

Key considerations for Hydraulic Fracturing of Gas Shales*

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Search and Discovery Article #80100 (2010)

Posted September 24, 2010

*Adapted from oral presentation at Geosciences Technology Workshop, “Pore Pressure & Fracturing Implications in Reservoir Characterization,” Napa, CA, May 11-13, 2010

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Descriptive Statement

Focus is on hydraulic fracture geometry in shales, the materials used in the fracturing process, and treatment monitoring via microseismic.

Key Considerations for Hydraulic Fracturing of Gas Shales

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May 12, 2010



Introduction

- Why Unconventional Gas Reservoirs need to be Hydraulically Fractured
- The importance of complex hydraulic fracture geometry
- The Hydraulic Fracturing Process described
- Fracturing Materials
- What Can We Control During a Fracture Treatment?



Why We Fracture Shale Gas Wells

- Sealed-natural-fracture-system shale wells, as they occur naturally, will not produce economic quantities of gas.
 - Implication of nano-Darcy matrix permeability on molecular travel rate
 - Mineralized and sealed natural fracture systems, in an undisturbed condition, do not allow mass transport of gas
- The hydraulic fracturing process creates not only tensile fractures, but also shears existing fractures in the target.
 - Goal is to give every gas molecule a high-speed path to the well-bore.

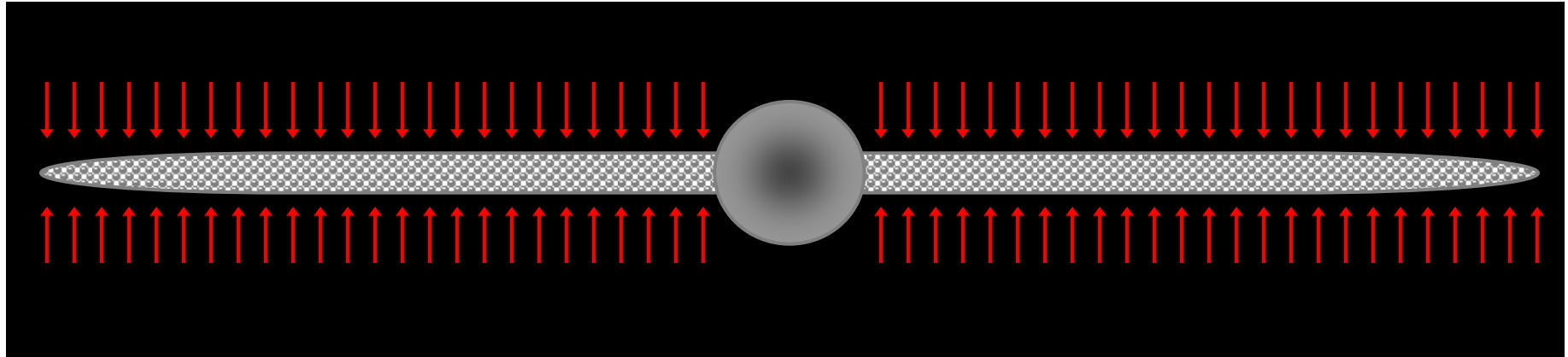


Begin With the End in Mind?

- Think about the frac before planning where to land the lateral.
- What frac fluid will be used?
 - How effectively can it transport proppant above the level of the horizontal in thick pay zones?
- Is there a good lower frac barrier?
- An effective set of propped fractures and sheared fractures is actually what you are buying in gas shales.
 - How much embedment is expected?
 - Is the proppant strong enough?
 - Will the proppant retain strength over the long term?
 - What is the maximum length of lateral that can be placed into the formation and effectively cleaned up after fracturing?



Classic Bi-Wing Fracture

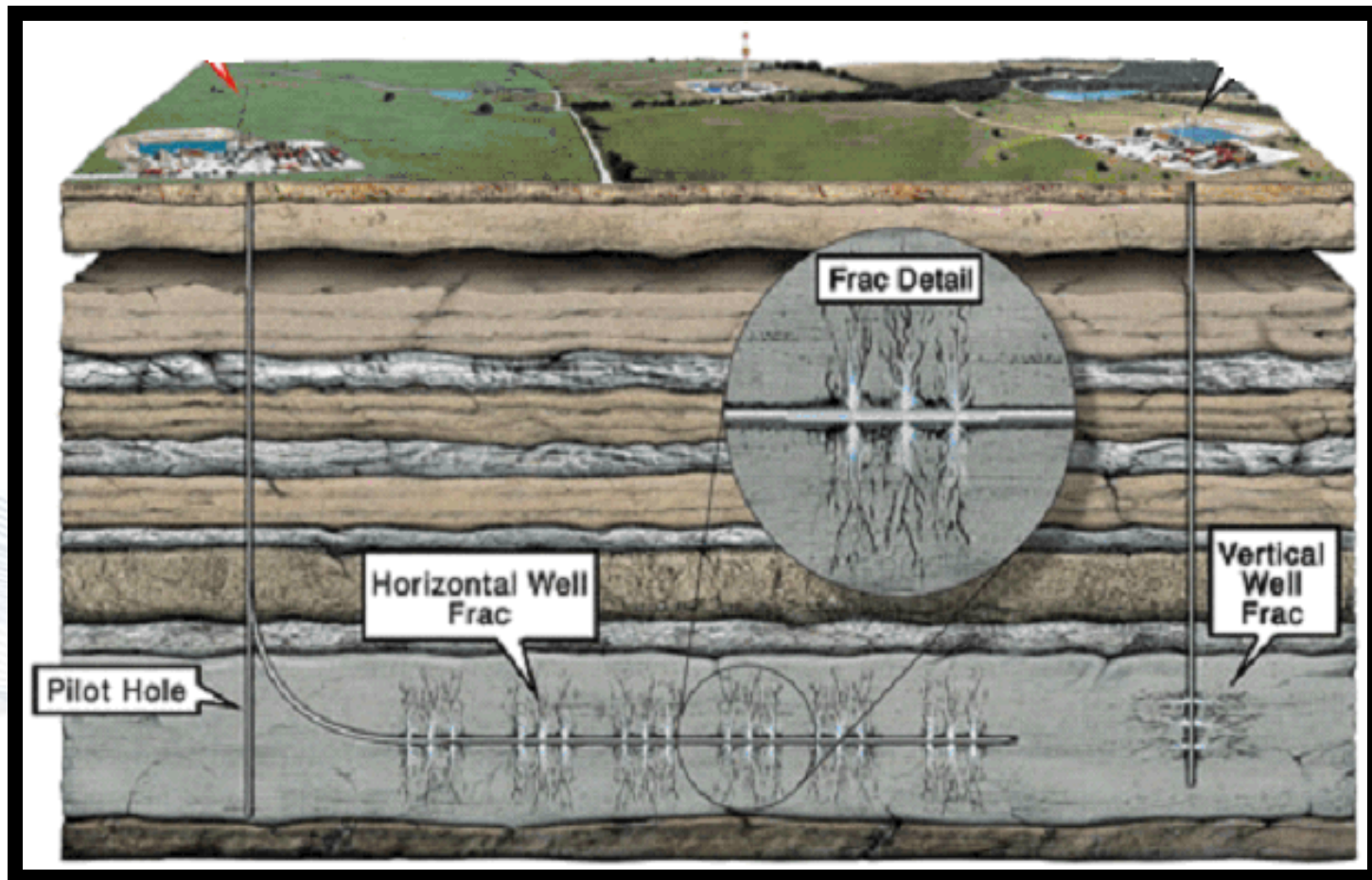


This fracture geometry is not a good thing for sealed-natural-fracture shale plays!



Complex Hydraulic Fracturing

- Requirement for sealed-natural-fracture shale gas systems



The Hydraulic Fracturing Process

Pump Pad, Slurry, & Flush (Repeat as Necessary), and Recover

- A fracturing treatment operation begins by rigging up a high pressure steel treating or flow line from special high-pressure fracturing pumps to the well and pressure-testing the equipment for safety.
- The next step is to inject a large volume of special fluid(s) into a prospective producing formation at an injection rate that will place sufficient stress on the rock to cause the rock to physically split (fracture) in one or more places. This initial volume of fluid is termed the “Pad” and typically comprises 20% of total fluid volume.
- The Pad fluid is pumped to create enough fracture width to accept proppant particles. Proppant is typically comprised of size-graded, rounded and nearly spherical white sand, but may also be man-made particles.
- Proppant particles are mixed into additional fracturing fluid and the resulting slurry is pumped into the reservoir, propping open the created fracture(s) so that they will remain open and permeable after pump pressure is relieved.
- At the end of placing the slurry, a tubular volume of clean “Flush” fluid is pumped to clear tubulars of proppant and the pumps are shut down.
- Well pressure is then bled off to allow the fracture(s) to close on the proppant.
- The final step in a fracturing treatment is to recover the injected fluid by flowing or lifting the well.



Basic Fracturing Fluid Materials (1)

- Base Fluids (make-up fluids)
 - Water, Oil
- Energizing Gases – used to aid in fracturing fluid recovery
 - CO₂ or N₂ or both
- Gelling Agents - Viscosifiers used to thicken fracturing fluids (1's to 10's of centipoise) to improve fluid efficiency and proppant transport.
 - Guar Gum or modified Guar Gum
- Crosslinkers – Used to super-thicken fracturing fluids (100's to 1000's of centipoise)
- Friction Reducers – Used in Slick Water Fracs to reduce friction losses in pipe while injecting fracturing fluids
- Breakers – used to reduce viscosity of fracturing fluids after the treatment to allow fluids to more easily flow out of the formation for recovery
- Surfactants and Non-emulsifiers
 - Surfactants reduce surface tension – aid in fluid recovery
 - Non-emulsifiers prevent treatment fluid and reservoir liquids from emulsifying

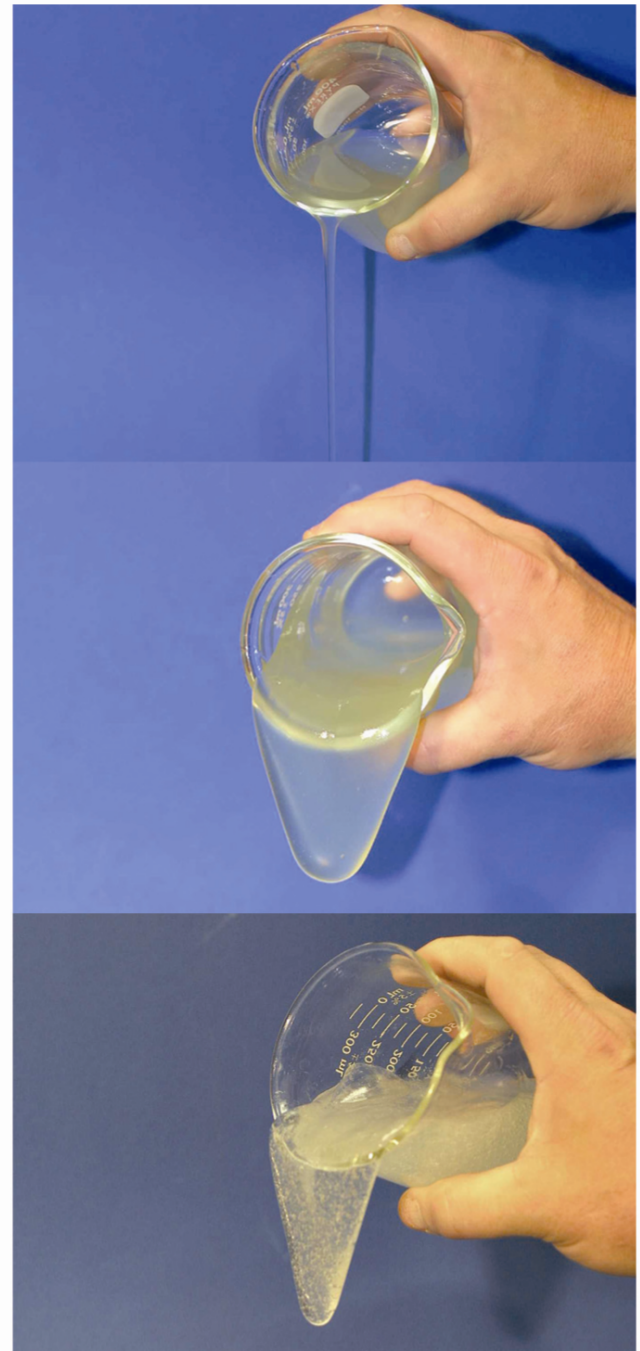


Basic Fracturing Fluid Materials (2)

- Temporary Clay Control Agents – prevent clay swelling and minimize migration of clay fines
 - 1 – 7% KCl
 - TMAC (Clay Treat 3C)
- Biocides – kill bacteria in fracturing fluid make-up waters
 - Used to minimize souring of reservoirs resulting from injection of contaminated surface water
 - Used to prevent bacteria in make-up water from destroying gelling agents before the treatment can be pumped
 - Gelling Agent = Bug Food



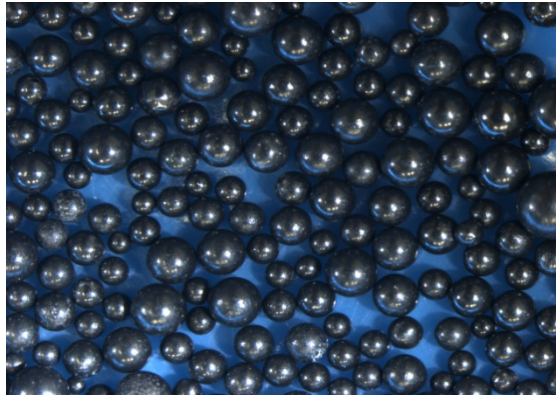
Crosslinked Polymer



Types of Proppant



Ottawa Frac Sand



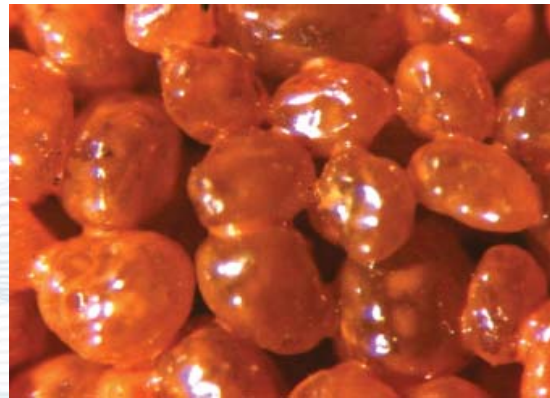
LiteProp™ 108 ULWP



Low Density Ceramic



Brown Frac Sand



Resin-Coated Sand



Sintered Bauxite



What Can We Really Control In the Fracturing Process?

- Proppant properties & quantity(ies)
- Proppant distribution?
 - Location in 3-D space and propped fracture width distribution
- Fluid rheology(ies) and volume(s)
- Injection point(s) – sometimes...
- Injection rate and rate of change
- Flowback rate
- What about how the rock cracks?



Fracturing Challenges in Unconventional Gas Reservoirs

- Simple or complex fracture geometry?
- Hydraulic fracture height, length, width or reservoir volume accessed?
- Fracture azimuth?
- Geohazards?
 - Faults
 - Karsts
 - Wet zones
- Where did the frac go and what did it touch (or not)?
- Where was the proppant placed and how was it distributed?
- Which zones cleaned up the frac fluid and are productive?

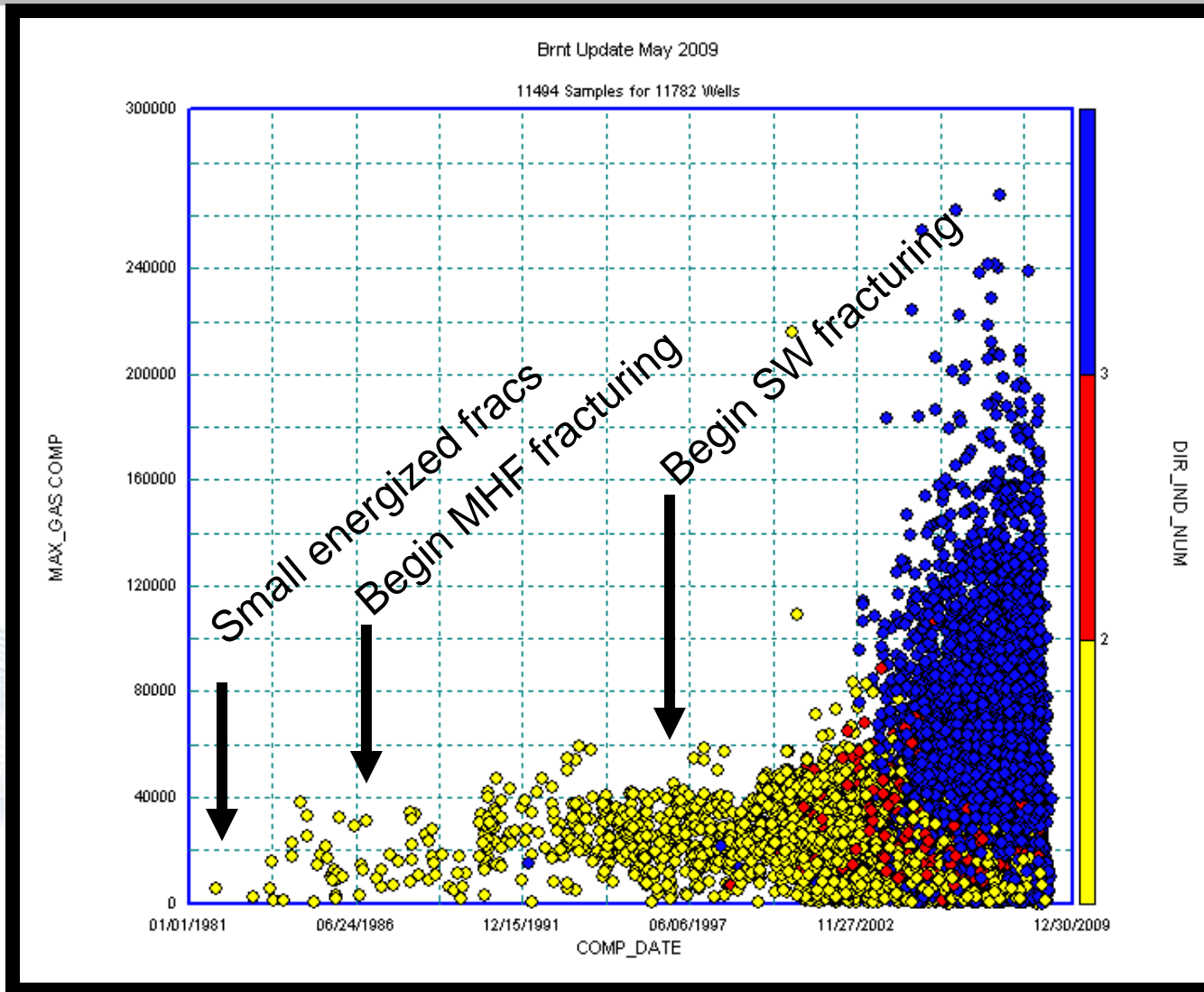


Post-Fracture Treatment Monitoring Methods

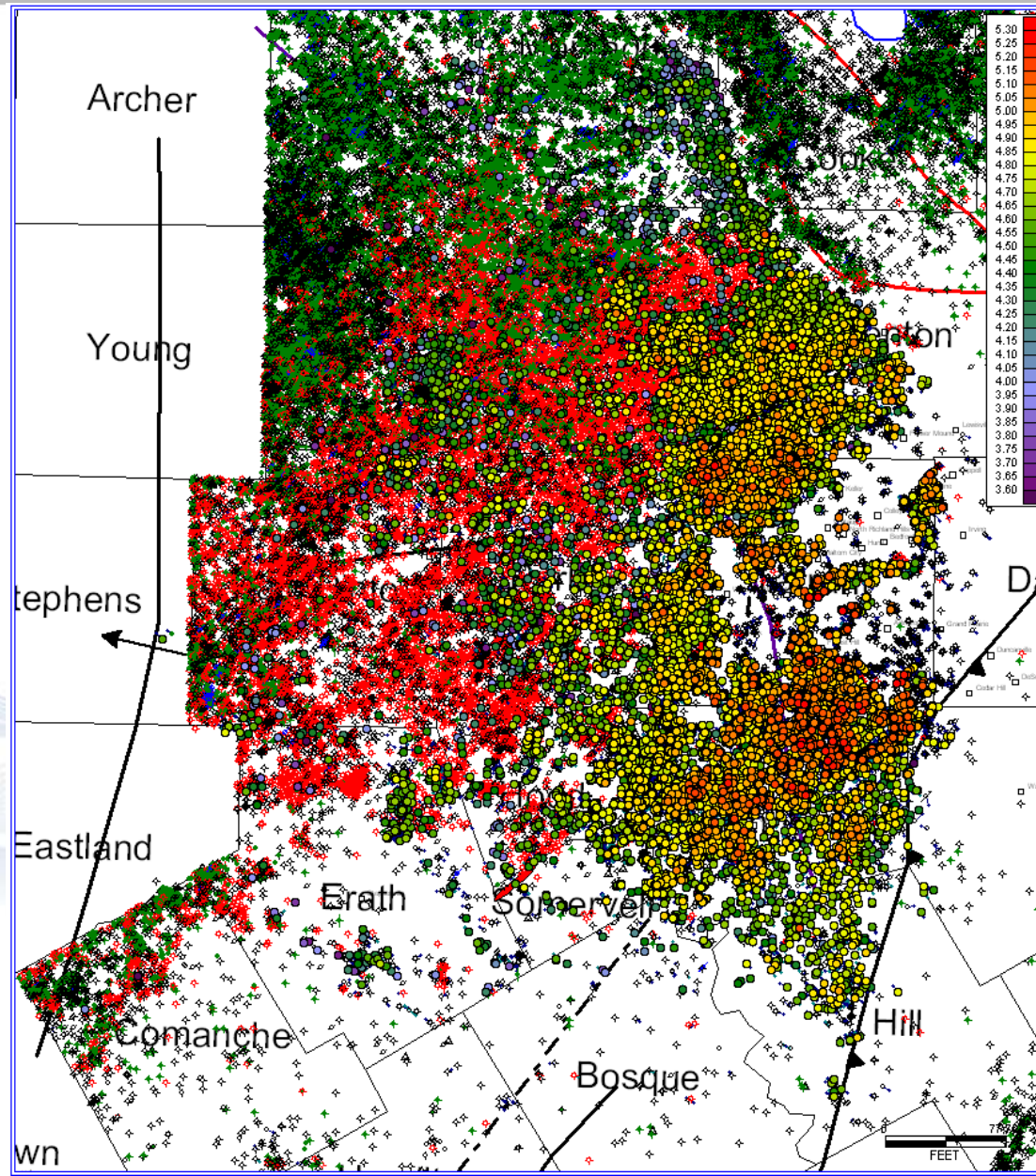
- Conventional Temperature and Tracer Surveys
 - Immediate or near-immediate post-frac
 - Data pertains only to immediate well-bore vicinity
 - Requires post-treatment logging
 - Fluids and proppant can be traced
- Distributed Temperature Sensing (DTS)
 - Especially useful for cleanup studies
- Production Logging
 - Spinner surveys
 - Requires logging well after fracture fluid cleanup
- Tiltmeter
 - Not commonly used to monitor Shale Gas treatments
- Microseismic Monitoring
 - During the fracture treatment
 - Near real-time
 - May be used for post-treatment analysis and for near real-time treatment management



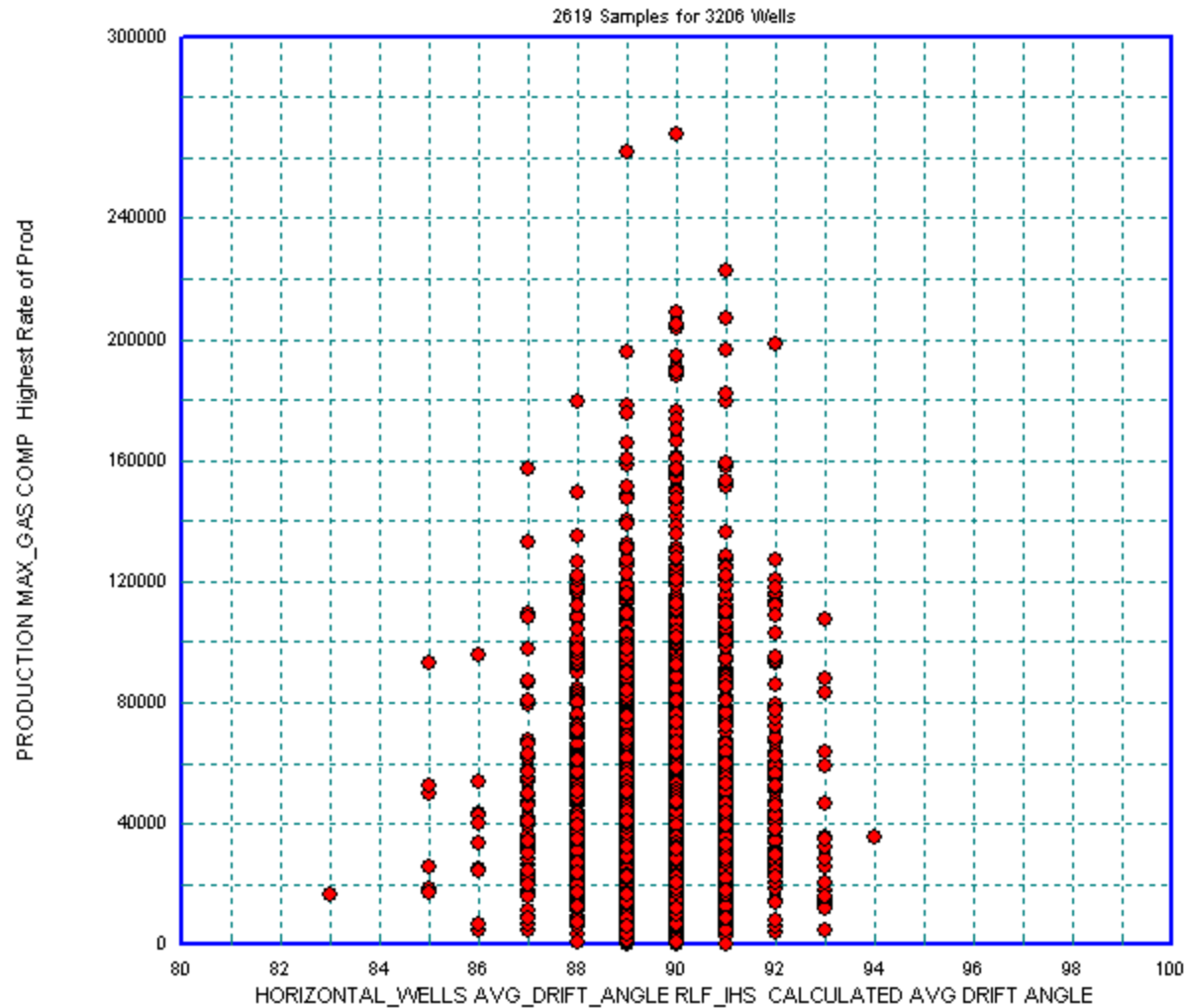
Barnett Shale Production Time Line



Effect of Thermal Maturity, Barnett Shale



Gross Effect of Drift Angle



A serene sunset scene over a body of water. The sky is filled with soft, horizontal bands of orange, pink, and purple. Two large, dark evergreen trees stand prominently on the horizon, their silhouettes reflected in the calm water below. The water's surface is dotted with reeds and other aquatic plants, also reflected. The overall mood is peaceful and contemplative.

Thank You!