Fracturing Challenges
The Journey to Innovative Solutions

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Outline

- Introduction
- Fracturing process
- Challenges
- R&D in fracturing
  - Fracture Mechanisms
  - Fracturing Fluids
  - Waterless Fracturing

Introduction

Hydraulic Fracturing

Process that involve injecting fluids at high pressures till the failure point of the rock to initiate and propagate crakes in the direction of the maximum stress.

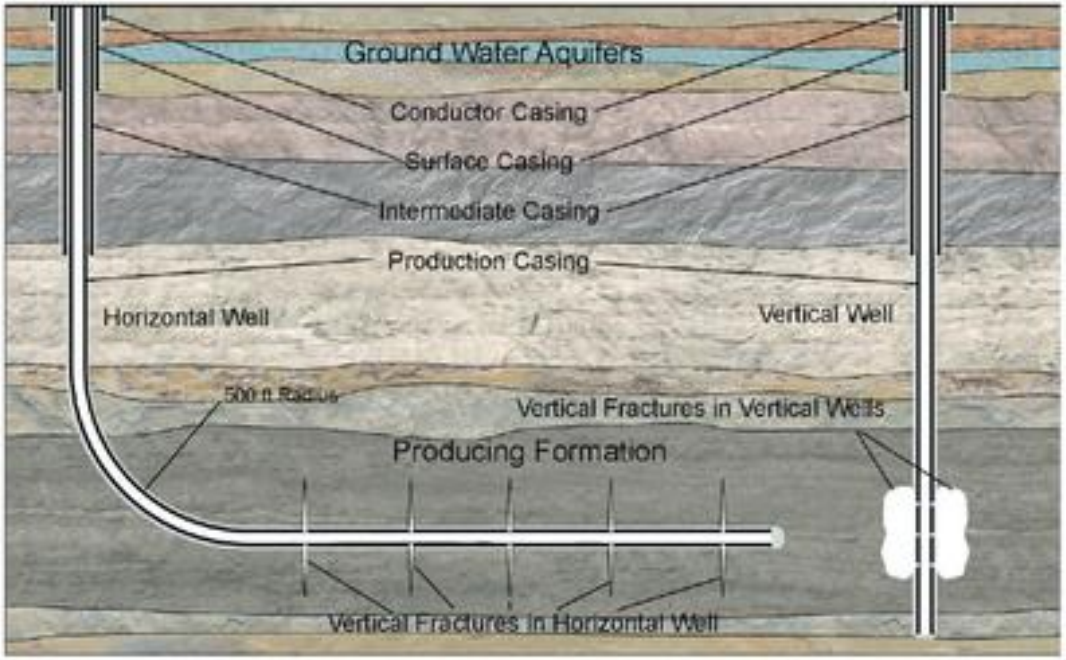
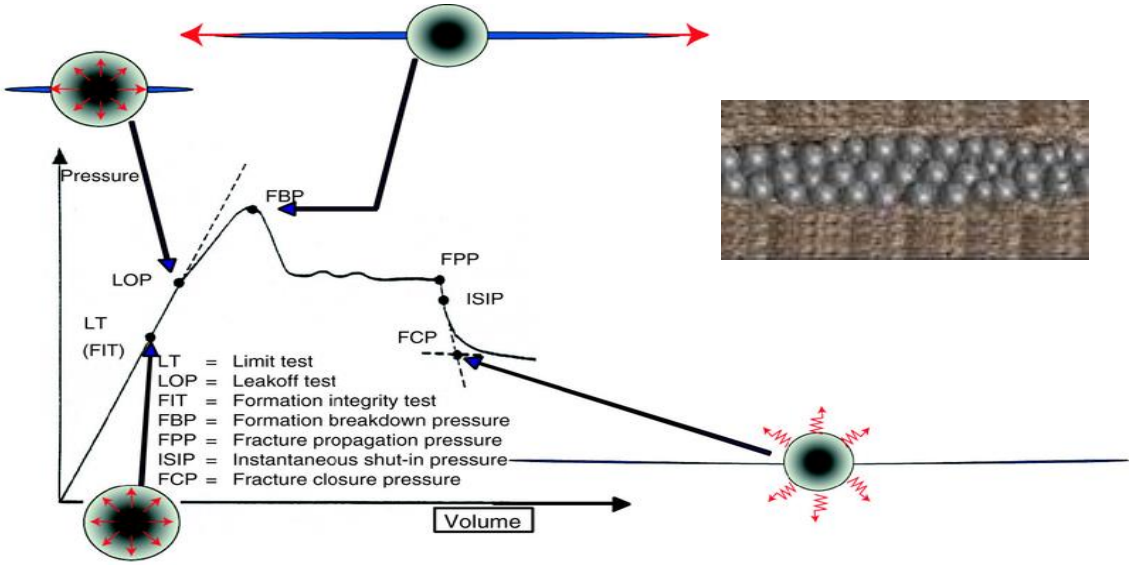


Figure 3—Example of a Horizontal and Vertical Well

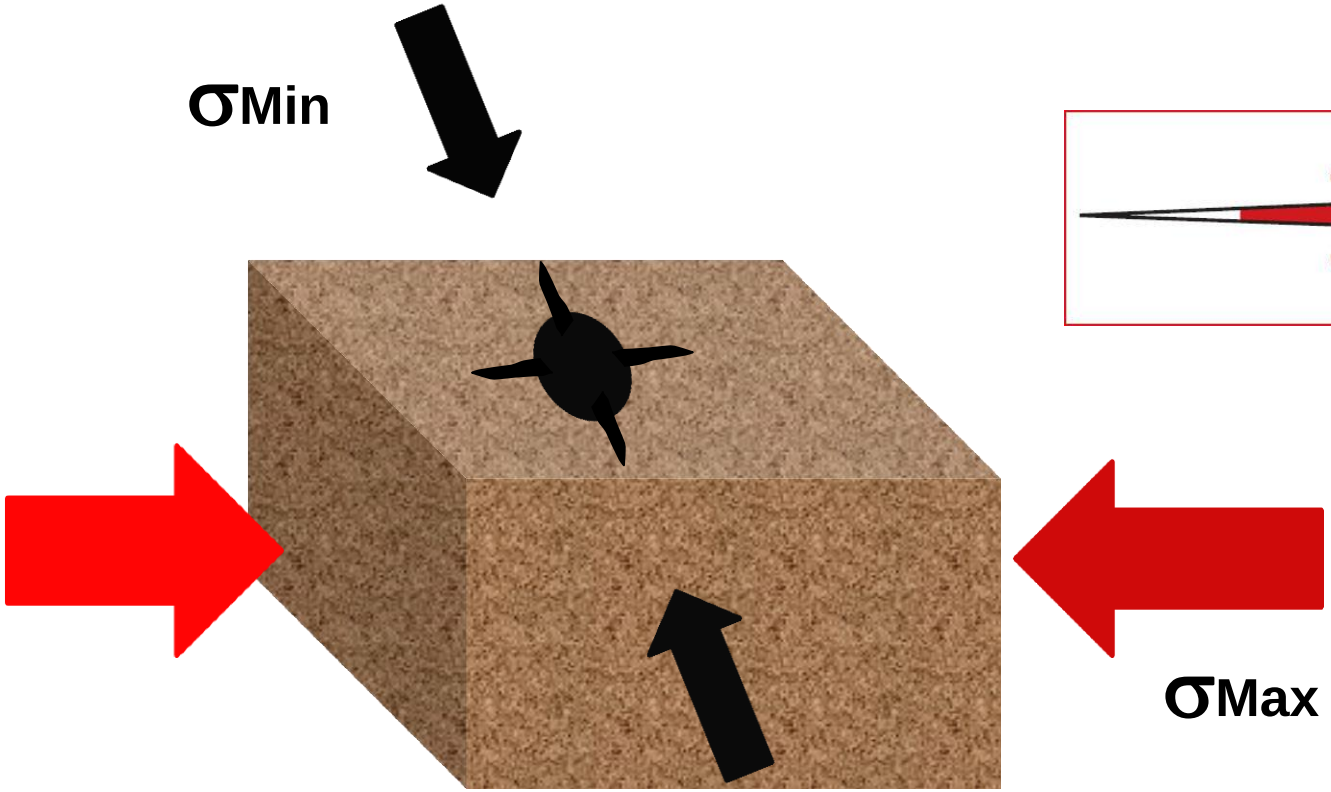
Fracturing Process

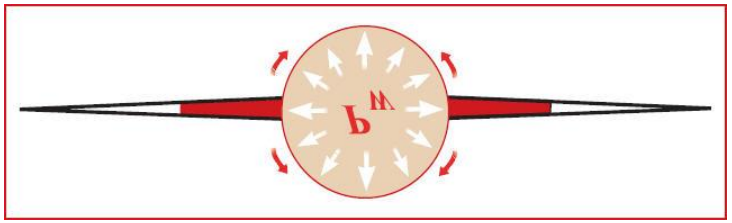
- Inject fracturing fluids to apply tensile stress to that exceed the cracking pressure of the rock.
- Prop the fracture open using sand or ceramics

Hydraulic fracturing .wmv



Stress Orientation and Rock Strength



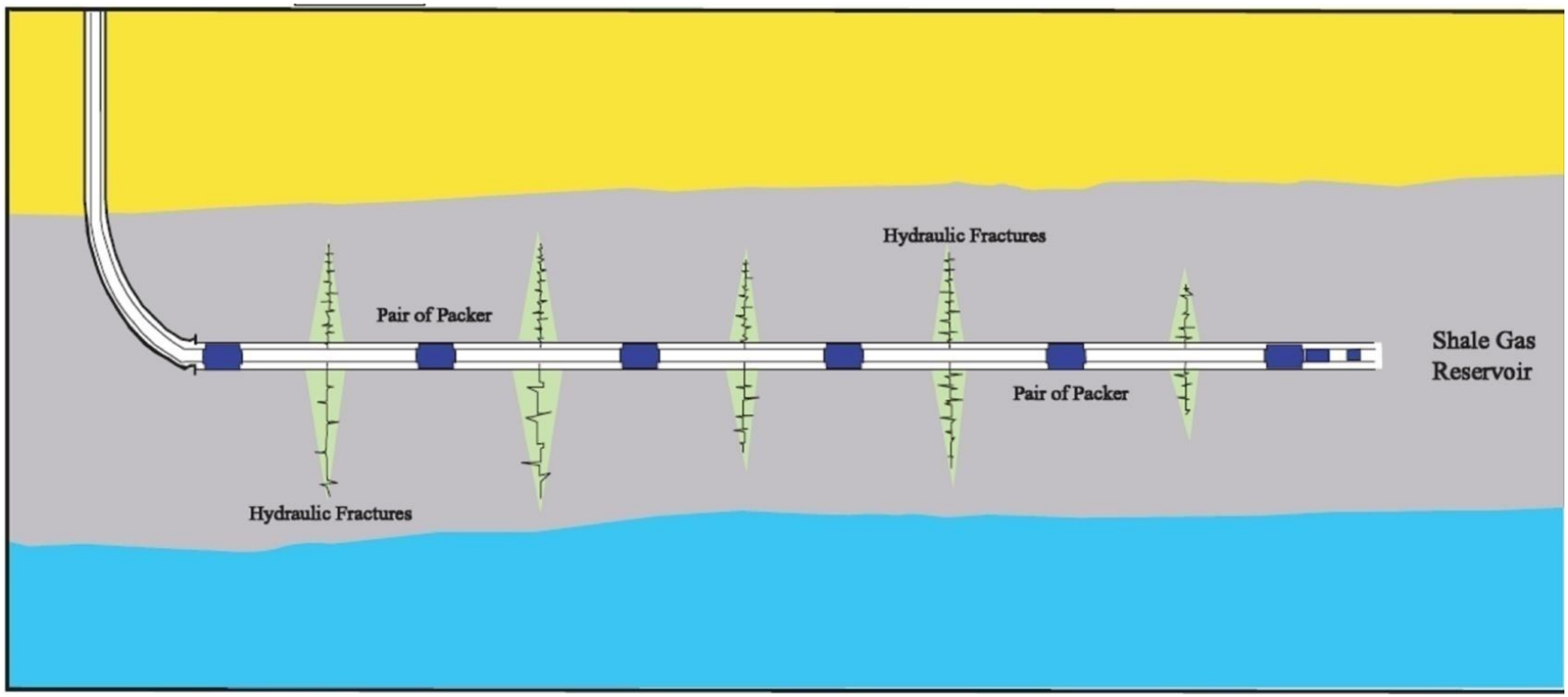


Challenges

- **High Completion and Operational Cost at Multistage Fracturing in Horizontal Wells**
- **Technical Challenges**
  - **Fracture Tortuosity**
  - **Extensive Leak-off**
  - **Damage in Fracture Conductivity**
- **Water Requirements**
  - **Quantities**
  - **Quality**

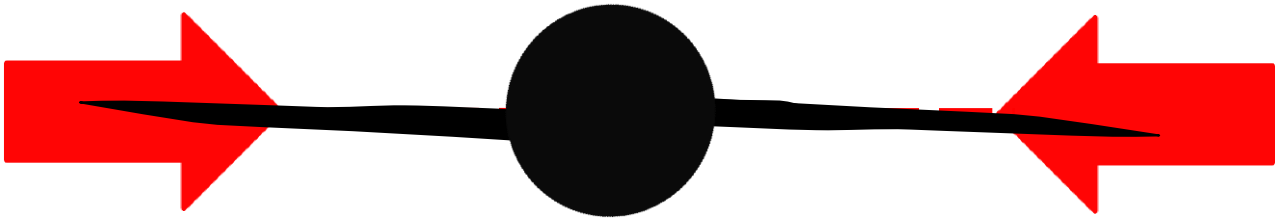
Fracturing Horizontal Wells

- **Mechanical isolation is required**
  - Openhole packers or sand plugs
  - Costly and time consuming

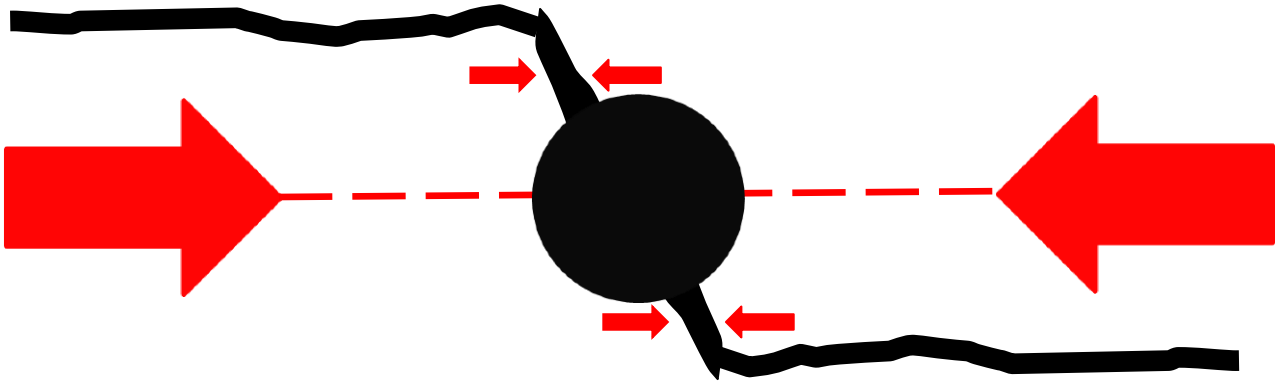


Fracture Tortuosity

Aligned fracture



Tortuous fracture



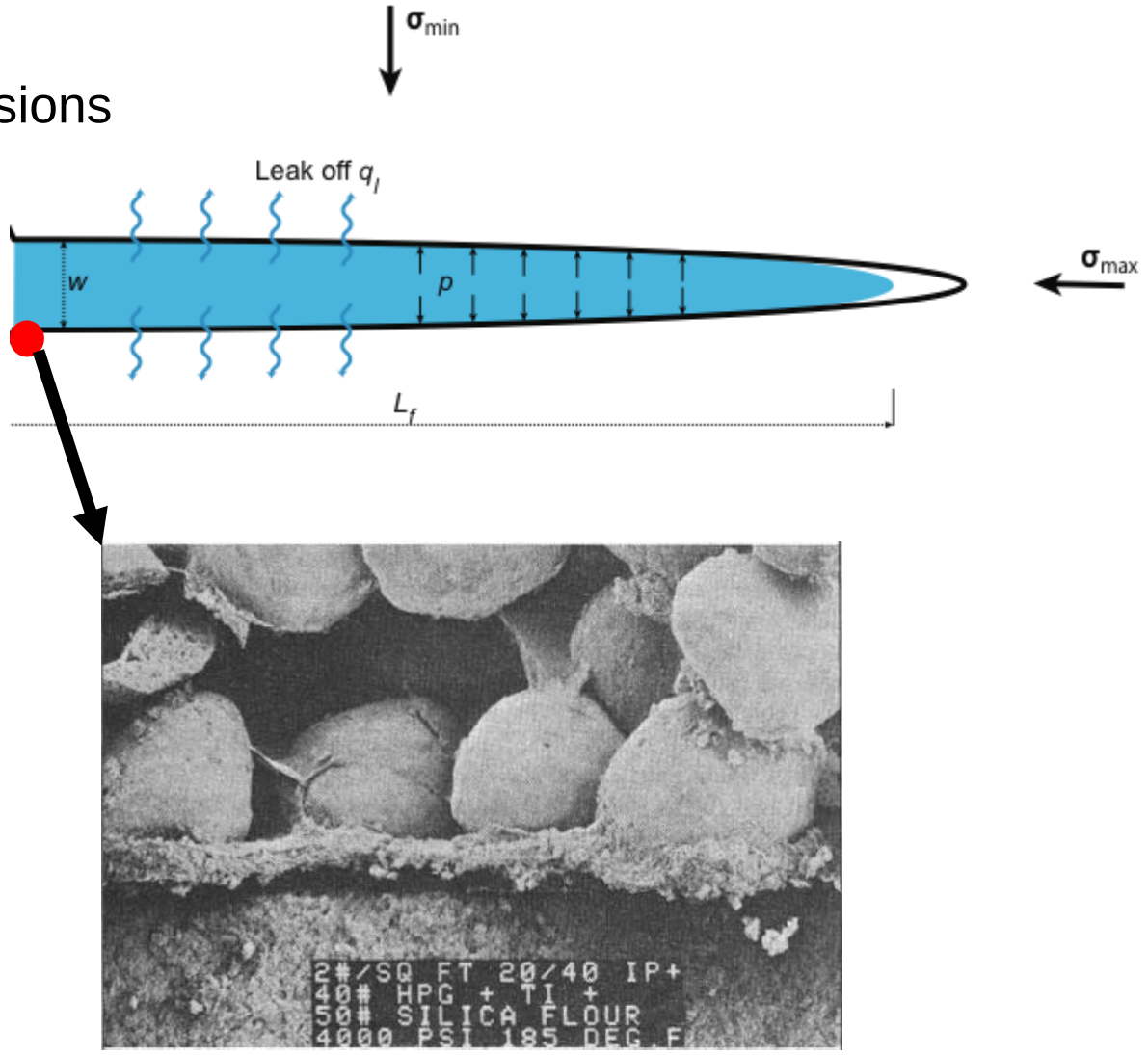
Fracture Tortuosity

- High friction near wellbore
- Impact proppant placement

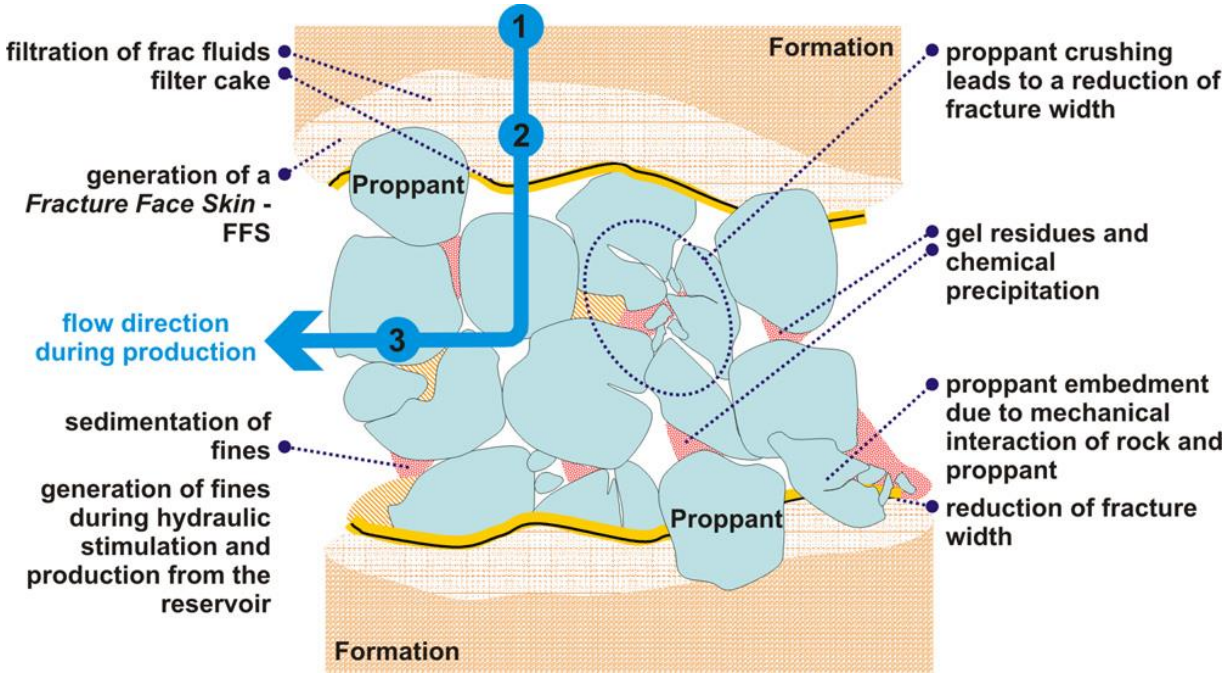
Extensive Leak-off

Effect of high leak-off

- Affect the fracture dimensions
- Formation damage
- Proppant placement



Fracture Conductivity



Zone-2

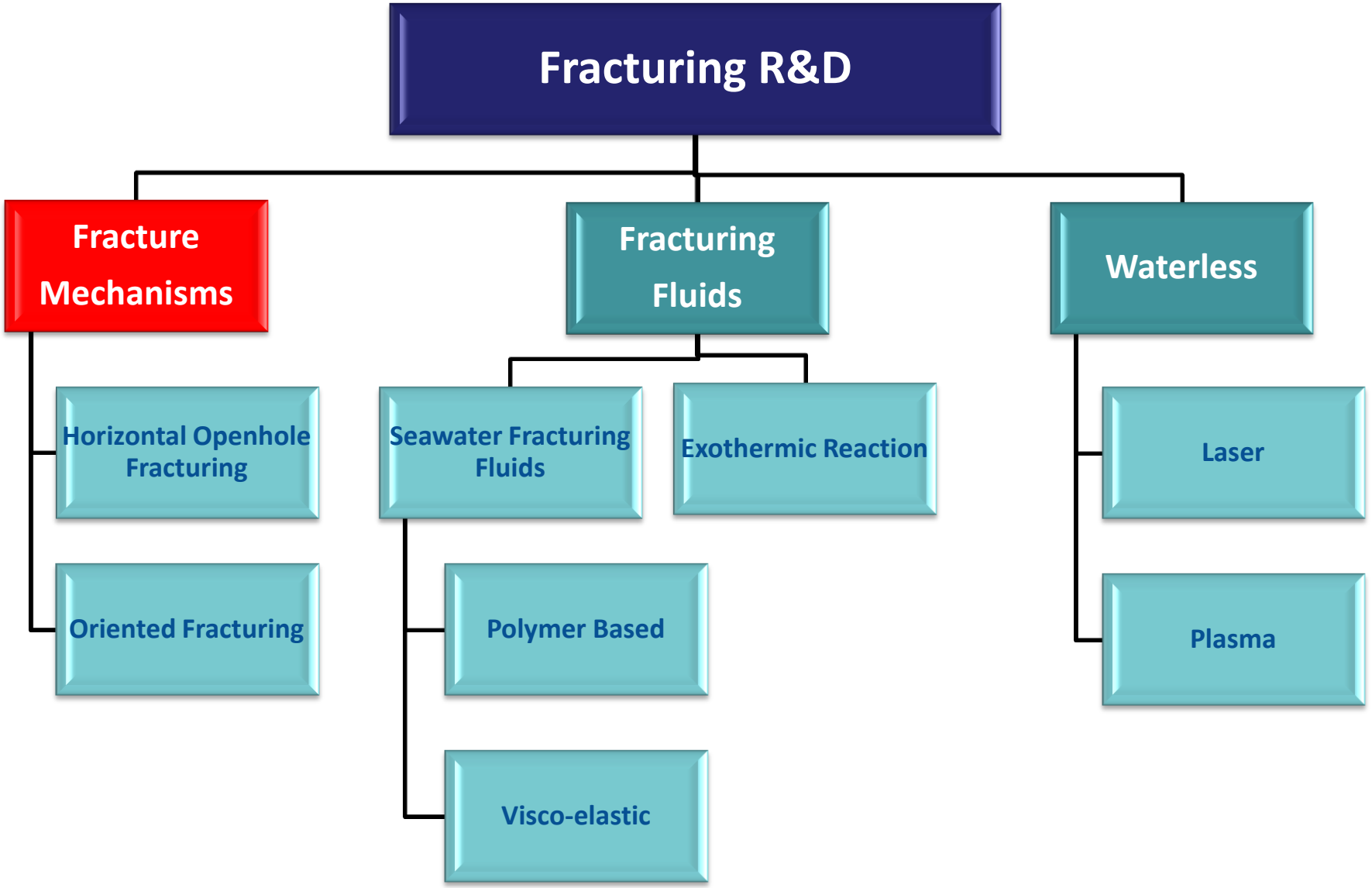
- Clay
- Incompatibility
- Water blockage

Zone-3

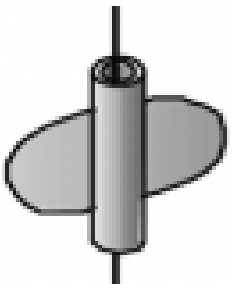
- Precipitation
- Gel residues
- Proppant crushing & embedment

Challenges in the Region

- Shortage of fresh water resources
- Lack of infrastructure to support commoditizing fracturing activities

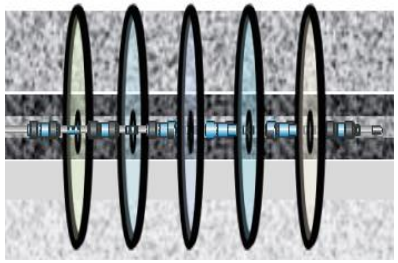


Evolution of Fracturing Technology

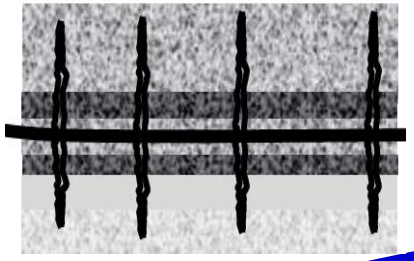


Vertical

With single fracture



Multistage fracturing of horizontal wells cased hole



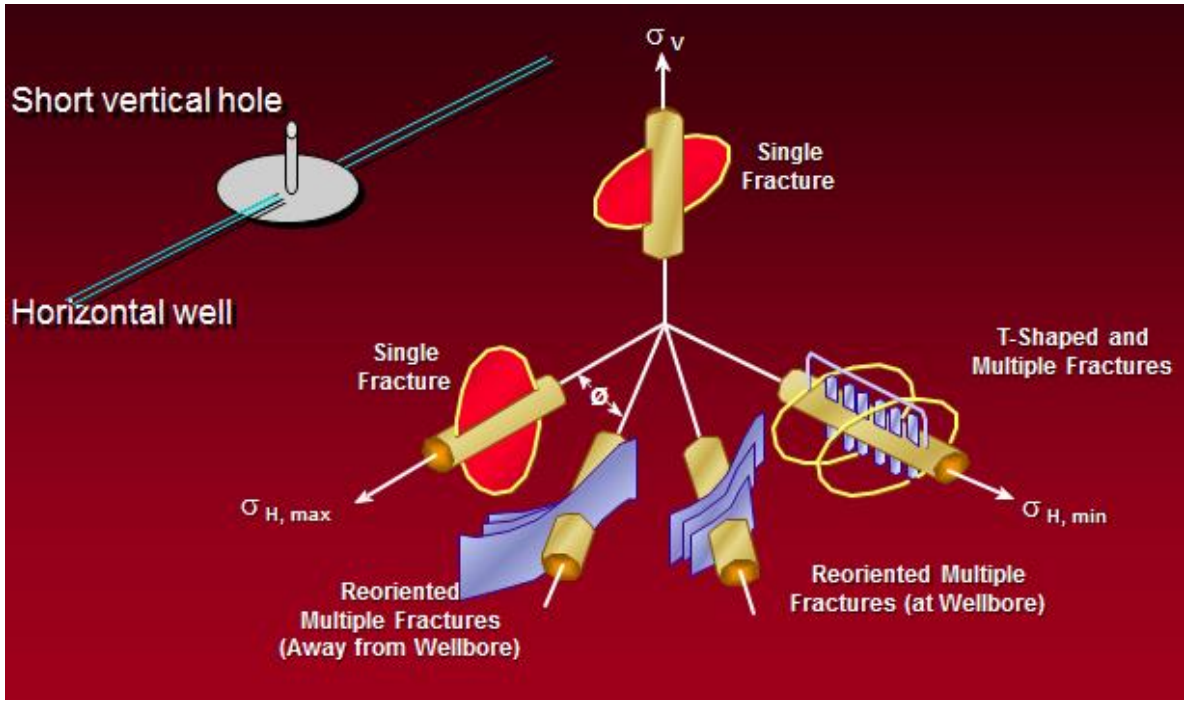
Multistage fracturing of horizontal wells openhole completion system

Multistage fracturing of horizontal wells openhole

Fracture Orientation in Horizontal Wells

Orientation of Fractures

- Transverse Fracture
- Re-oriented Fracture
- Longitudinal Fracture



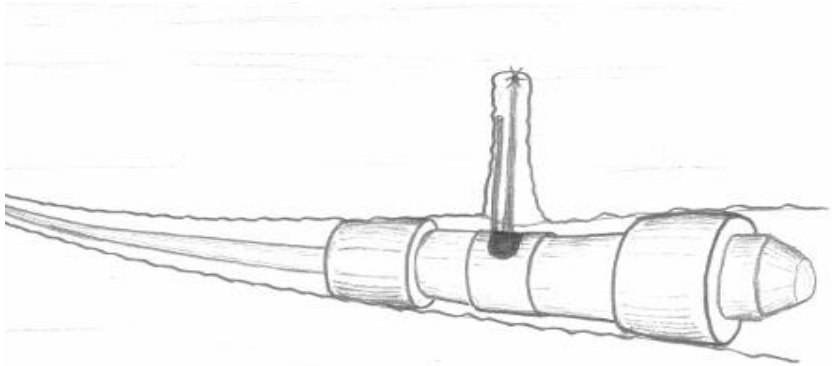
Fracture Mechanisms R&D

Objective

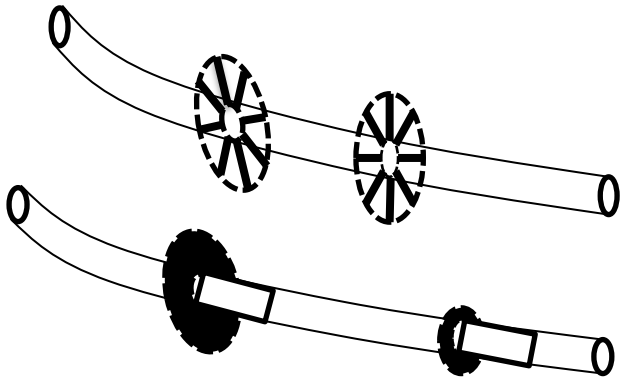
- Develop cost effective technologies by eliminating mechanical isolation in horizontal open-hole fracturing.
- Create multiple hydraulic fractures along a horizontal open hole.
- Understanding the controlling parameters and near wellbore stress of fracture initiation
- Develop oriented notching tools

Fracture Mechanisms R&D

Oriented Fracturing
(Vertical Mini-hole)



Openhole Fracturing
(Radial Notch)

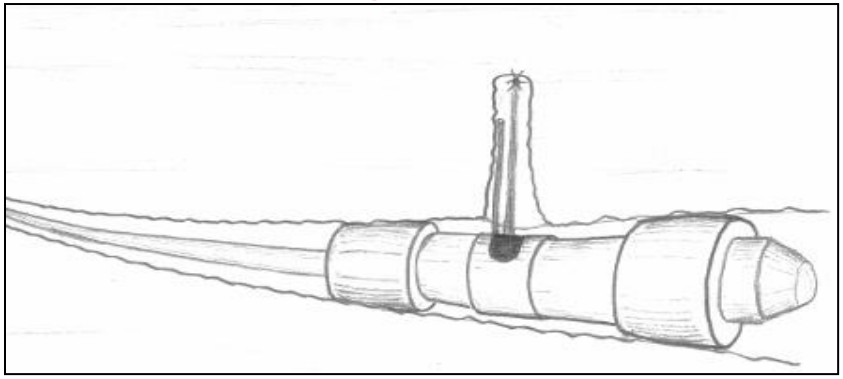


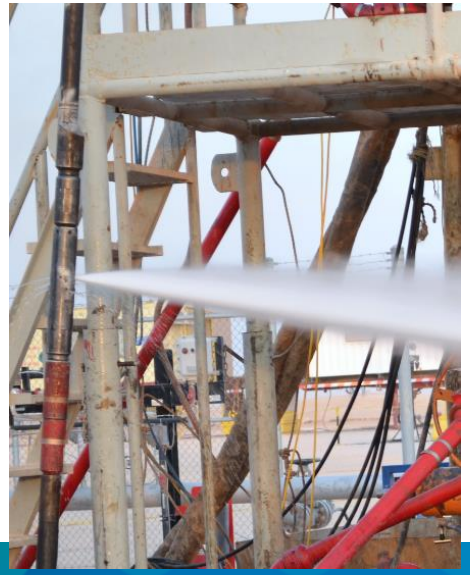
Fracturing Mechanics – Oriented Fracturing

Concept

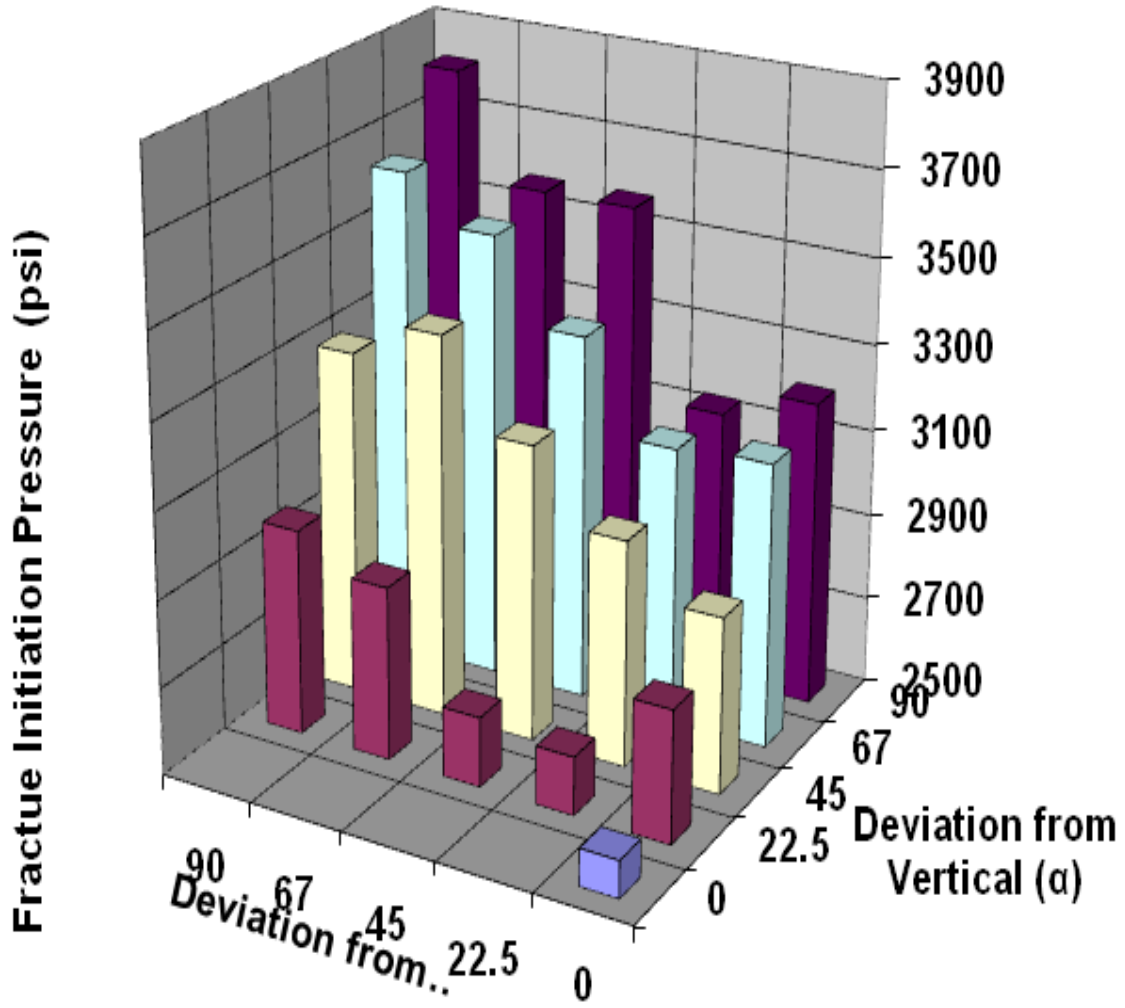
- ✓ Creating a vertical minihole (2 inches in diameter & 2 ft height) via jetting from any point along a horizontal well.
- ✓ This vertical hole goes beyond the near wellbore stress field; therefore,
- ✓ the fracture will initiate from this hole as it is designed to have the lowest breakdown pressure.
- ✓ A jetting tool was manufactured and yard tested on large scale cement block.

What is the optimum hole, orientation? Diameter? Length?

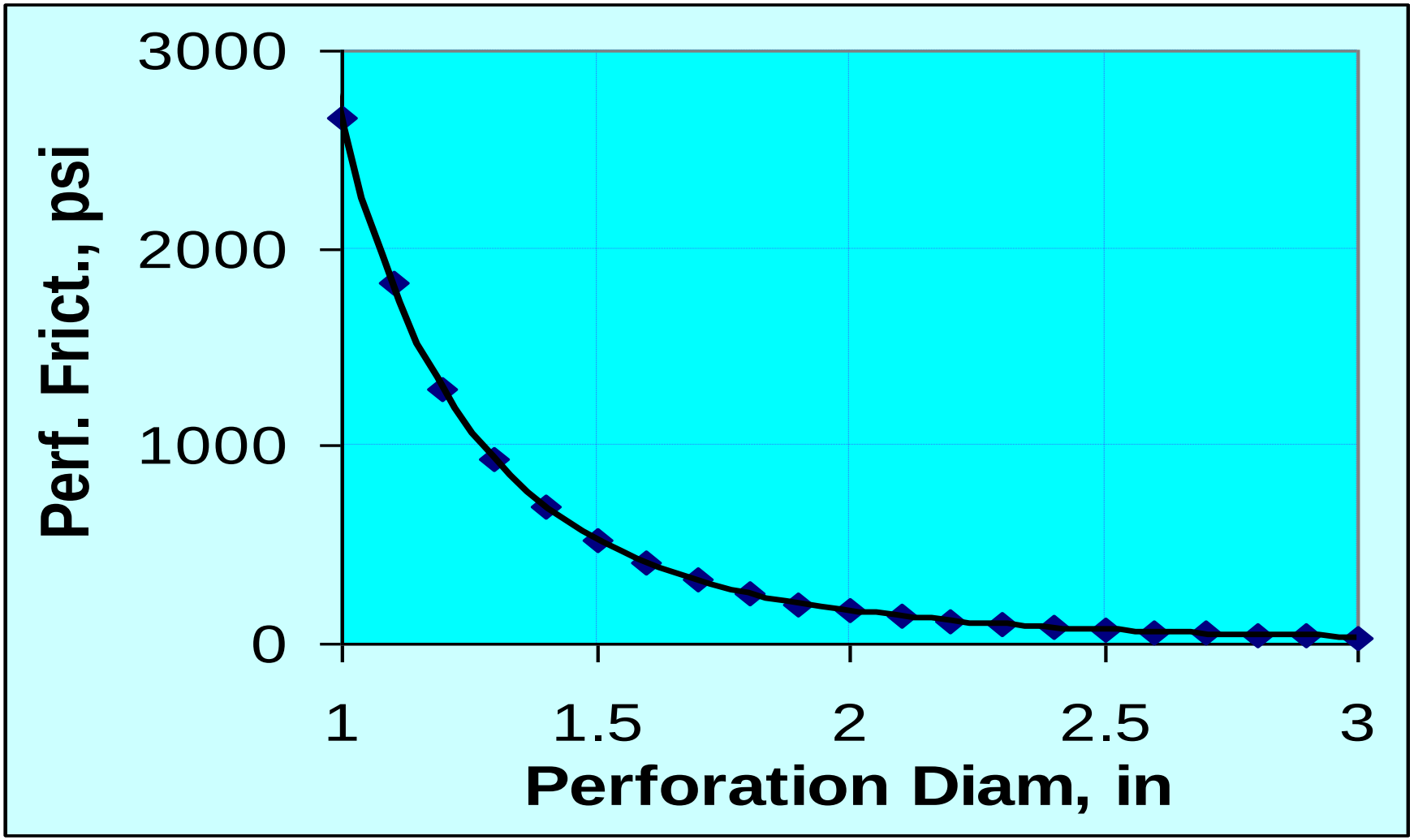




Mini-Hole Orientation

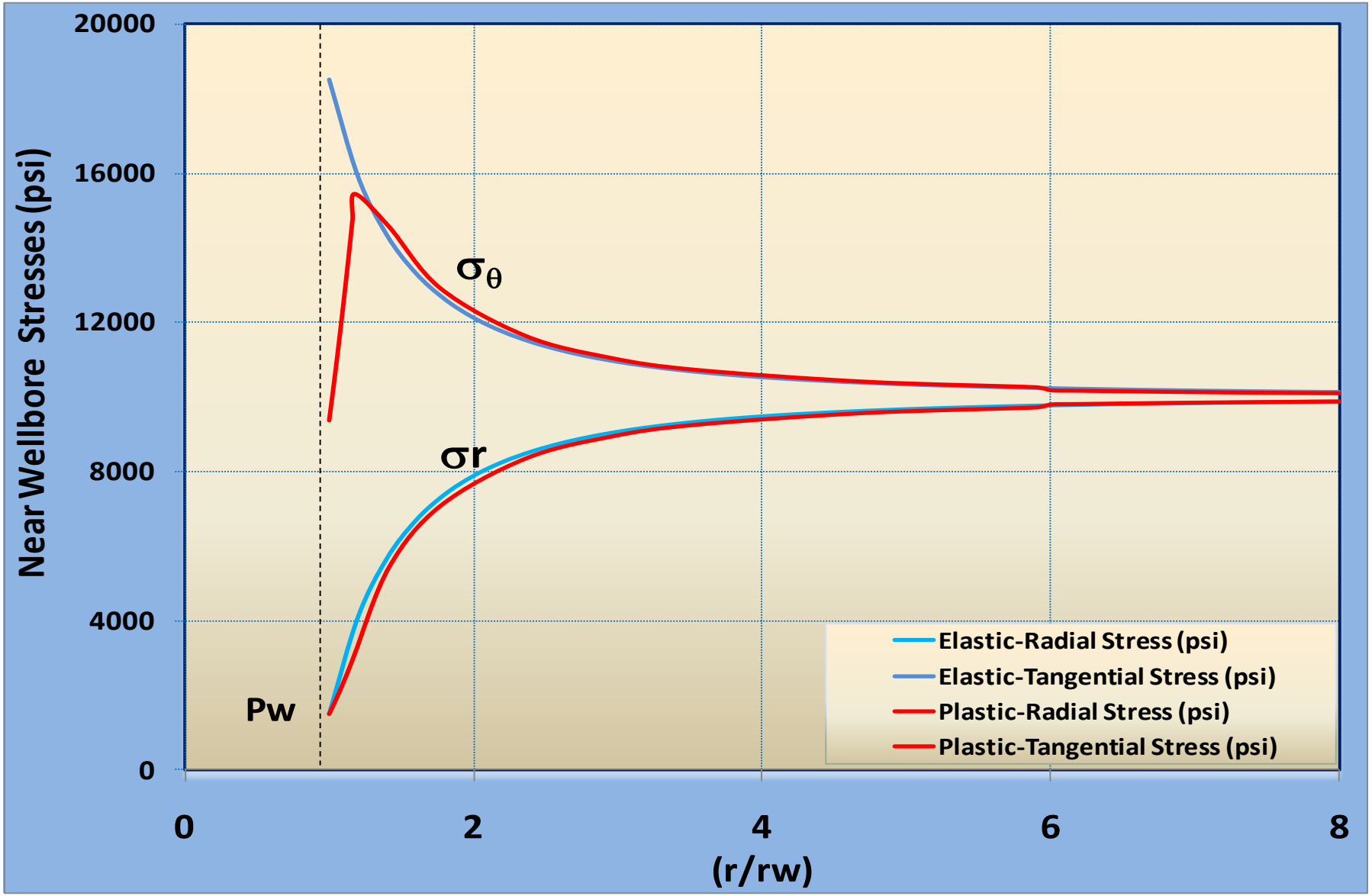


Hole Diameter



Q=30 bbls/min, ρ=10 lb/gal, N=1, D_p= 2”, and C_d =0.8,

Hole Length



Fracturing Mechanics – Oriented Fracturing

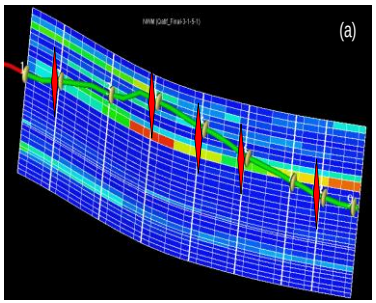
Experimental

- Block Testes conducted @ 6”x6”x10”.
- Lab testing prove the ability of this technique to place and initiate the fracture at created Mini-hole.
- Yard testing of oriented jetting tool is capable to create the required jetting dimension.

Fracturing Mechanics – Openhole Fracturing

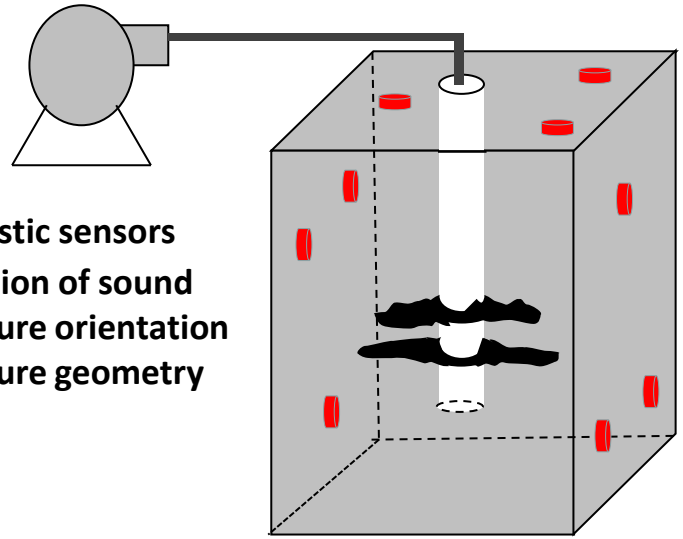
Concept:

- ✓ Creating weak points along horizontal wells based on reservoir properties
- ✓ Simultaneously initiating fractures at all week points
- ✓ Fluid diversion to stop dominant fractures to sequentially propagate all fractures
- ✓ Degradable diverting material to cleanup all fractures

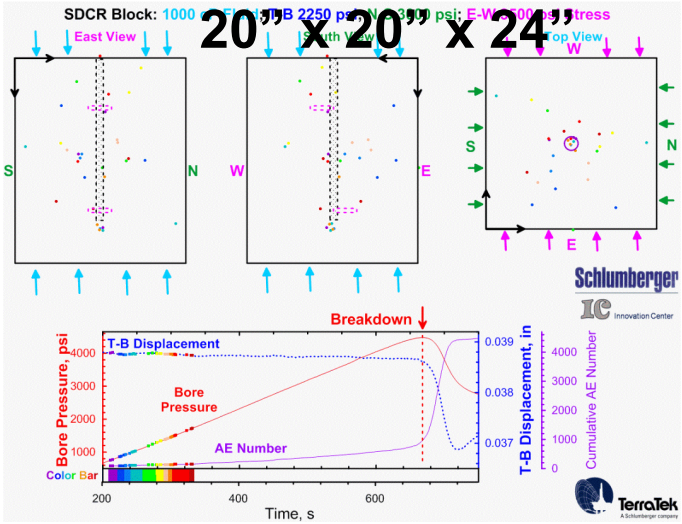


Fracturing Mechanics – Openhole Fracturing

Experimental

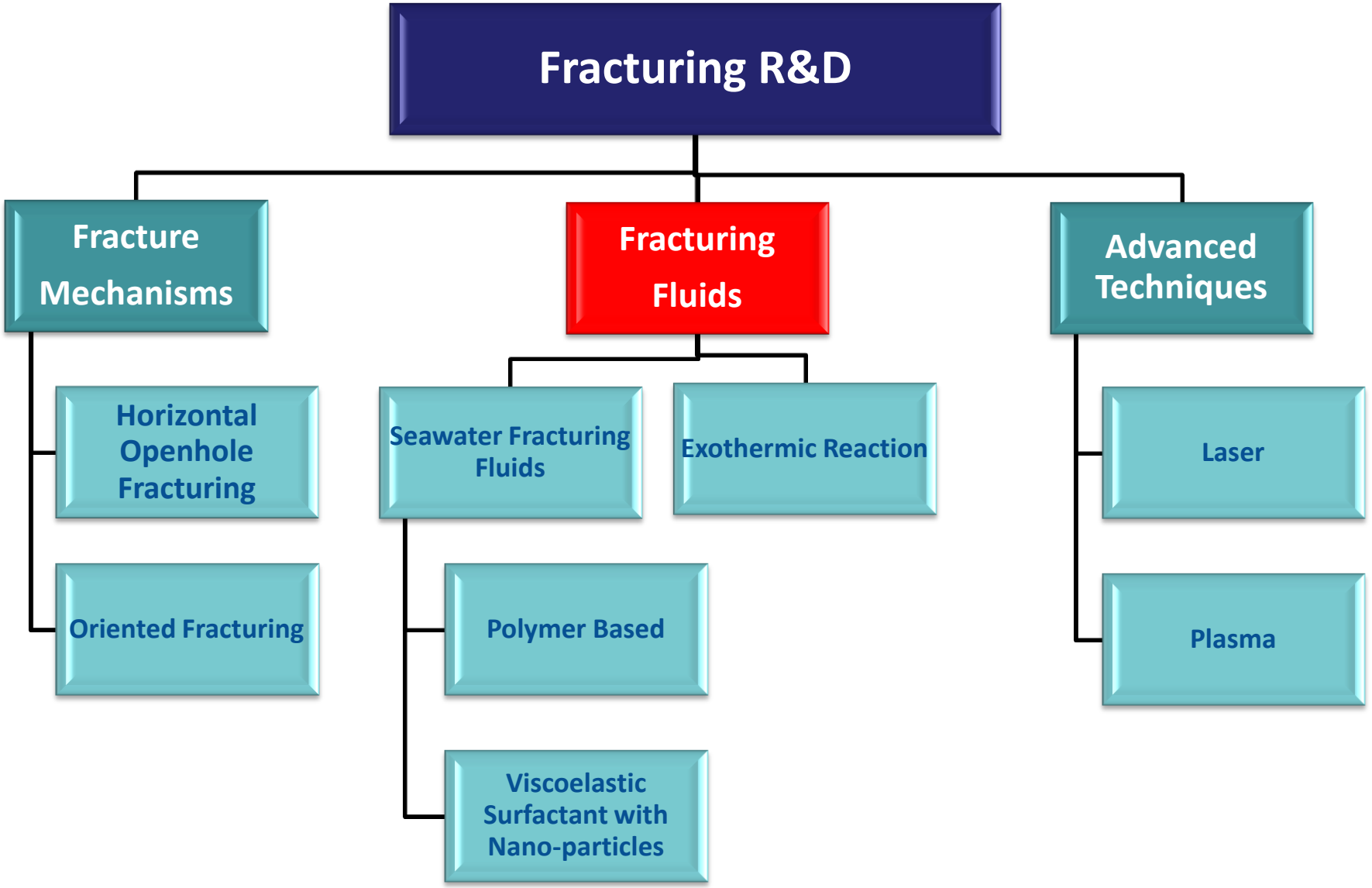


= Acoustic sensors
- Location of sound
- Fracture orientation
- Fracture geometry



Field Trail

- Preliminary results indicated multiple fractures
- Improved productivity compared to adjacent wells in the field



HT Seawater Fracturing Fluids R&D

Objective

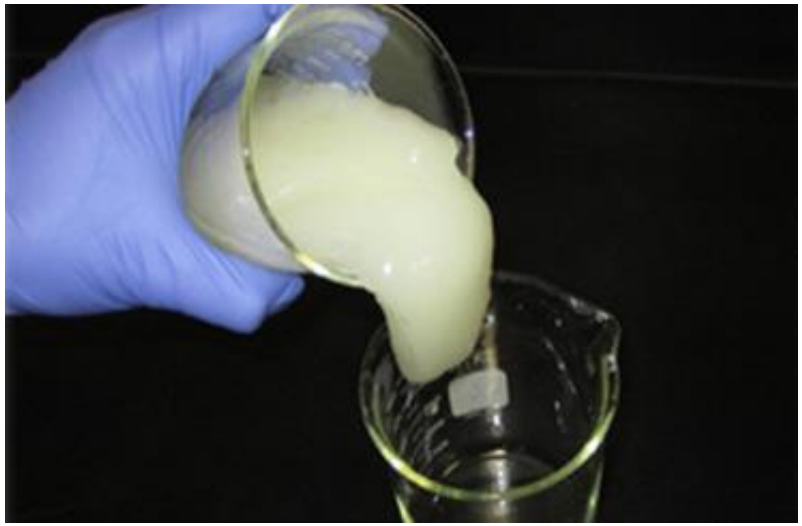
- Develop superior fracturing fluid using sea waters in the Kingdom.
- Alleviate burden of lacking fresh water resources
- Enhanced fracture cleanup and conductivity
- Simplified chemistry for easy QA/QC on location
- Applicable to both conventional reservoirs and unconventional resources
- Applicable to temperature up to 350^{o}F

Requirements of Fracturing Fluid

- Provide good proppant transport property
- Compatible with the formation rock and fluids
- High fluid efficiency - low fluid loss
- Low friction during pumping
- Build viscosity inside the fracture
- Break down effectively after treatment - low residue

Fracturing Fluid Composition

- Water
- Gelling agent
- Cross-linker
- Gel Breaker
- Clay stabilizer
- Friction reducer
- Biocide

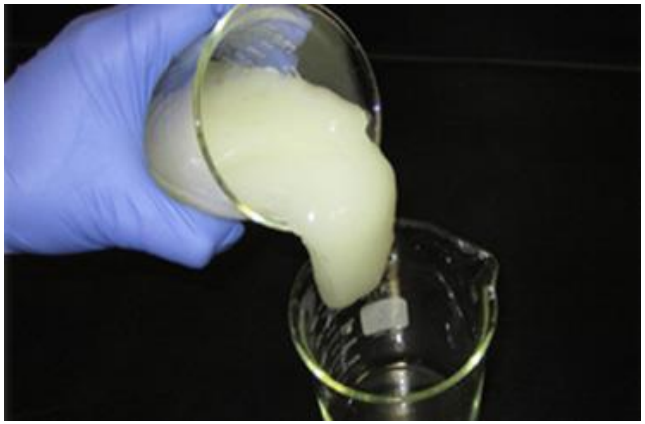


Technical Challenges by HT & Seawater

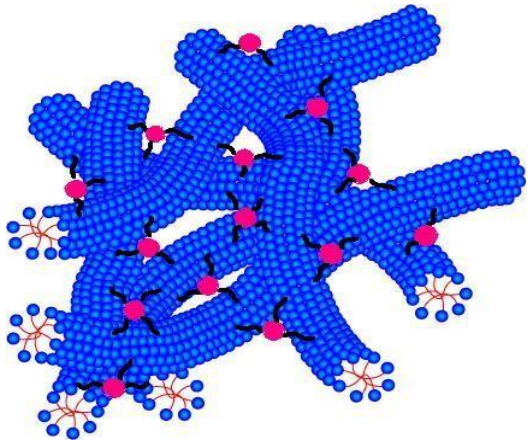
- **Rheology**
  - **Hydration**
    - Less hydration in high salinity and hardness
  - **Crosslinking**
    - Impact pH by precipitating hydroxides
  - **Stability**
    - Available systems shows low thermal stability at 350^{o} F
- **Cleanup**
  - **Potential scales forms in the fracture**
  - **High reactivity of breakers at high temperatures**
  - **Inefficient removal of polymer from the proppant pack in the fracture**
- **Scaling**
  - **Incompatibility with pH modifiers (hydroxides)**
  - **Incompatibility between filtrate and formation brine (sulfates)**

High Temperature Seawater Fracturing Fluids R&D

Polymer Based



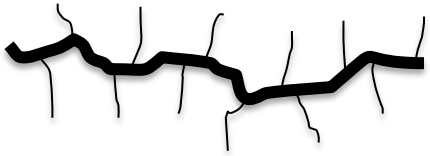
Surfactant Based



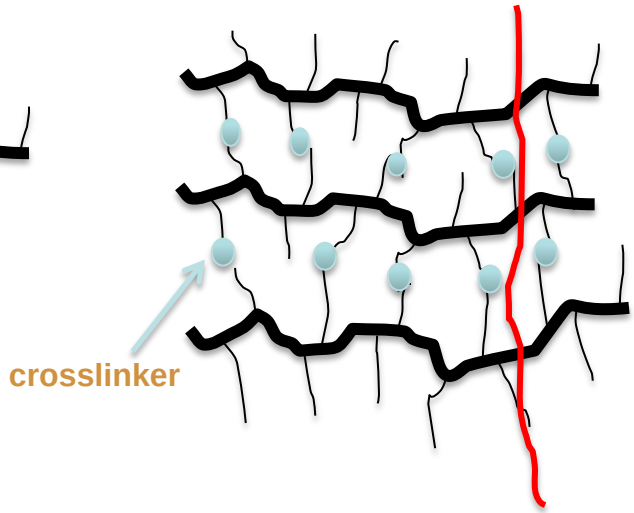
Comparison Between Polymer & Surfactant Based Fracture Fluids

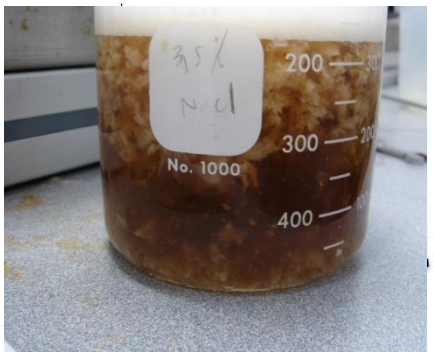
Property	Polymer	Viscoelastic Surfactant
Thermal Stability	More stable	Less stable
Fluid Efficiency	More efficient	Need Leak-off control
Mixing	Several Steps	Easier
Cleanup & Fracture Conductivity	Residue	Cleaner & better conductivity
Cost	Cheap	Expensive

Seawater Fracturing Fluid



Polymer
M.W. 200K to 2 Million

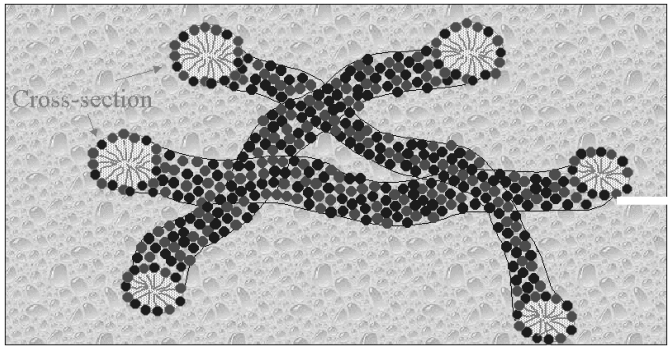




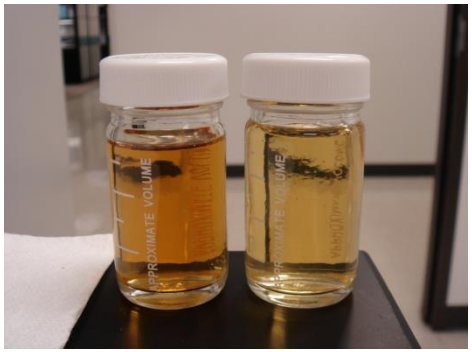
Broken Polymer Gel
Insoluble residue

Viscoelastic
Surfactant

M.W. Hundreds



Entangled Worm-like Micelles

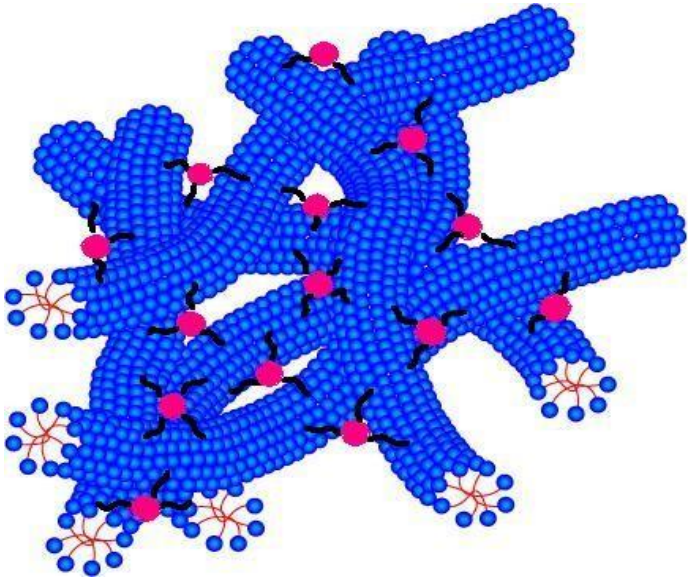


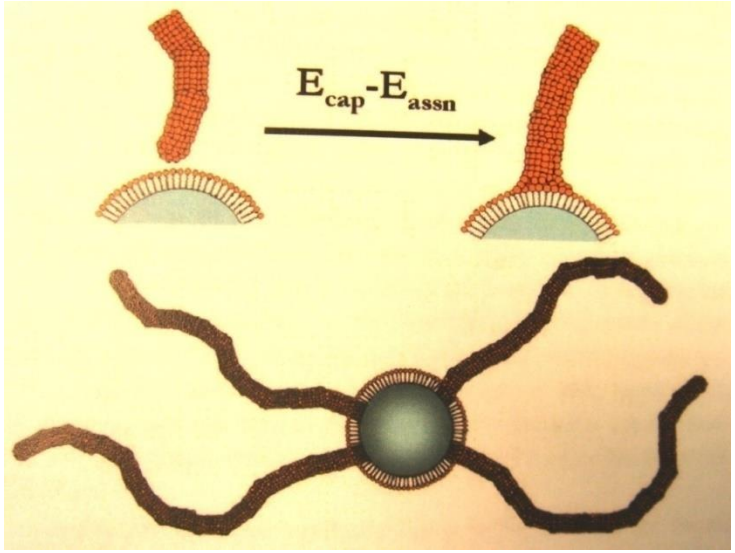
Broken VES Gel Soluble
spherical micelles

Seawater Frac Fluid - Viscoelastic Surfactant

Concept

- ✓ Use viscoelastic surfactant as gelling agent
- ✓ New mechanism to associate into elongated micelles:
  - ✓ Based on use of selected nanoparticles
  - ✓ Nanoparticles are able to 'pseudo-crosslink' elongated micelles into 3-D structures



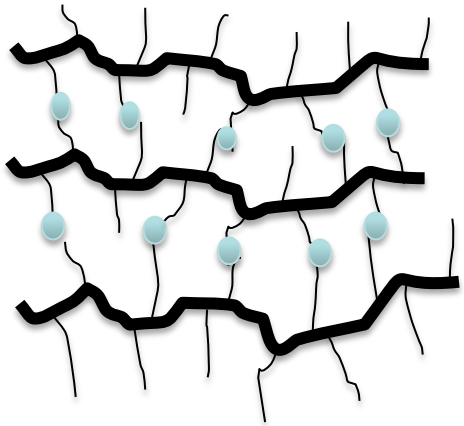


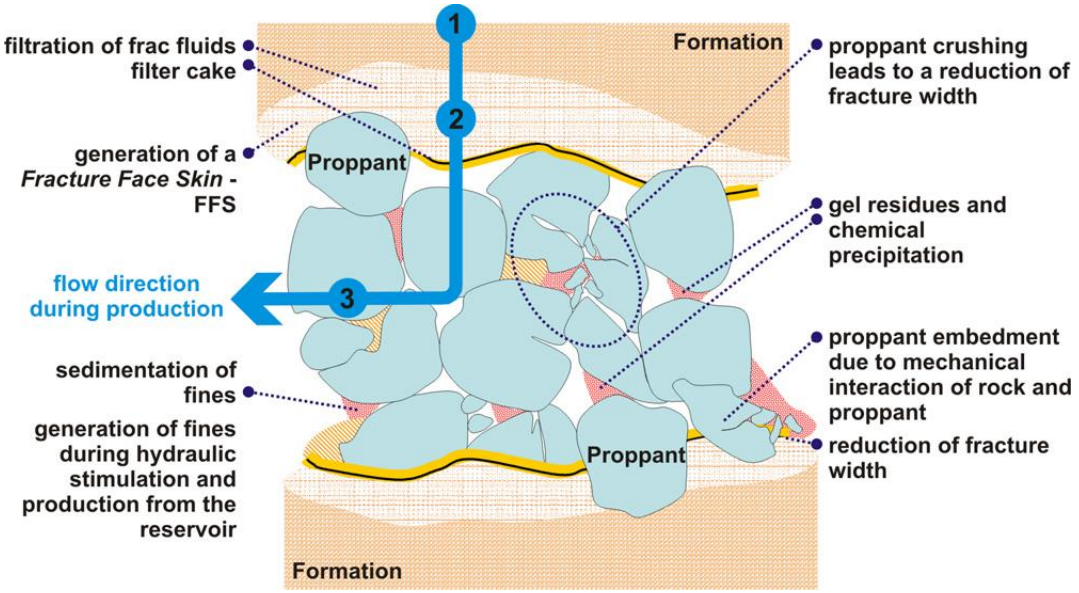
Nettesheim et al. *Langmuir* 2008, *24,*

Seawater Fracturing Fluid – Polymer-based

Concept

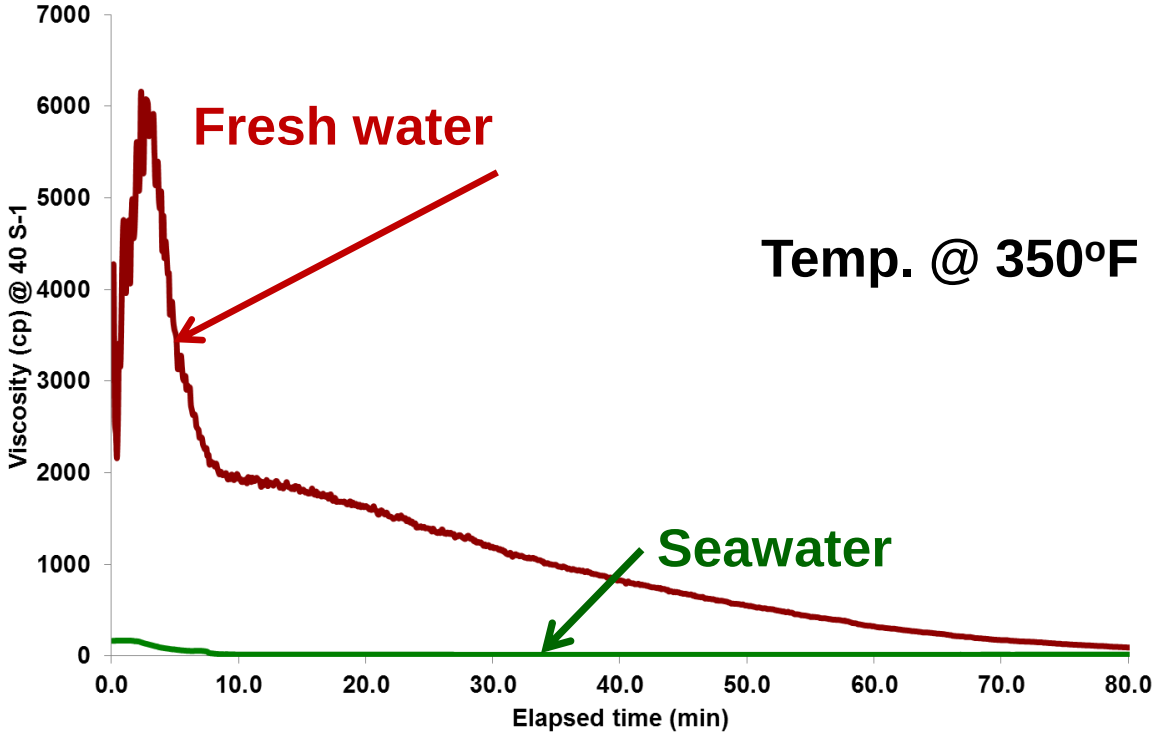
- ✓ Improve current polymers thermal stability or design new copolymer
- ✓ Develop new sulfate scale inhibitor that operates at 350°F without interfering with crosslinking process





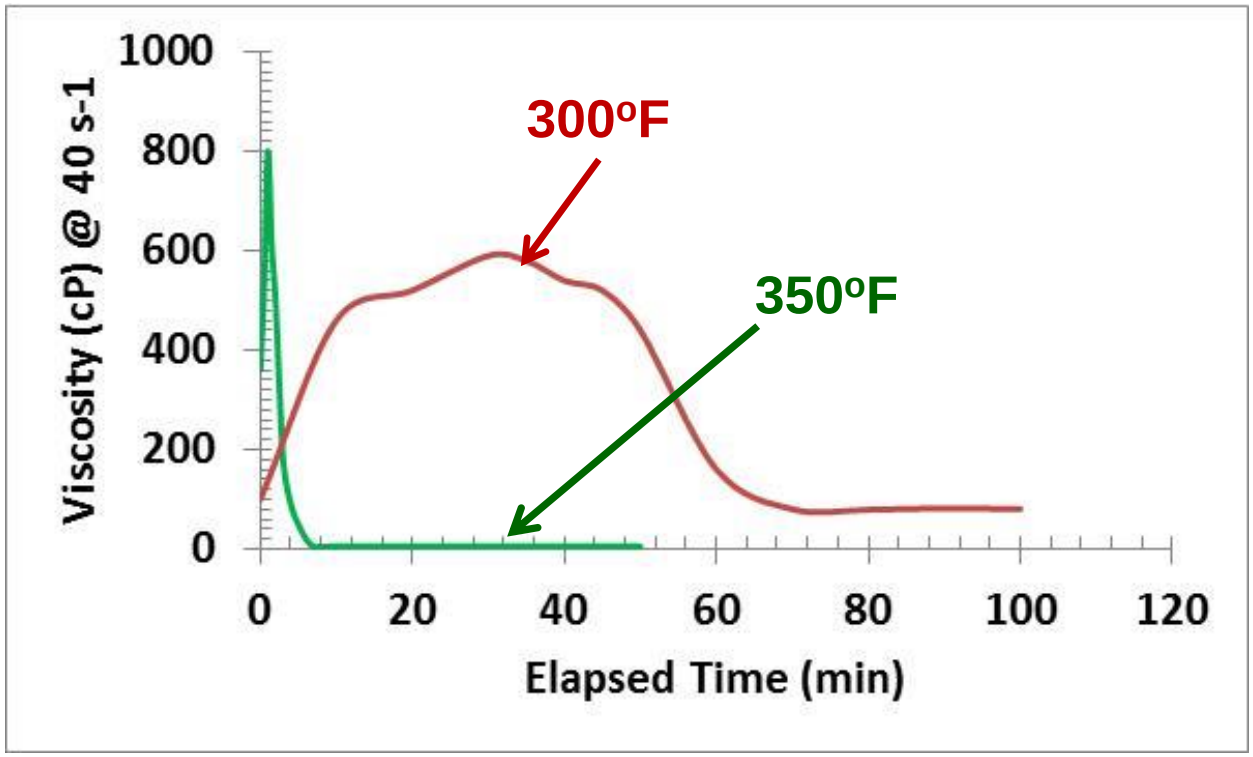
Seawater Fracturing Fluid – Polymer-based

Effect of Seawater on high temperature fracturing fluid



Seawater Fracturing Fluid – Polymer-based

Effect of high temperature on seawater fracturing fluid



Exothermic Reaction R&D

Objective

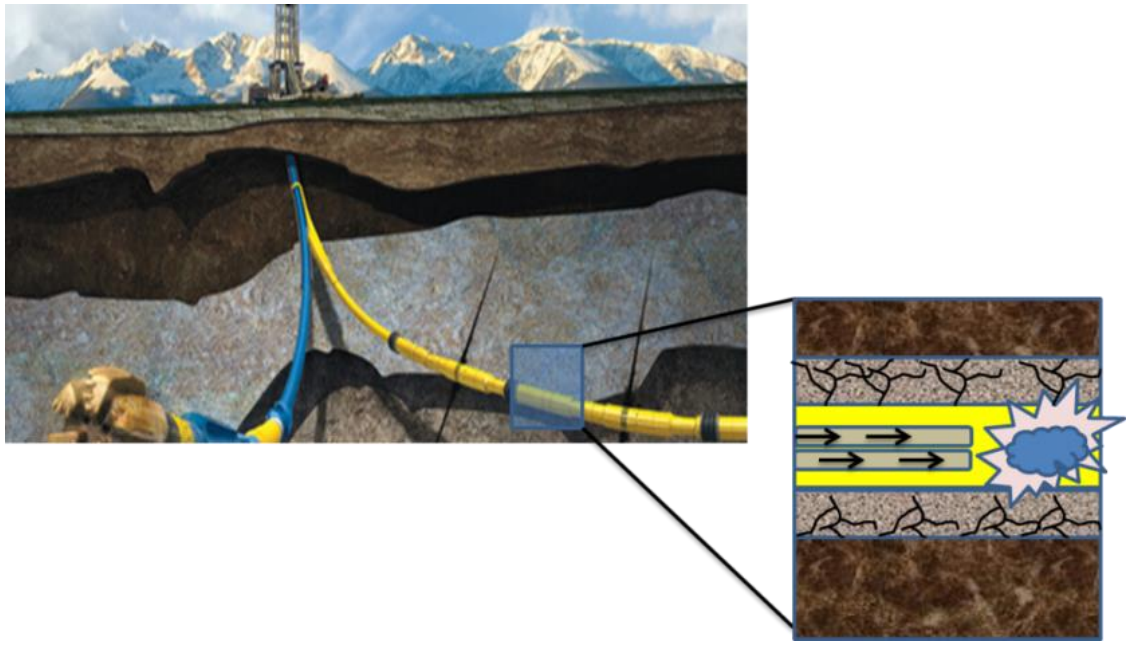
- Generate multiple fractures
- Minimize water requirement during fracturing
- Improve wellbore cleanout

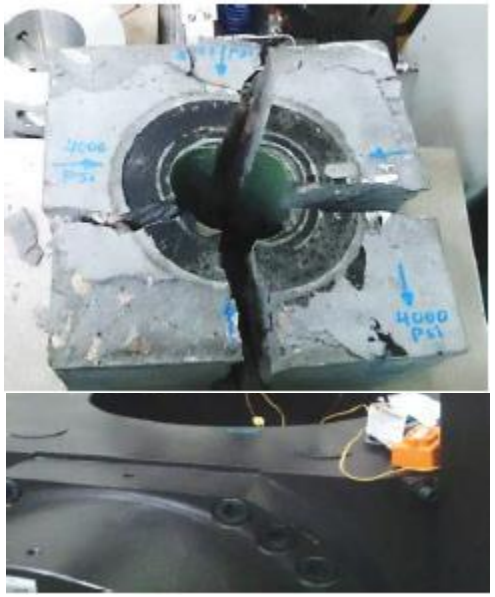
Concept

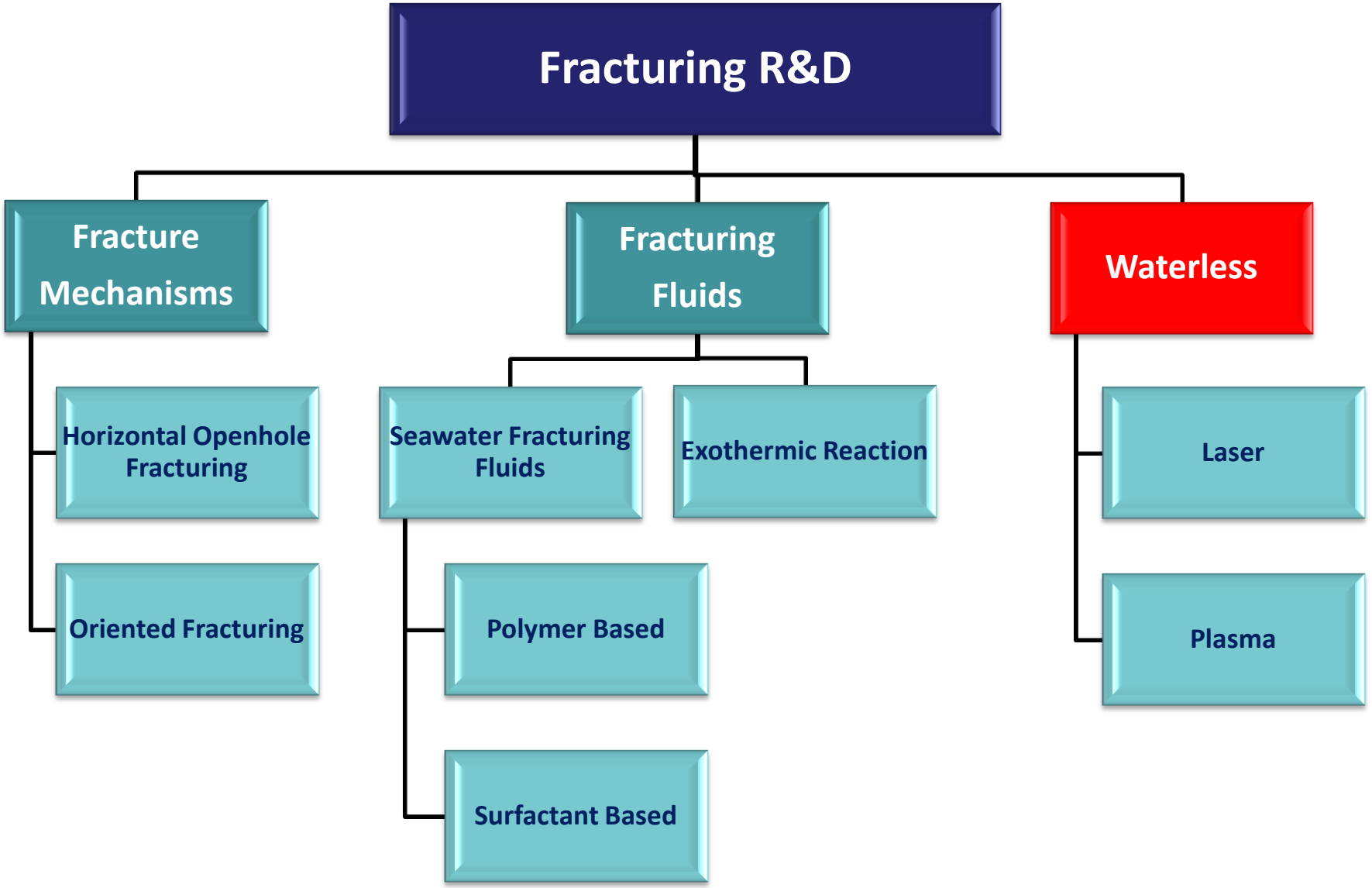
✓ Incorporate exothermic reactants with the fracturing fluid to generate in-situ pressure and heat pulses.

Exothermic Reaction R&D

Chemical ⟶ **Pressure + Heat**







Waterless Fracturing Techniques R&D

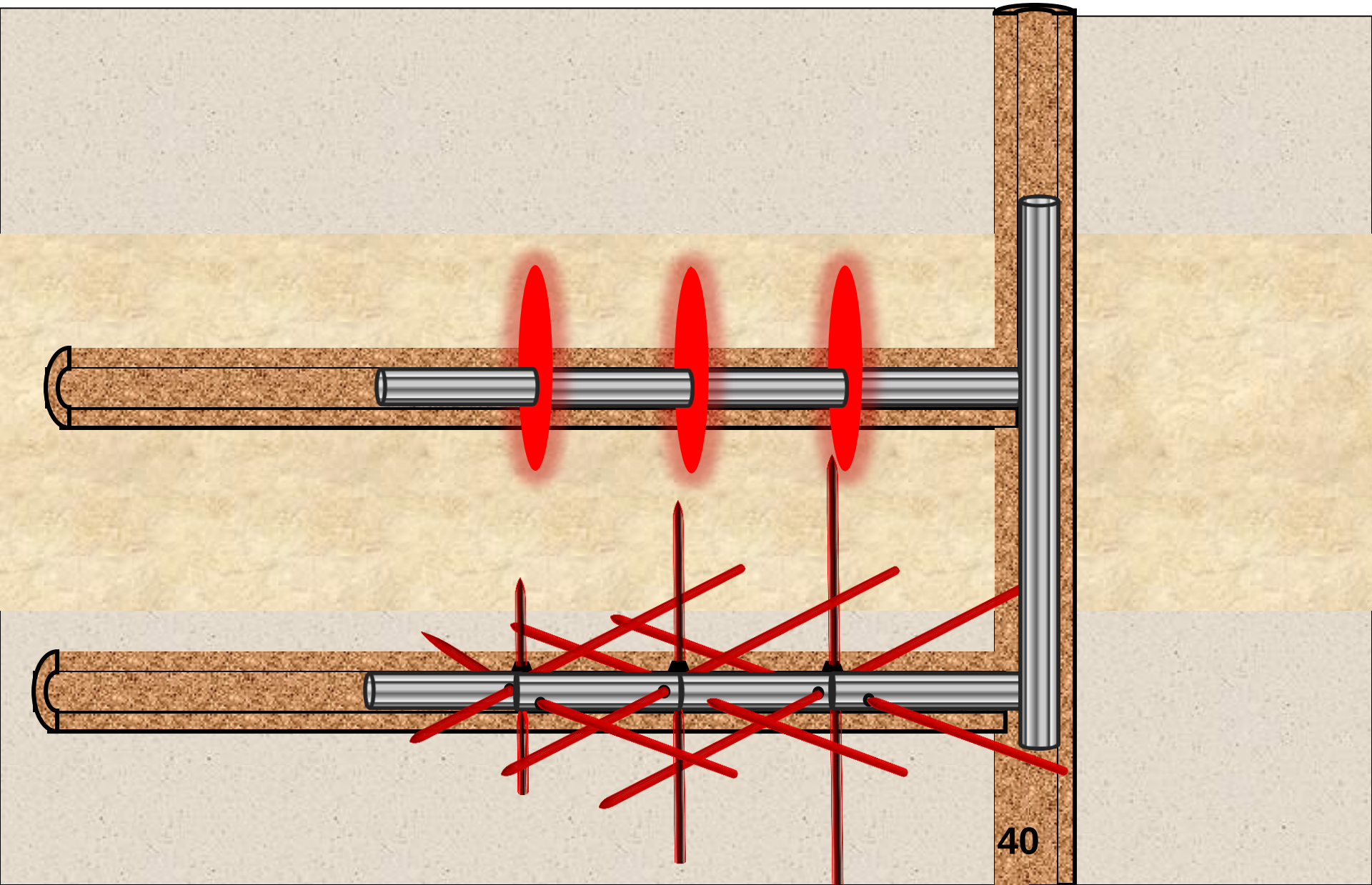
Objective

- Develop waterless fracturing technology.
- Non-damaging
- Cost effective
- Environmentally friendly

Concept

- Generate reservoir stimulated volume
- Utilize Laser to enable current fracturing techniques
- Create multi lateral, multi perforated tunnel, slots and notches with geometry control
- Generate Laser at surface and transmitted via fiber optics

Laser Fracturing

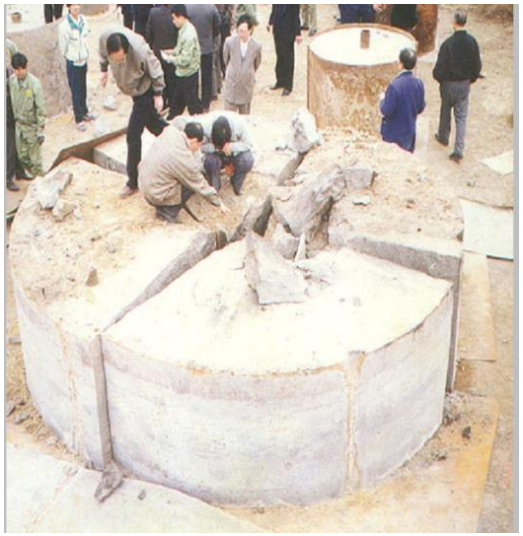


Plasma Fracturing

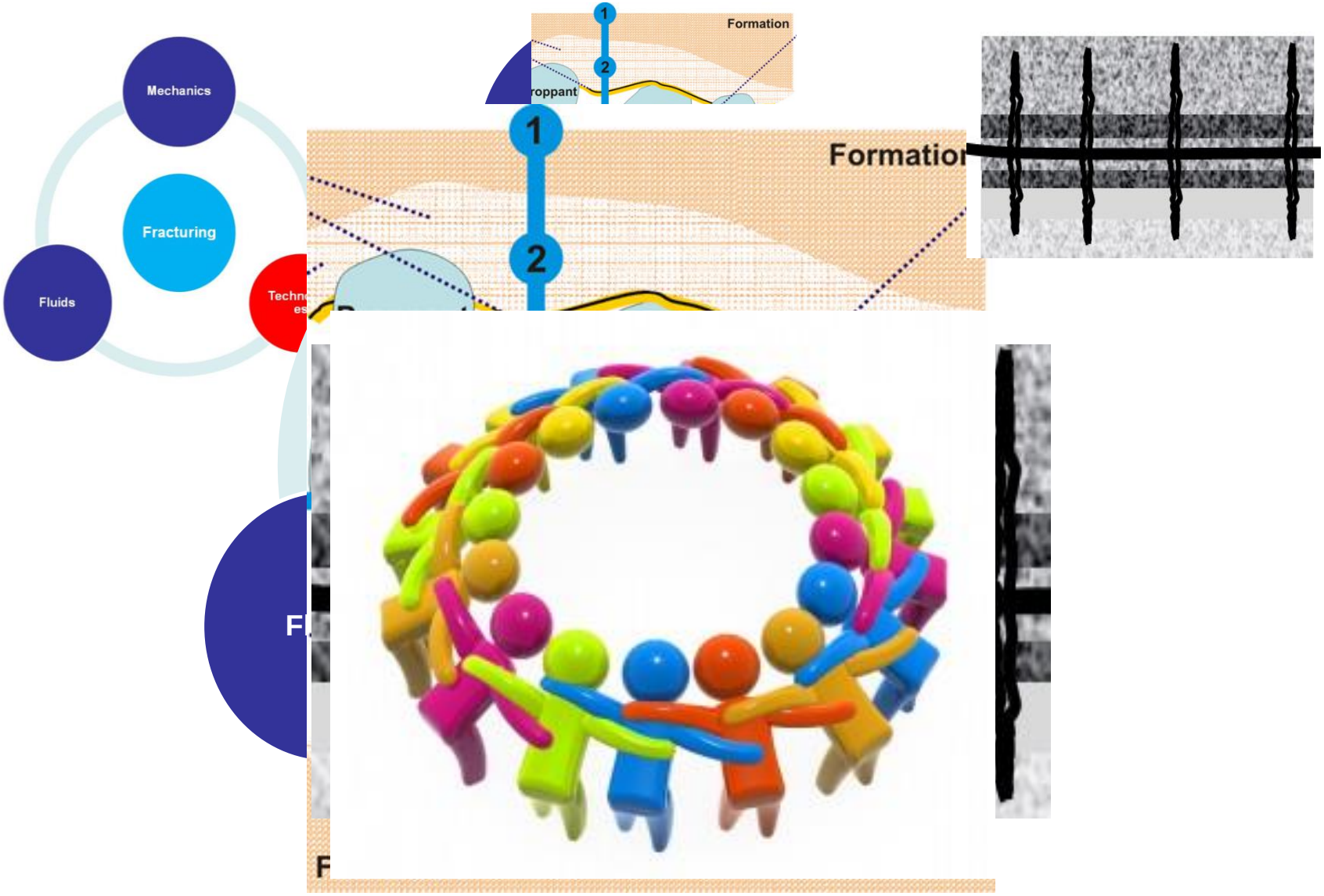
Concept

- ✓ Energy storage & pulse release (pulsed power technology concept)
- ✓ Discharging in nanosecond window to create high current electrical pulse carrying power in giga-watt range
- ✓ High-power electrical discharges transformed into fast expanding plasma in water-filled borehole

Plasma Fracturing



Conclusion



Thank You