Hydraulic Fracturing Basics

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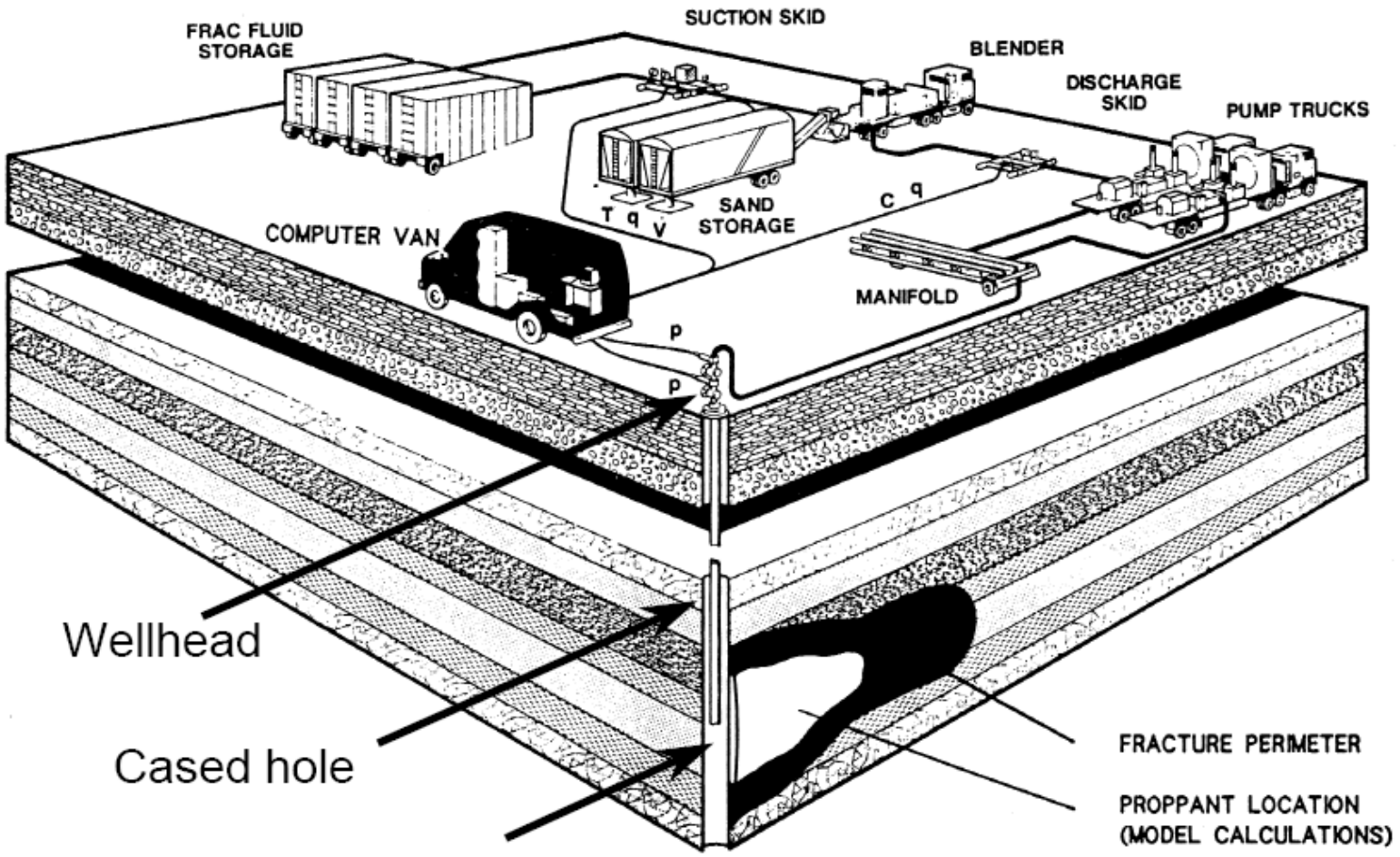
Outline

- General hydraulic fracturing
- Why we do it
- Evolution of fracturing techniques
- How it works
- Conventional vs. unconventional reservoirs
- Resources

General Hydraulic Fracture Process

- Inject a “pad” (fluid, no solids) at a sufficient pressure and injection rate to breakdown (crack) the formation;
- Inject a “slurry” (fluid w/ proppant) to propagate and develop the fracture;
- Shut down the injection at the surface and allow the fracture to close around the injected proppant;
- Flow back the well to clean up the fluids; and,
- Start producing the well.

Producing Zone

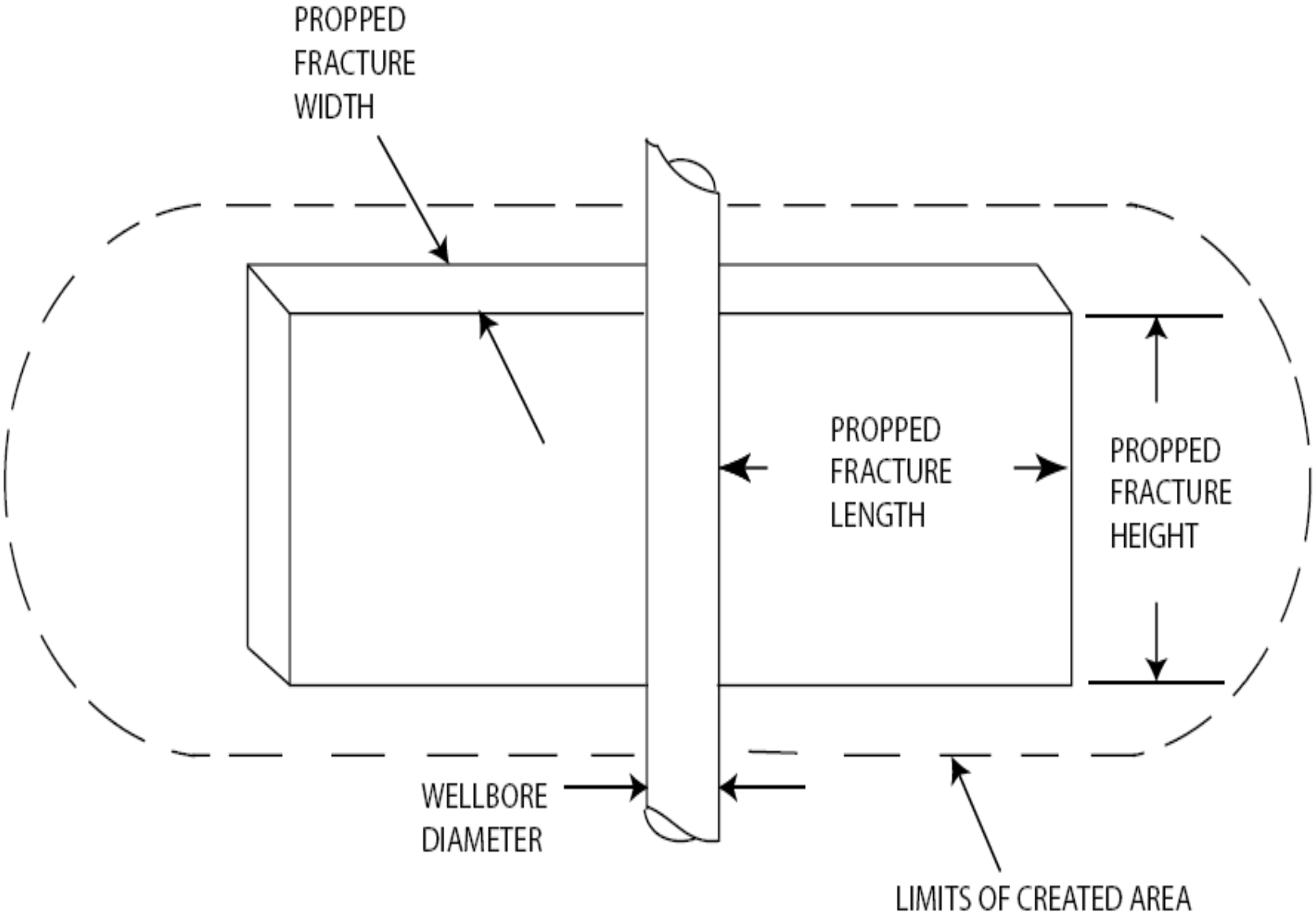

FRAC FLUID STORAGE
SUCTION SKID
BLENDER
DISCHARGE SKID
PUMP TRUCKS
SAND STORAGE
T q v
C q
COMPUTER VAN
MANIFOLD
P
P
Wellhead
Cased hole
FRACTURE PERIMETER
PROPPANT LOCATION
(MODEL CALCULATIONS)

Oilfield Stimulation History

- Acidizing and nitroglycerin were the main stimulation services provided until the late 1940's.
- In 1947, the first intentional fracture treatment took place in the Hugoton gas field of western Kansas. It was pumped in the Klepper Gas Unit No. 1 well and was called it a "hydrofrac".

Hydraulic Fracturing

- Critical completion technique in low permeability sands
- In 1989, it was estimated that 35-40% of all wells completed worldwide were fractured and in the United States and that 25-30% of reserves would not be economically producible without hydraulic fracturing
- In certain areas, +95% of wells are fractured


PROPPED
FRACTURE
WIDTH
PROPPED
FRACTURE
LENGTH
PROPPED
FRACTURE
HEIGHT
WELLBORE
DIAMETER
LIMITS OF CREATED AREA

Why we do it?

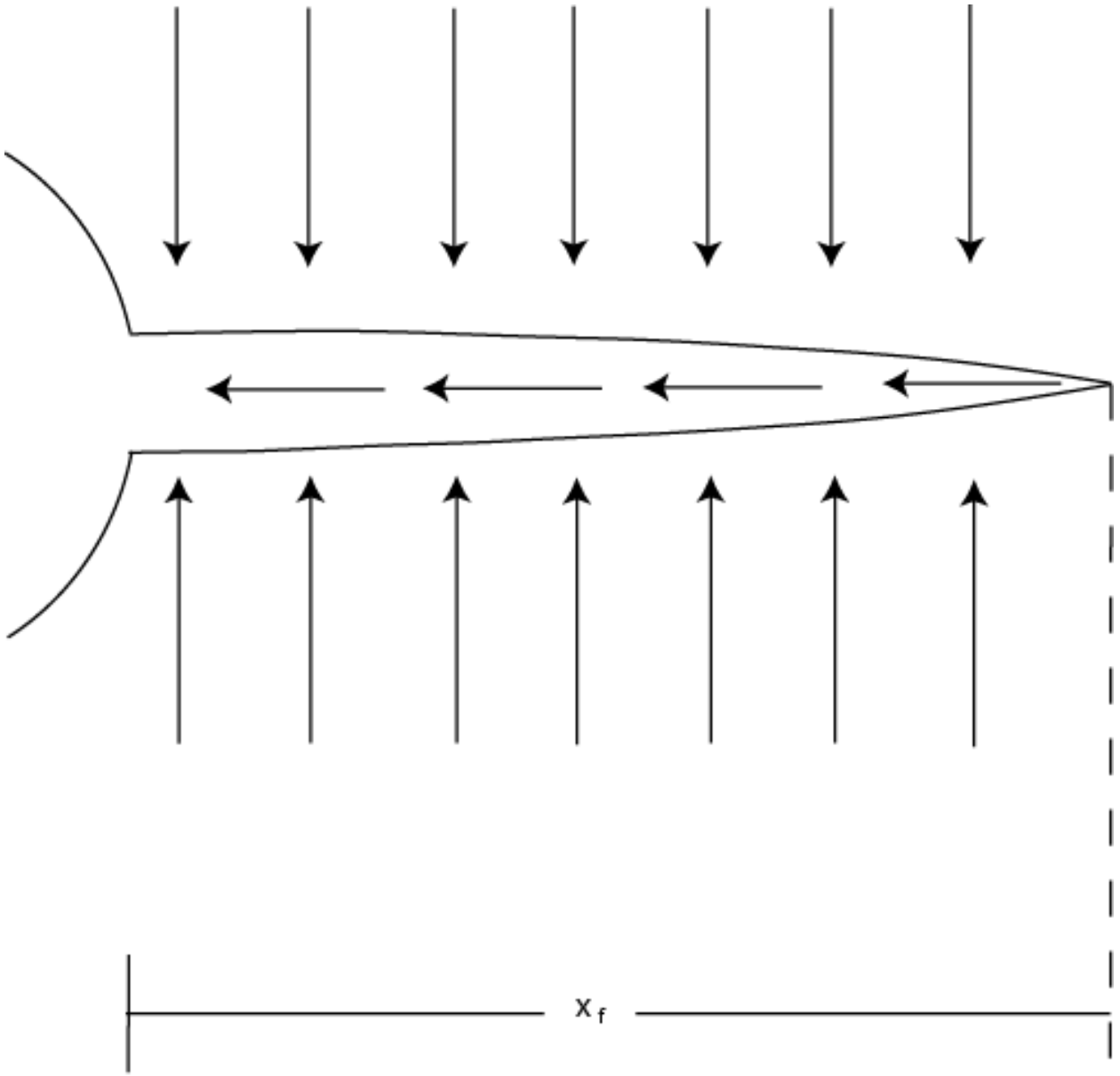
- Bypass near-wellbore damage
- Extend a conductive channel into reservoir (increases/stimulates natural productivity of well)
- Alter flow in formation
- Reservoir management

Fracturing Fluids

- Ideal properties
  1. Adequate viscosity
  2. Good fluid loss control
  3. Low residue
  4. Low friction pressure
  5. Temperature and shear stable throughout the treatment
  6. Non-damaging to formation
  7. Easy to prepare
  8. Easy to recover
  9. Cost effective

Fracturing Fluids

- Main types of fluids
  - Water-based (slickwater)
  - Oil-based
  - Acid-based
  - Multiphase (foams)


x_f

Dimensionless Fracture Conductivity

$$F_{CD} = \frac{k_f w}{k X_f}$$

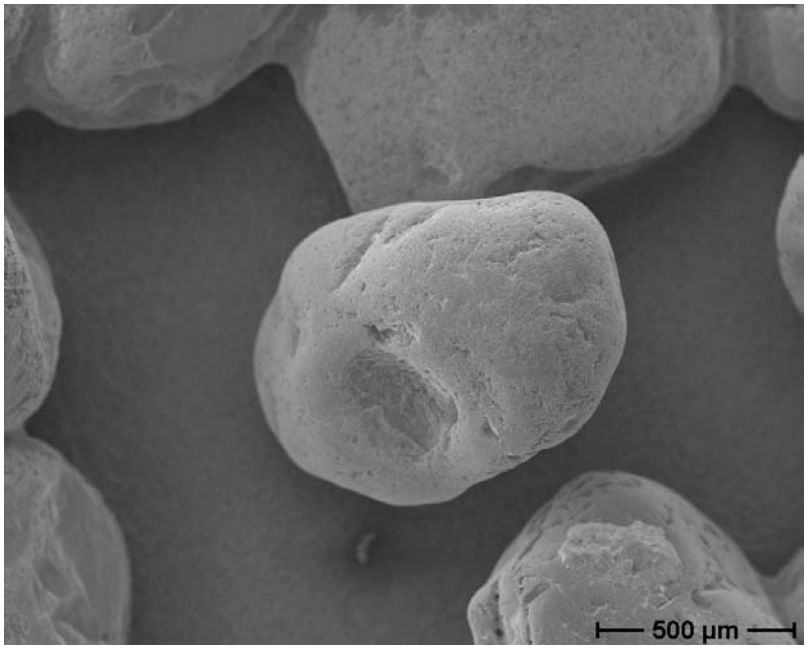
- k_f = fracture permeability, mD
- w = width of fracture, ft
- k = permeability of formation, mD
- X_f = fracture half-length, ft

Generic Proppant Types

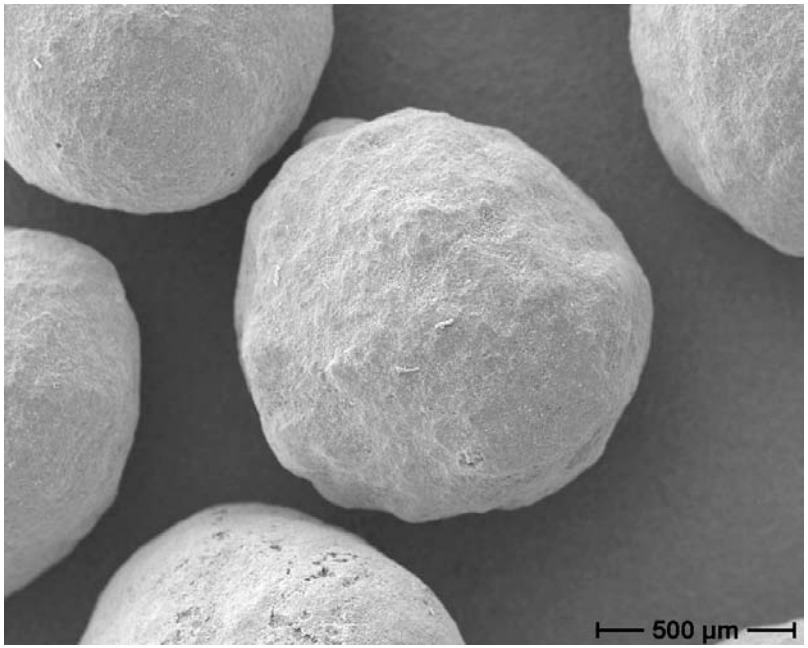
- Sand
- Artificial or ceramics

Proppant Comparisons - Shape

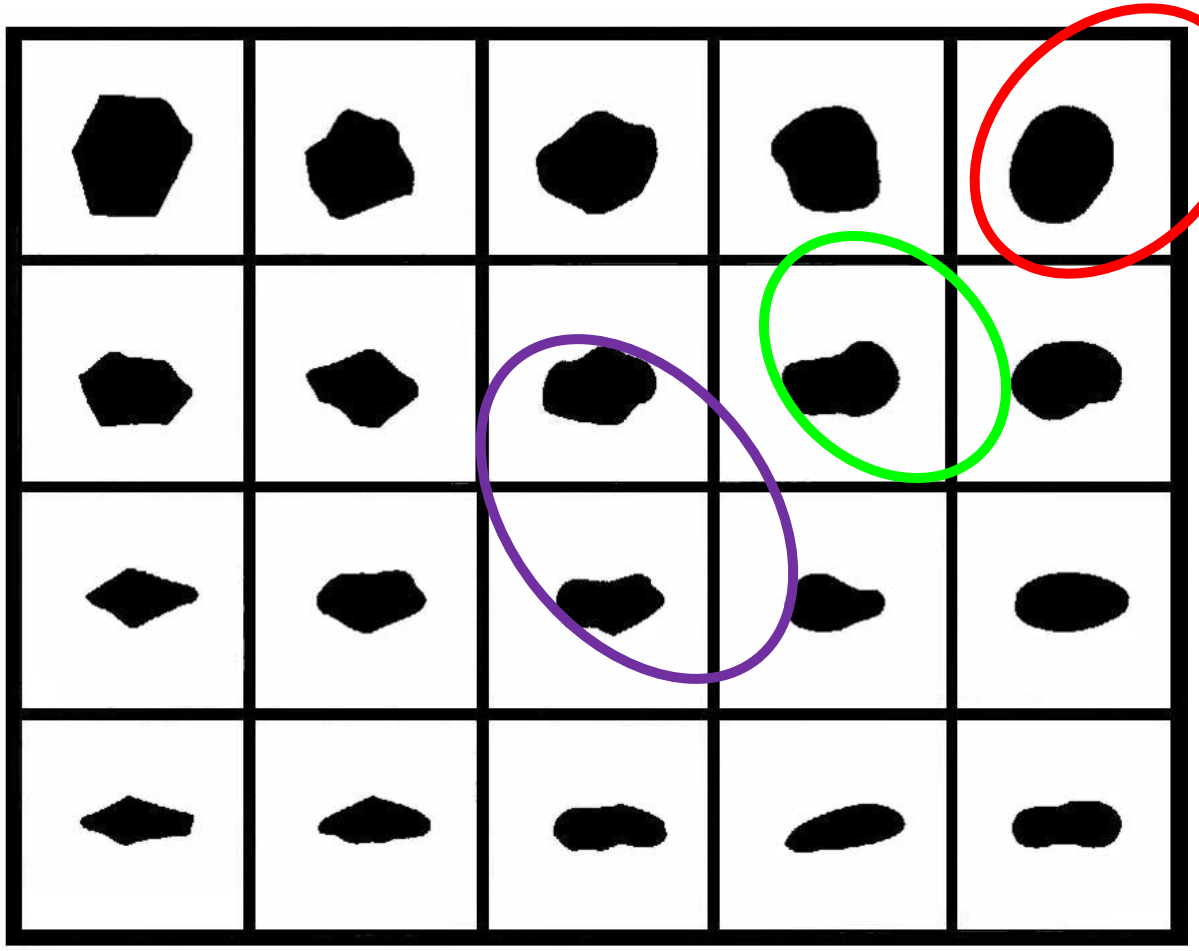
- **White Sand**



- **Artificially Manufactured**

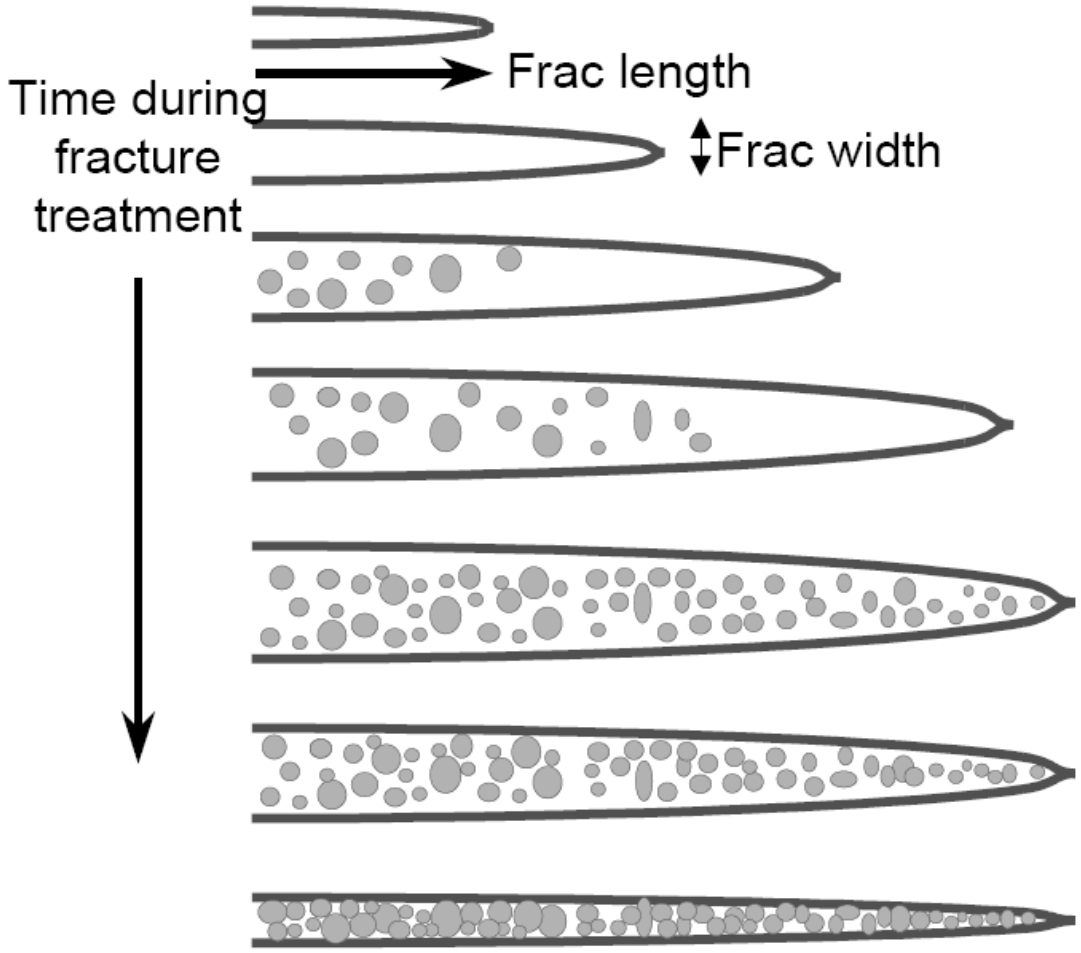


Proppant Comparisons - Shape



API RP60, From *Stratigraphy and Sedimentaion,* Krumbein and Sloss

Simplified cross-sectional view of the fracture



1 - Fracture initiation as pumping of fluid is started

2 - Fracture propagation with fluid

3 – Proppant (usually sand) enters hydraulic fracture as it is suspended in the fracturing fluid

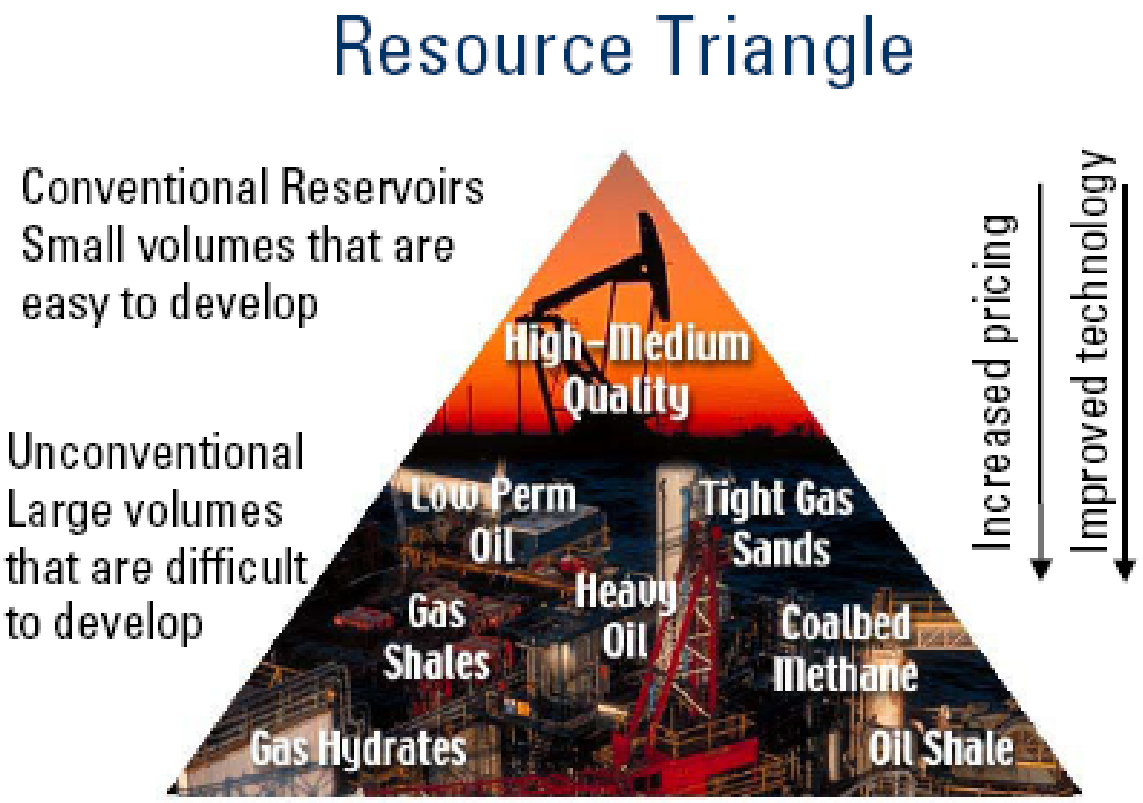
4 - Proppant advances further into the fracture as pumping continues

5 – Proppant advances further in the fracture and may reach the tip of the hydraulic fracture as fluid continues to leak into the permeable formation

6 – Pumping of the fluid/proppant mixture is stopped and fluid continues to leak away into the permeable formation

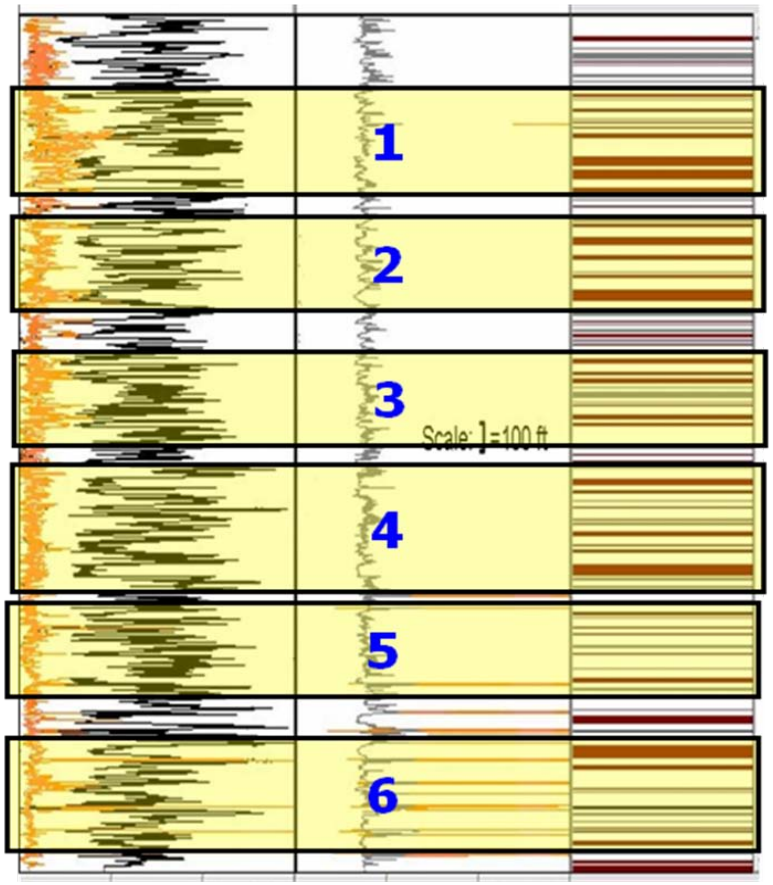
7 – Formation closes on proppant and a conductive path remains in the reservoir

Conventional vs. Unconventional



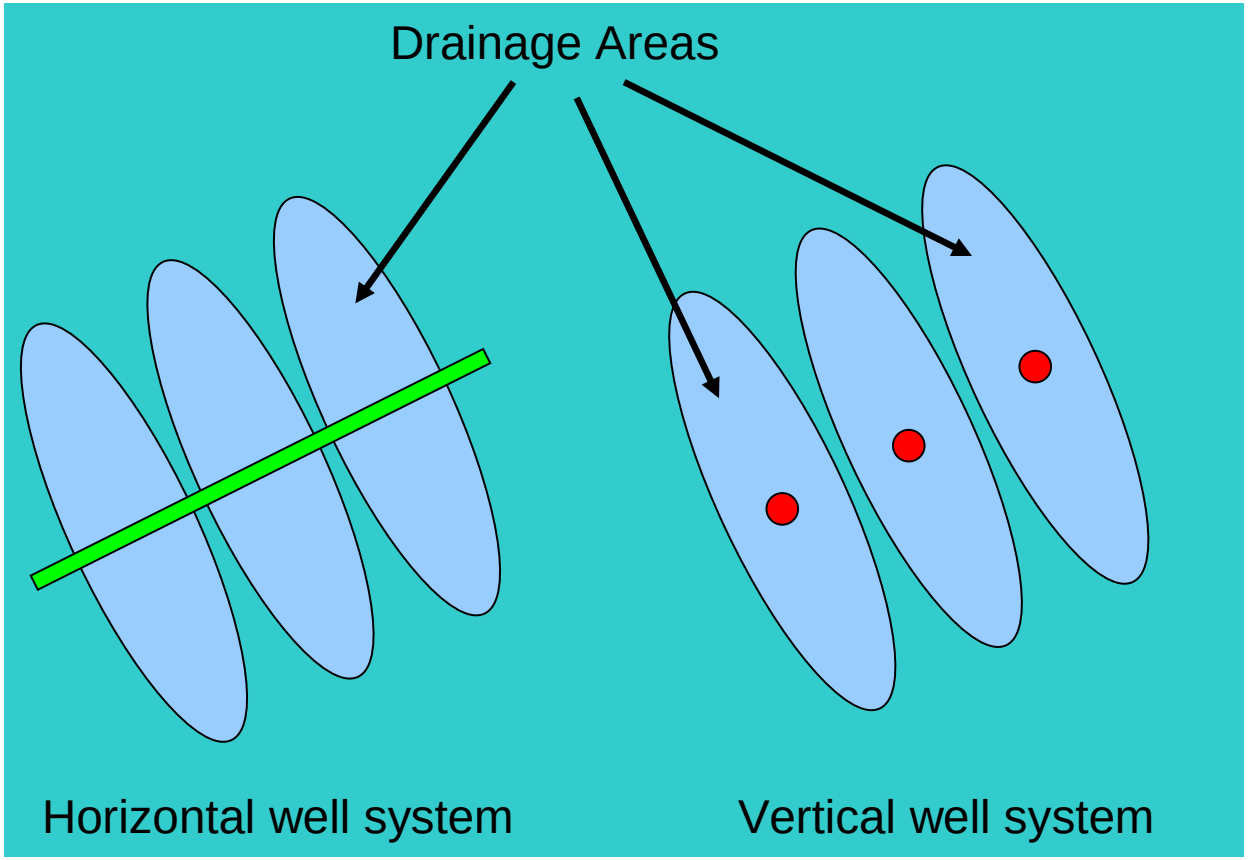
From Holditch 2001

Multiple Vertical Completions



From Green 2006

Vertical vs. Horizontal Completions



From Miskimins 2008

References

- www.energyindepth.com/PDF/At-A-Glance.PDF
- www.all-llc.com
- www.garfield-county.com

QUESTIONS?