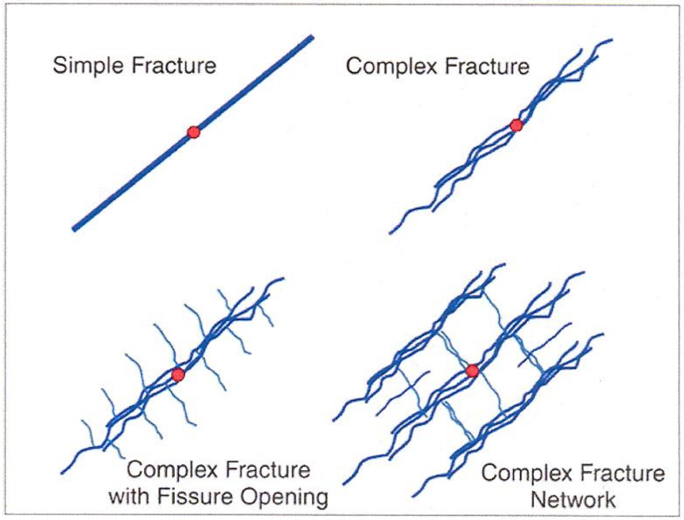


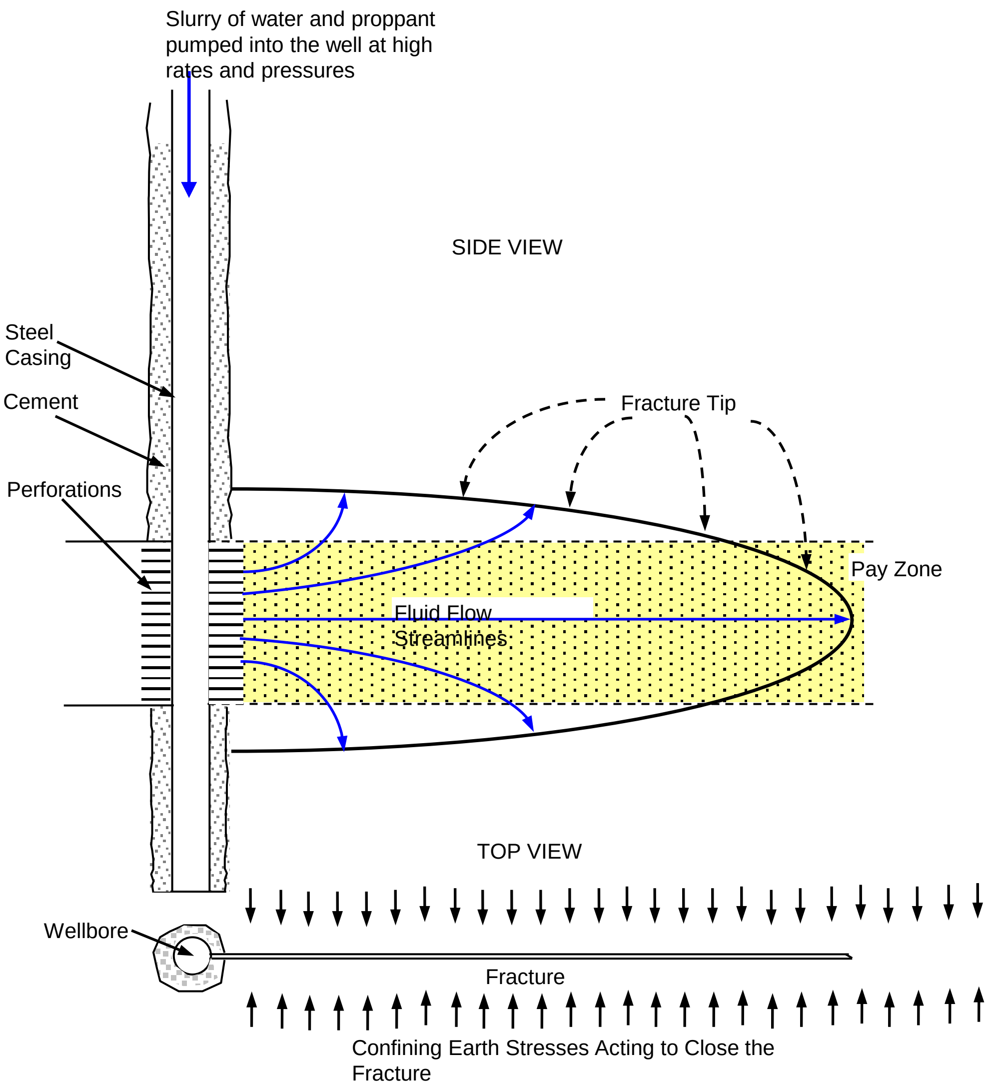
The sharp edge of the axe initiates the split. The energy from the axe head lengthens the split and creates width.

When the axe head is moving forward, the log is being split. However, compressive forces from the log create friction that halts the penetration of the axe head.

Long logs are very difficult to split unless an extreme amount of force is applied.

Visualization of Hydraulic Fractures



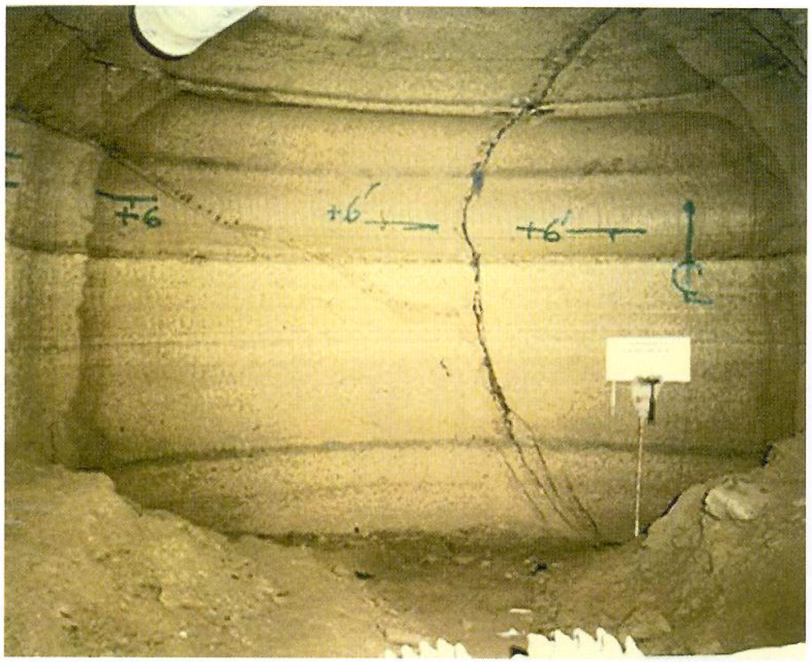


The fracture propagates outwards, upwards, and downwards as it is being created by the pressure of the incompressible fluid.

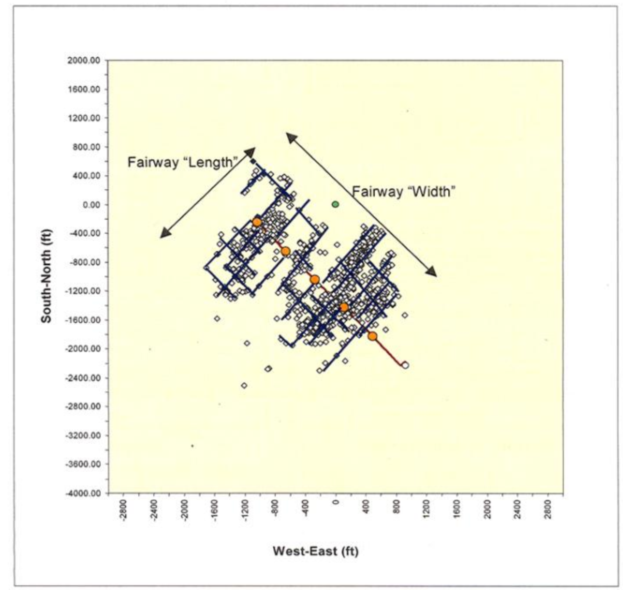
Fluid loss, due to leak-off into permeable rock, minimizes fracture growth. Also, pressure at the tip decreases due to friction losses as the fracture grows.

Eventually, the volume of frac fluid reaching the tip and the pressures at the leading edge are too low to create further fracture penetration.

Types of Hydraulic Fractures



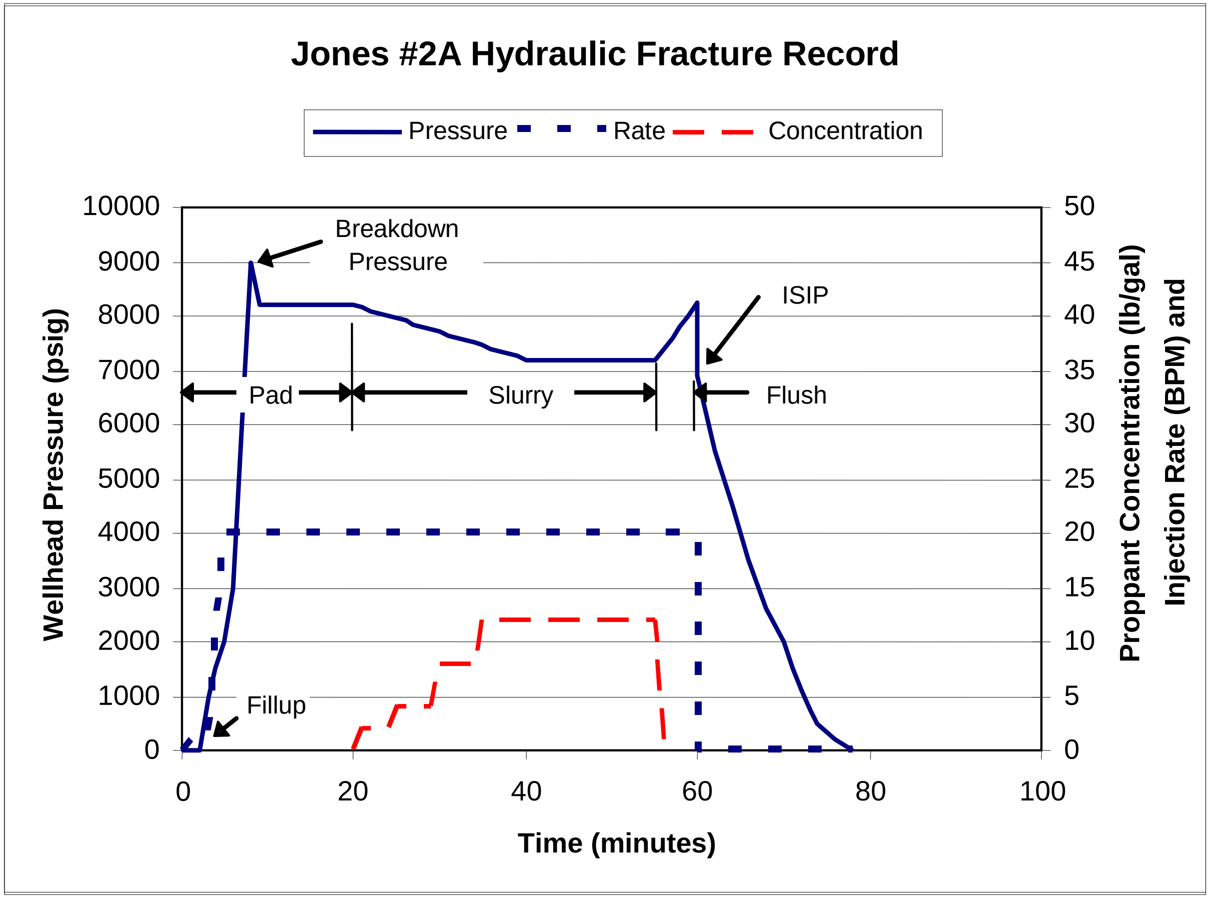
Mineback photo showing a simple vertical fracture with multiple fracture strands.



Interpreted microseism data showing the created fracture pathways in the fractured rock.

Fracture treatments in naturally fractured formations open existing fissures and the result is a stimulated reservoir volume that contains a complex 3-D network of sporadically propped fractures.

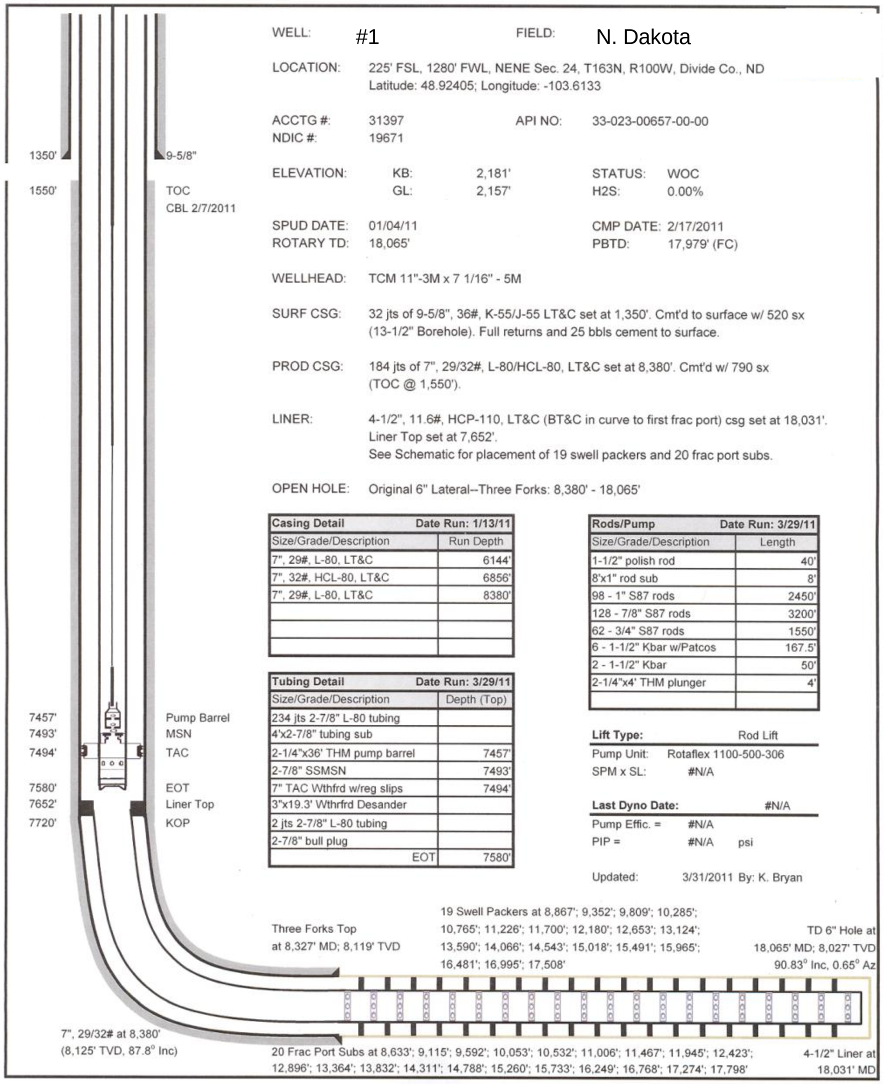
Fracing Record



Can a Vertical Fracture Intersect a Shallow Fresh Water Aquifer?

- No.
- Evidence
  - ✓ Well construction
  - ✓ Microseismic measurements
  - ✓ Tiltmeter data
  - ✓ RA tracer surveys
  - ✓ Volumetric calculations
  - ✓ Pressure recordings during treatment

Wellbore Diagram



WELL: #1 FIELD: N. Dakota

LOCATION: 225' FSL, 1280' FWL, NENE Sec. 24, T163N, R100W, Divide Co., ND
Latitude: 48.92405; Longitude: -103.6133

ACCTG #: 31397 API NO: 33-023-00657-00-00
NDIC #: 19671

ELEVATION: KB: 2,181' STATUS: WOC
GL: 2,157' H2S: 0.00%

SPUD DATE: 01/04/11 CMP DATE: 2/17/2011
ROTARY TD: 18,065' PBTD: 17,979' (FC)

WELLHEAD: TCM 11"-3M x 7 1/16" - 5M

SURF CSG: 32 jts of 9-5/8", 36#, K-55/J-55 LT&C set at 1,350'. Cmt'd to surface w/ 520 sx (13-1/2" Borehole). Full returns and 25 bbls cement to surface.

PROD CSG: 184 jts of 7", 29/32#, L-80/HCL-80, LT&C set at 8,380'. Cmt'd w/ 790 sx (TOC @ 1,550').

LINER: 4-1/2", 11.6#, HCP-110, LT&C (BT&C in curve to first frac port) csg set at 18,031'.
Liner Top set at 7,652'.
See Schematic for placement of 19 swell packers and 20 frac port subs.

OPEN HOLE: Original 6" Lateral--Three Forks: 8,380' - 18,065'

Casing Detail	Date Run: 1/13/11
Size/Grade/Description	Run Depth
7", 29#, L-80, LT&C	6144'
7", 32#, HCL-80, LT&C	6856'
7", 29#, L-80, LT&C	8380'

Rods/Pump	Date Run: 3/29/11
Size/Grade/Description	Length
1-1/2" polish rod	40'
8'x1" rod sub	8'
98 - 1" S87 rods	2450'
128 - 7/8" S87 rods	3200'
62 - 3/4" S87 rods	1550'
6 - 1-1/2" Kbar w/Patcos	167.5'
2 - 1-1/2" Kbar	50'
2-1/4"x4' THM plunger	4'

Tubing Detail	Date Run: 3/29/11
Size/Grade/Description	Depth (Top)
234 jts 2-7/8" L-80 tubing	
4'x2-7/8" tubing sub	
2-1/4"x36' THM pump barrel	7457'
2-7/8" SSMSN	7493'
7" TAC Wthfrd w/reg slips	7494'
3"x19.3' Wthrfrd Desander	
2 jts 2-7/8" L-80 tubing	
2-7/8" bull plug	
EOT	7580'

Lift Type: Rod Lift
Pump Unit: Rotaflex 1100-500-306
SPM x SL: #N/A

Last Dyno Date: #N/A
Pump Effic. = #N/A
PIP = #N/A psi

Updated: 3/31/2011 By: K. Bryan

Stimulation:

20 individual frac treatments

Transverse fractures

Each approximately

70,000 gal frac fluid

67,000 lbs proppant

74,000 gal slurry

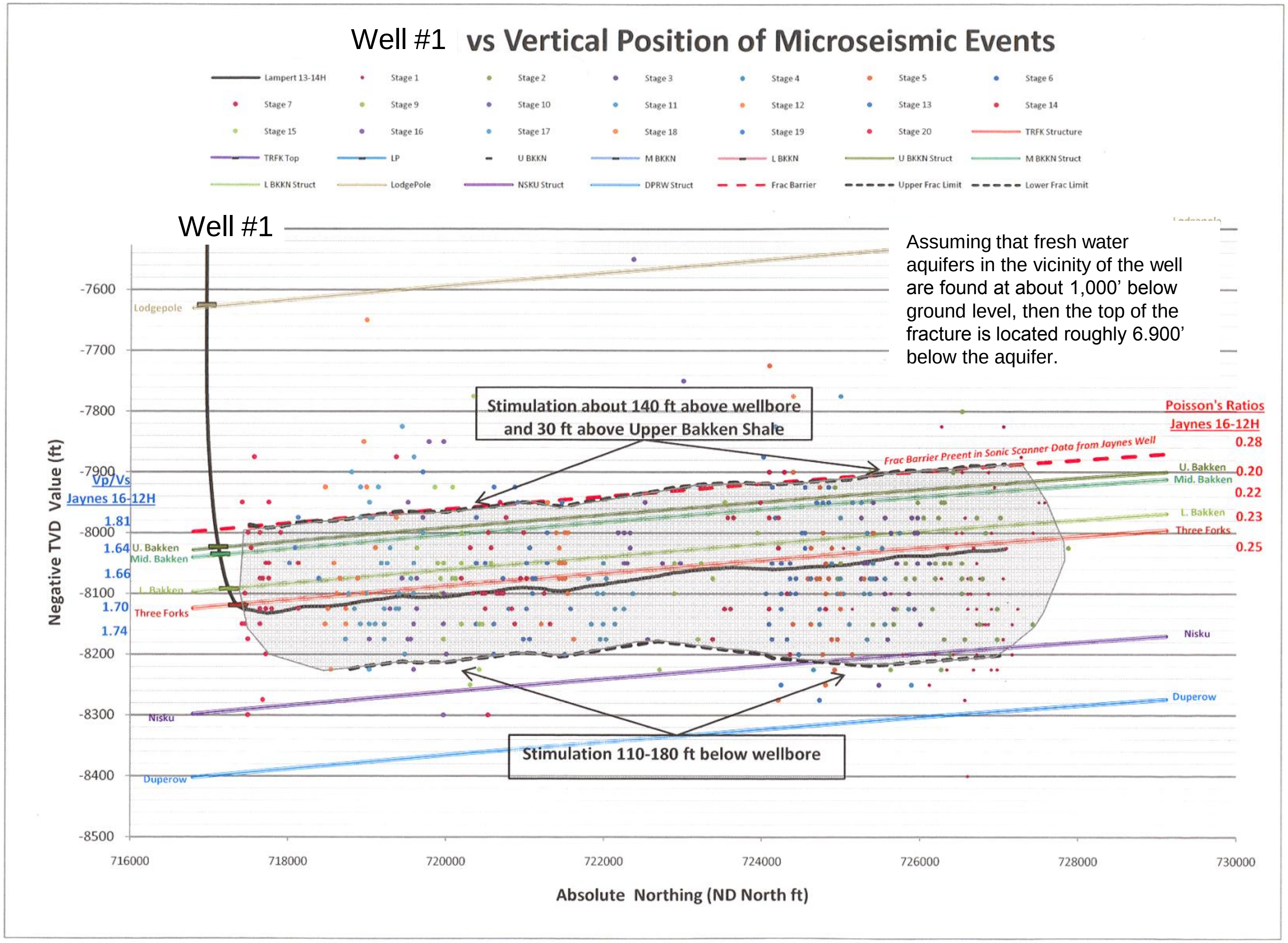
30 BPM @ 5,300 psi

Totals

1,400,000 gal frac fluid

1,340,000 lbs proppant

Frac Height from Microseismic Data



Microseismic Sections

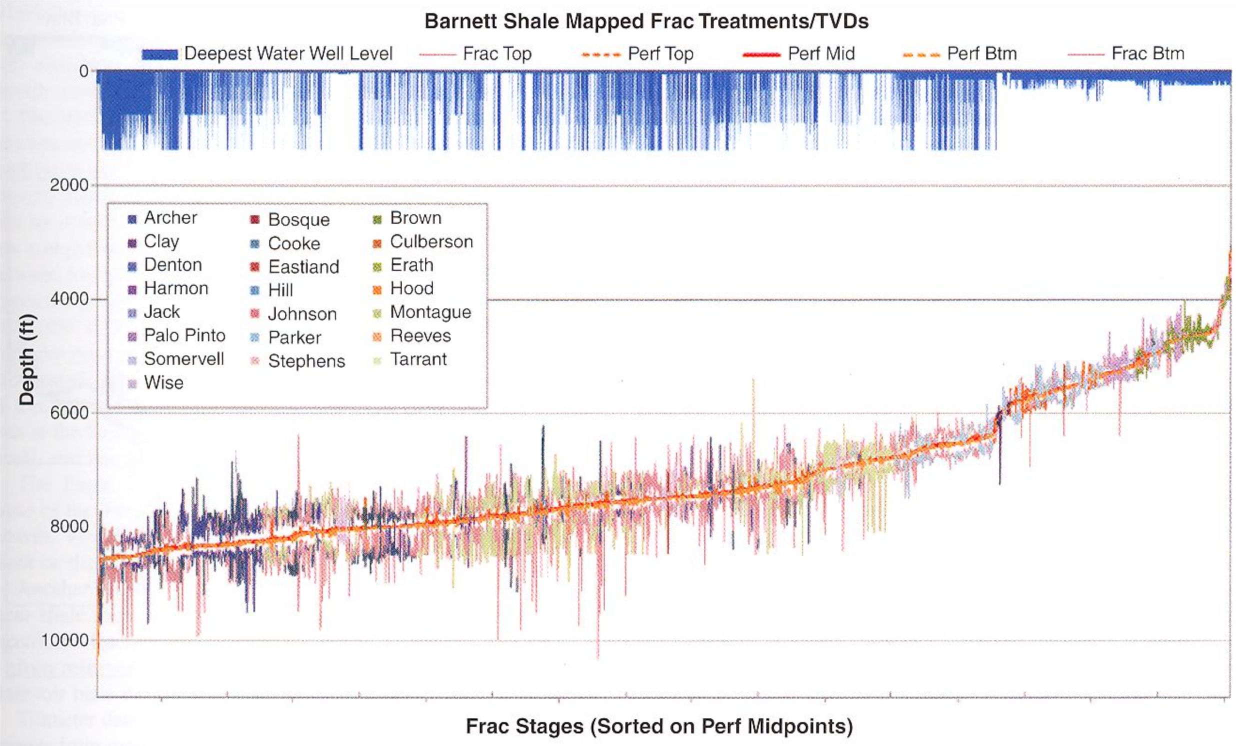
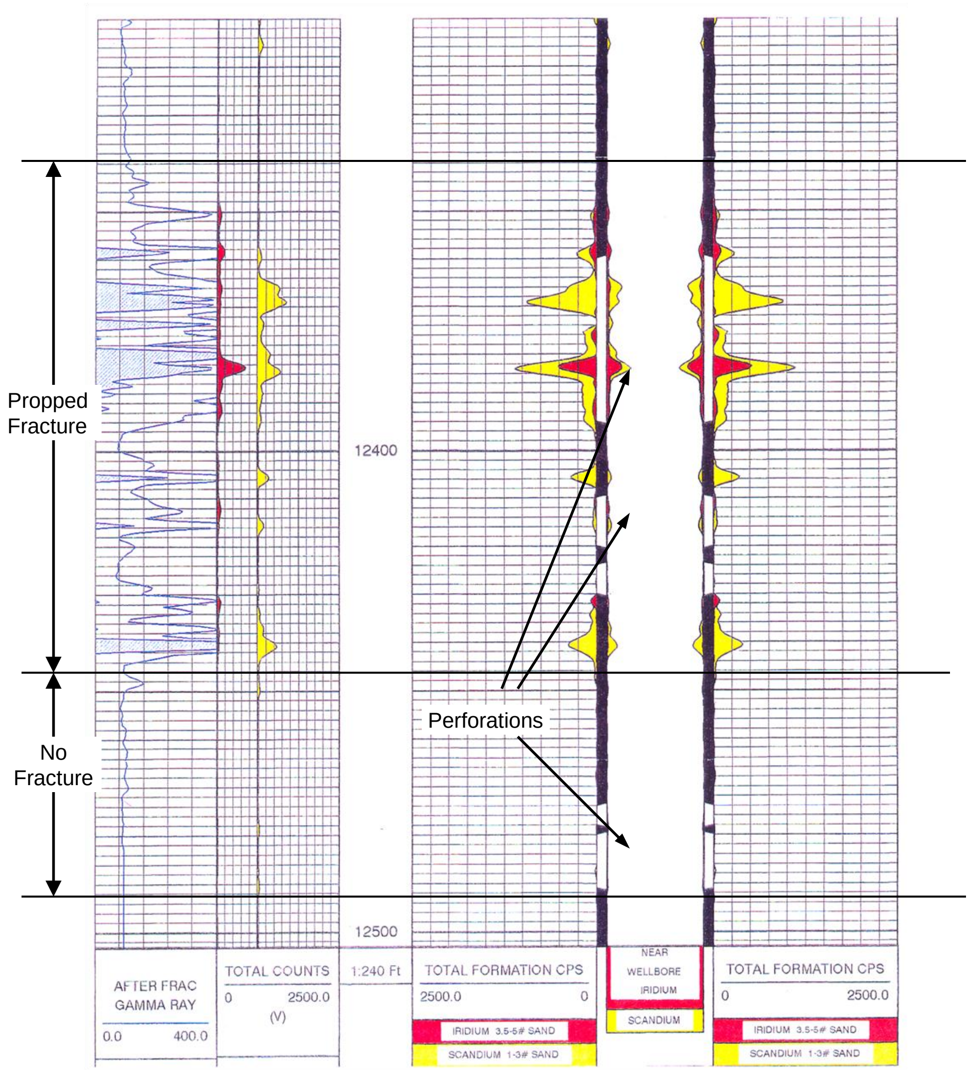


Fig. 2—Barnett shale measured fracture heights sorted by depth and compared to aquifers.

Frac Height from Post Treatment Measurements

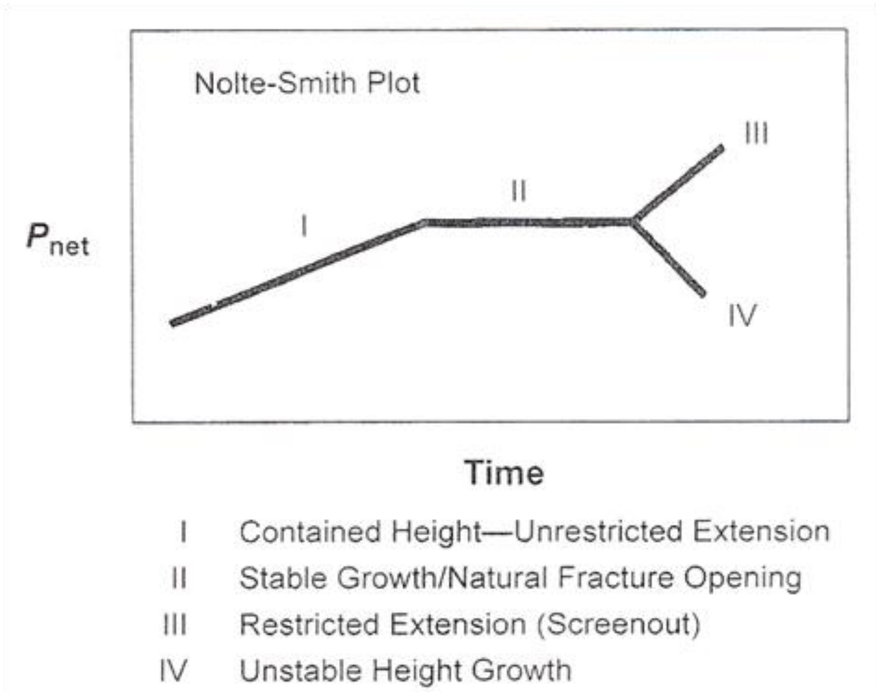


Proppants, coated with short half-life radioactive material, placed in hydraulic fractures can be located with gamma ray measurements. GR logs identify the position of the proppant behind the casing.

These logs show where the fracture exited the wellbore and the near-wellbore height of the propped fracture.

Similar logs can be made by measuring wellbore temperature after the fracturing treatment is concluded.

Checks While Performing Frac Treatment



Plot is made in real time to monitor the performance of the treatment.

If unstable height growth is shown, the treatment is terminated immediately.

Treating & Recycling Produced Water

- Total volumes of water required for drilling and fracturing a horizontal well average 20,000 barrels in the Williston Basin to over 250,000 barrels in other basins.
- Water is expensive to handle. Published transportation and disposal costs range from $2 to $14 per barrel.
- Roughly 20 to 40% of frac water is recovered following the treatment.
- Once fresh water becomes oilfield waste and is disposed below the fresh water table, it is permanently removed from the fresh water cycle.
- Strong reasons to recycle oilfield water
  - ✓ Conservation
  - ✓ Economic
  - ✓ Environmental

Treating & Recycling Produced Water

Common methods of treating water

1. Thermal, create water vapor by evaporation or distillation.
2. Physical
   - Particle filtration
   - Membrane filtration
     - ✓ Ultrafiltration, removes colloidal sized particles
     - ✓ Nanofiltration, removes multivalent cations
     - ✓ Reverse osmosis, removes virtually any ion
3. Chemical
   - Liquid chemicals treatments
   - Oxidative and electrochemical processes
     - ✓ ClO_2
     - ✓ O_3
     - ✓ Electrochemical precipitation

Treating & Recycling Produced Water

Benefits of onsite water treatment

1. Minimizes truck traffic and emissions.
2. Reduces dependency on fresh water for frac treatments.

Hydrozonix LLC is expanding its fleet of EF80™ treatment units to service fracturing operations in the Permian Basin and the Marcellus Shale, with the company planning to build two units each quarter over the next two years, depending on market demand. Each EF80 unit can treat 80 bbl/minute during fracturing and post-frac flow back. The systems use the patented Ozonix™ oxidation process that incorporates ozone, hydrodynamic cavitation, acoustic cavitation, and electro-chemistry for microbial control and scale inhibition.

This mobile water treatment and recycling unit is shown in operation at a site in the Barnett Shale. The NOMAD™ skid is based on mechanical vapor recompression, and is constructed and operated by Fountain Quail Water Management. Each skid recovers up to 2,000 bbl/d of demineralized water from brines.