Improving the Effectiveness and Managing the Impact of Hydraulic Fracturing

Guy Lewis

Gas Technology Institute

IGRC October 2011

Topics

- Who is GTI
- Hydraulic Fracturing & Unconventional Gas
  - Brief History
  - Hydraulic Fracturing Research
- Societal Concerns
  - Fracturing and Water
    - Water Required
    - Fluids Injected
    - Fluid Flow Back
  - Other Issues
- Looking Ahead
  - Role of Collaboration
  - Next R&D Opportunities

GTI takes on important energy challenges, turning raw technology into practical solutions that create exceptional value for our customers in the global marketplace.

GTI Overview

> Not-for-profit research, with 70 year history

> Facilities
  – 18 acre campus near Chicago
  – 300,000 ft^2, 28 specialized labs
  – Other sites
  – $140 M installed R&D and testing capacity

> Staff of 250

> 1000 patents; 500 products

> 13 spin-out companies

Offices & Labs

Flex-Fuel Test Facility

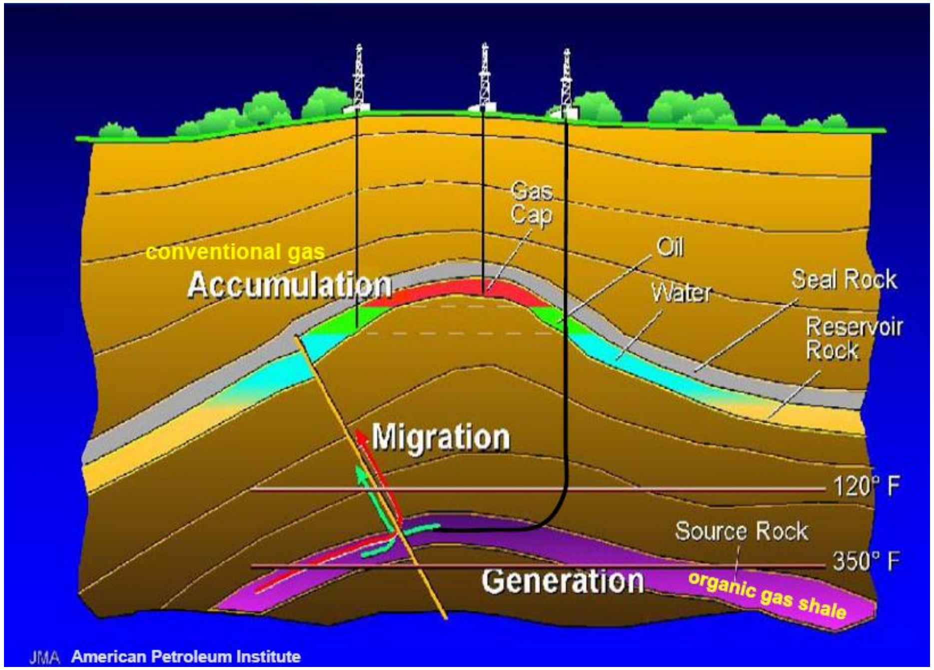
Energy & Environmental Technology Center


APRIL 11, 2011
Libya's Civil War
A GRAVE SCANDAL AT ARLINGTON
People Power for Palestine
BY JOE KLEIN
BATTER UP! YOUR GUIDE TO THE 2011 BASEBALL SEASON
The last great work of David Foster Wallace
BY LEV GROSSMAN
TIME
ENVIRONMENT SPECIAL
THIS ROCK COULD POWER THE WORLD
WHY SHALE CAN SOLVE THE ENERGY CRISIS
BY BRYAN WALSH
www.time.com

Unconventional Gas

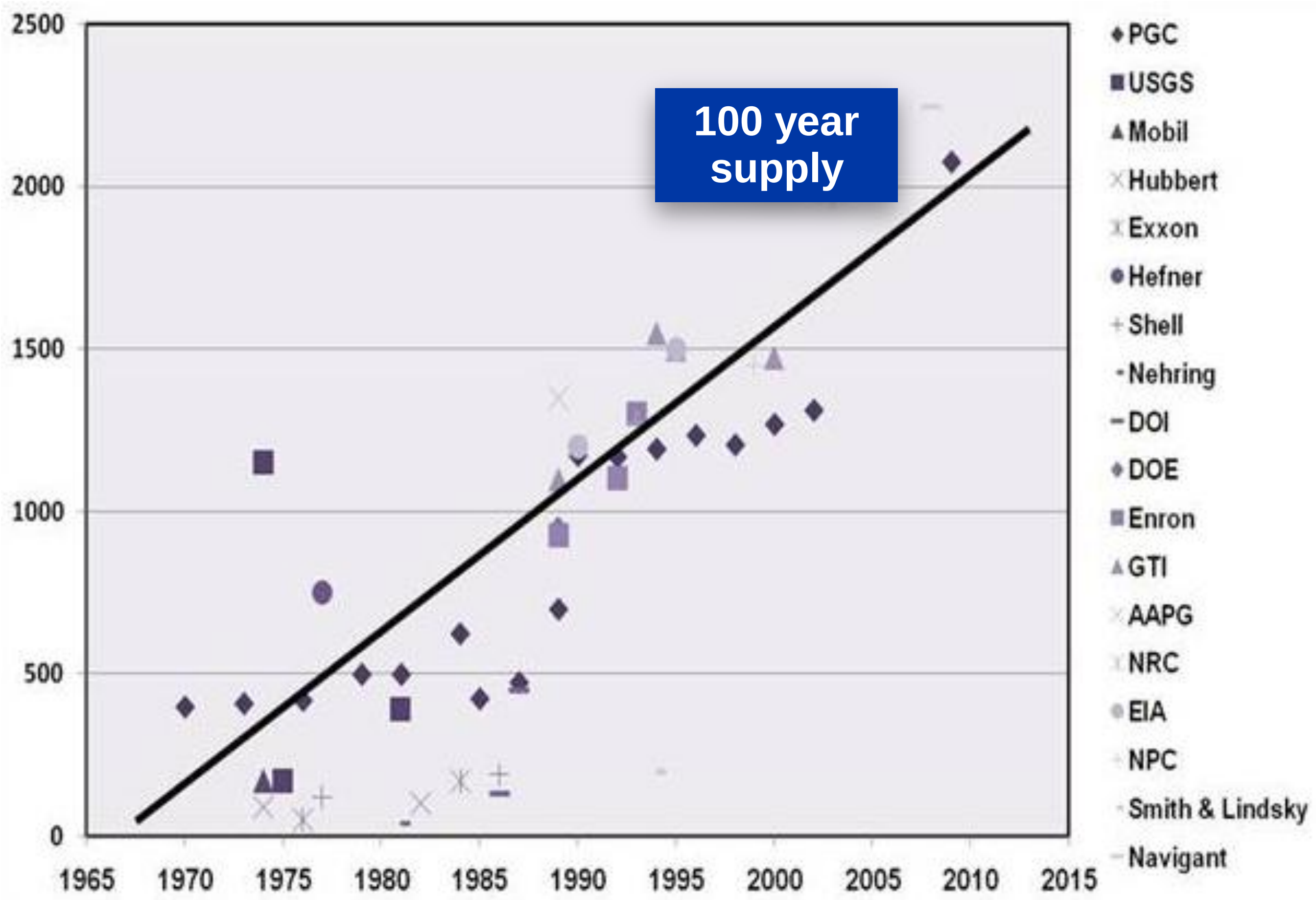
Conventional gas = harder to find, easier to produce.
Unconventional gas = easier to find, harder to produce.

Requires some type of stimulation (e.g. hydraulic fracturing) for economic production.

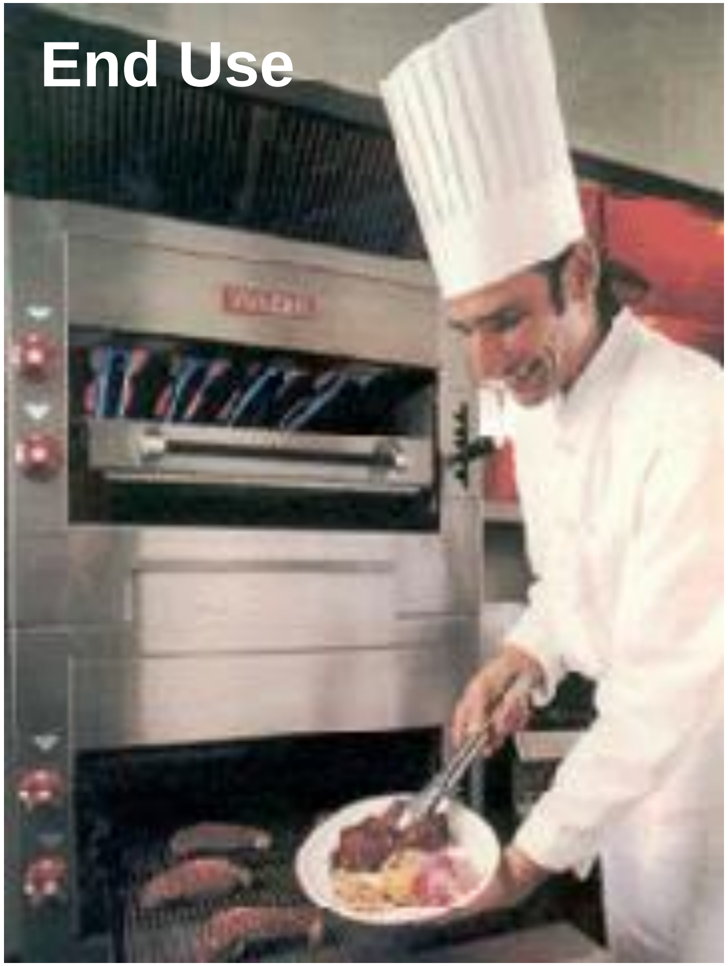


U.S. is Self Sufficient for 100 Years

U.S. Technically Recoverable Resource (Tcf)



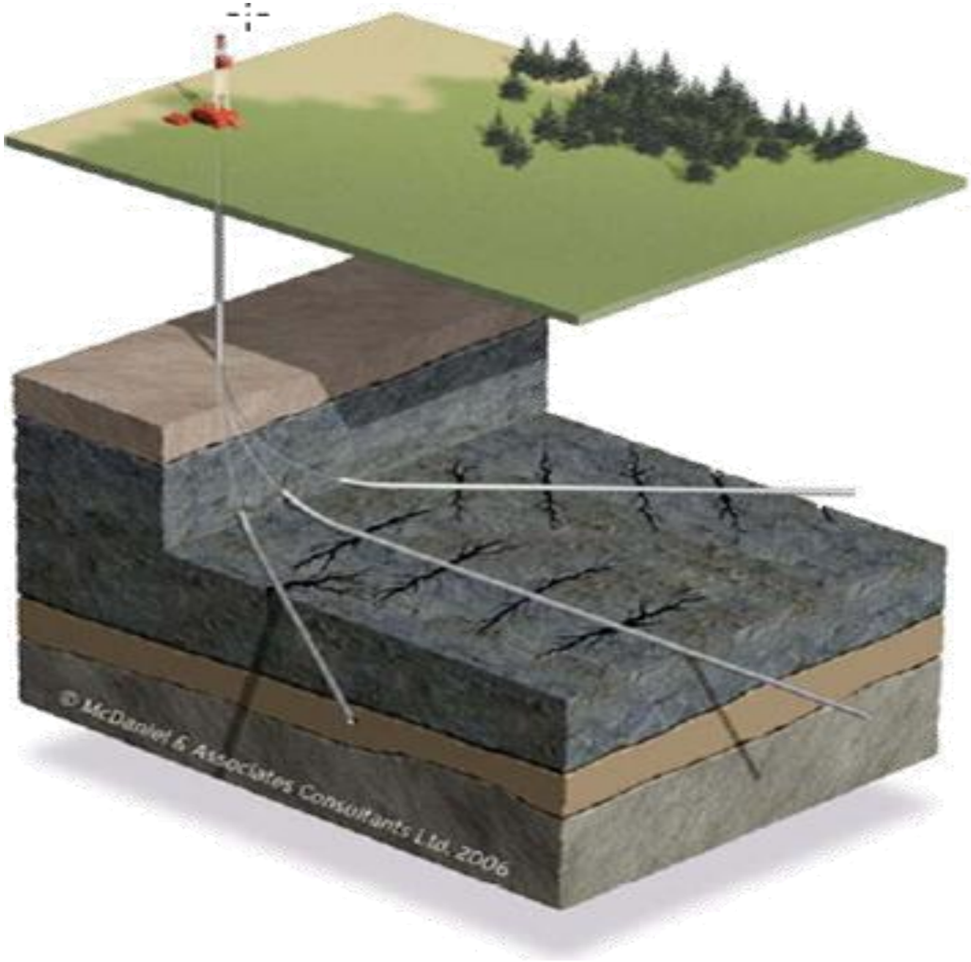
Abundant Supply Leads to Expanded Use



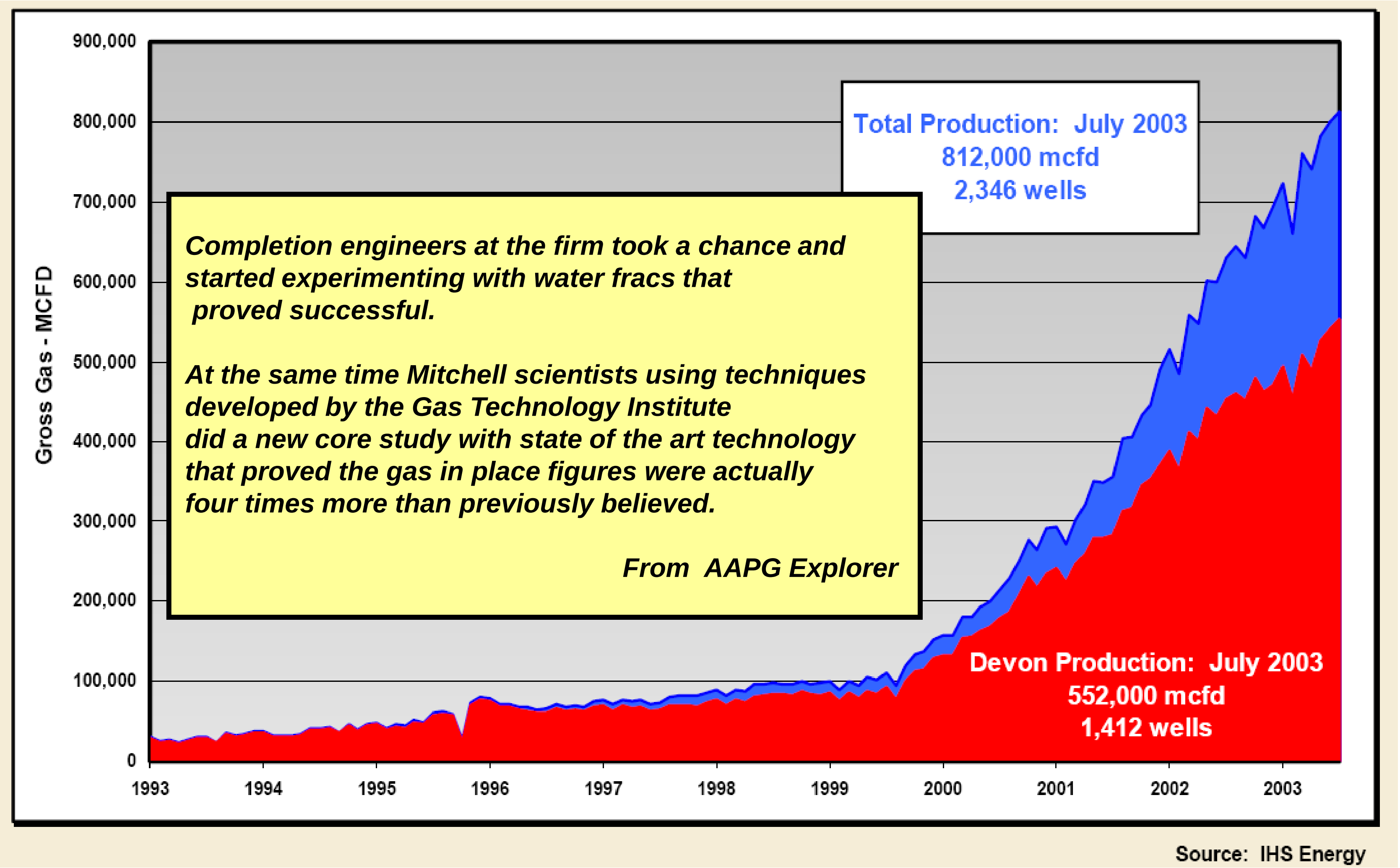
Key Technologies Unlocked Shale

- Horizontal Wells
- Hydraulic Fracturing
- Seismic Imaging

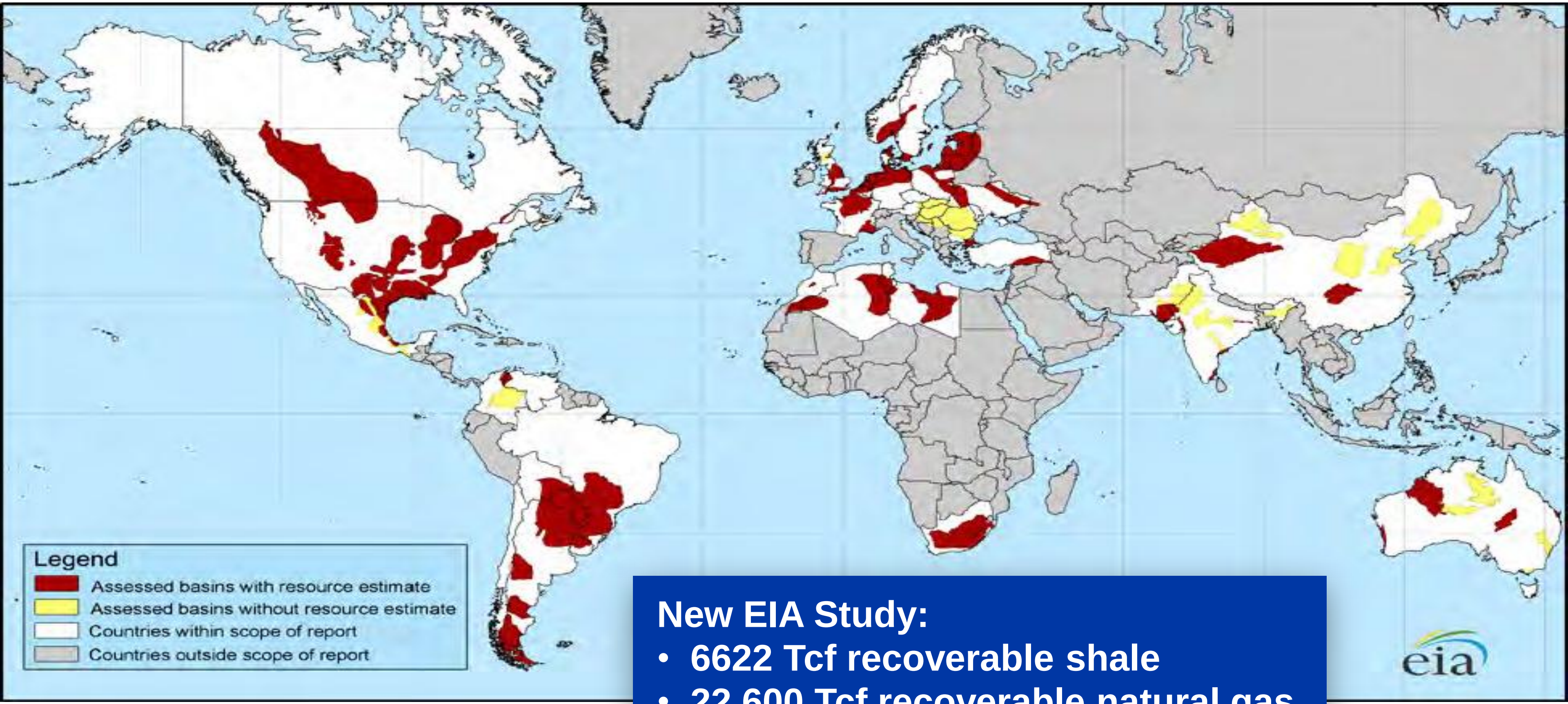
George Mitchell, Pioneer of the U.S. shale gas revolution



Barnett Production



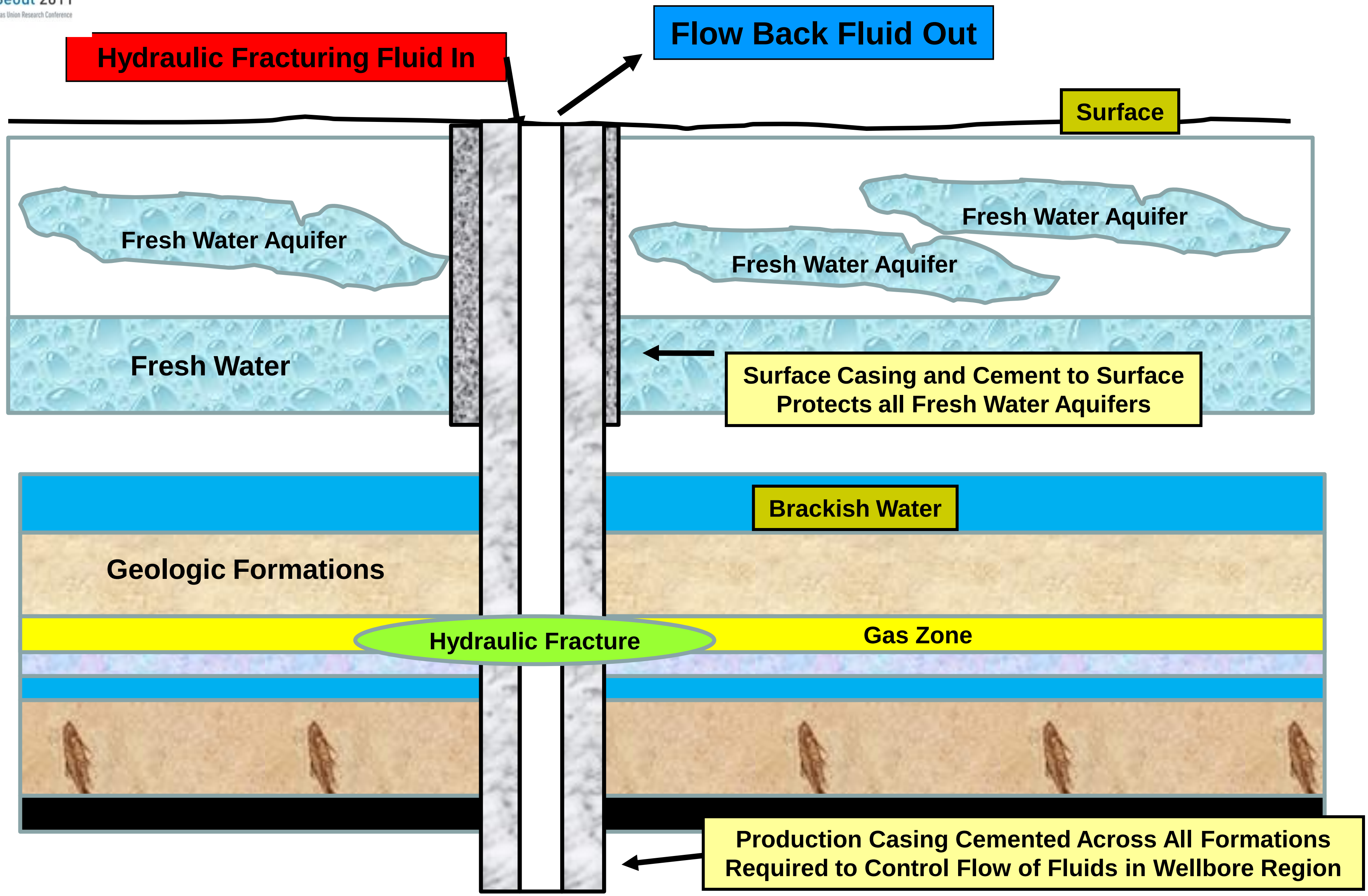
A Global Resource



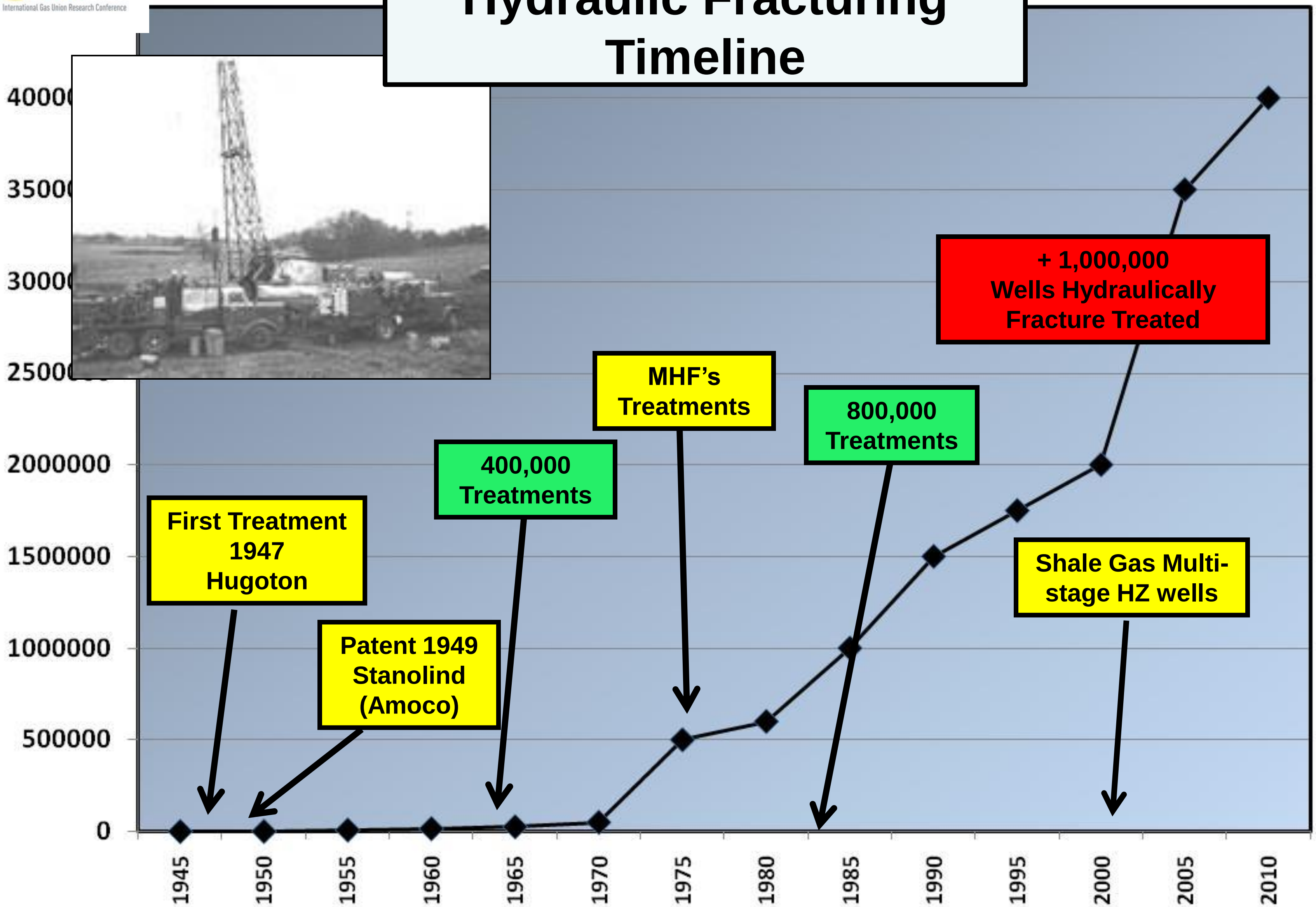
New EIA Study:
- **6622 Tcf recoverable shale**
- **22,600 Tcf recoverable natural gas**

Global shale adds 40%!

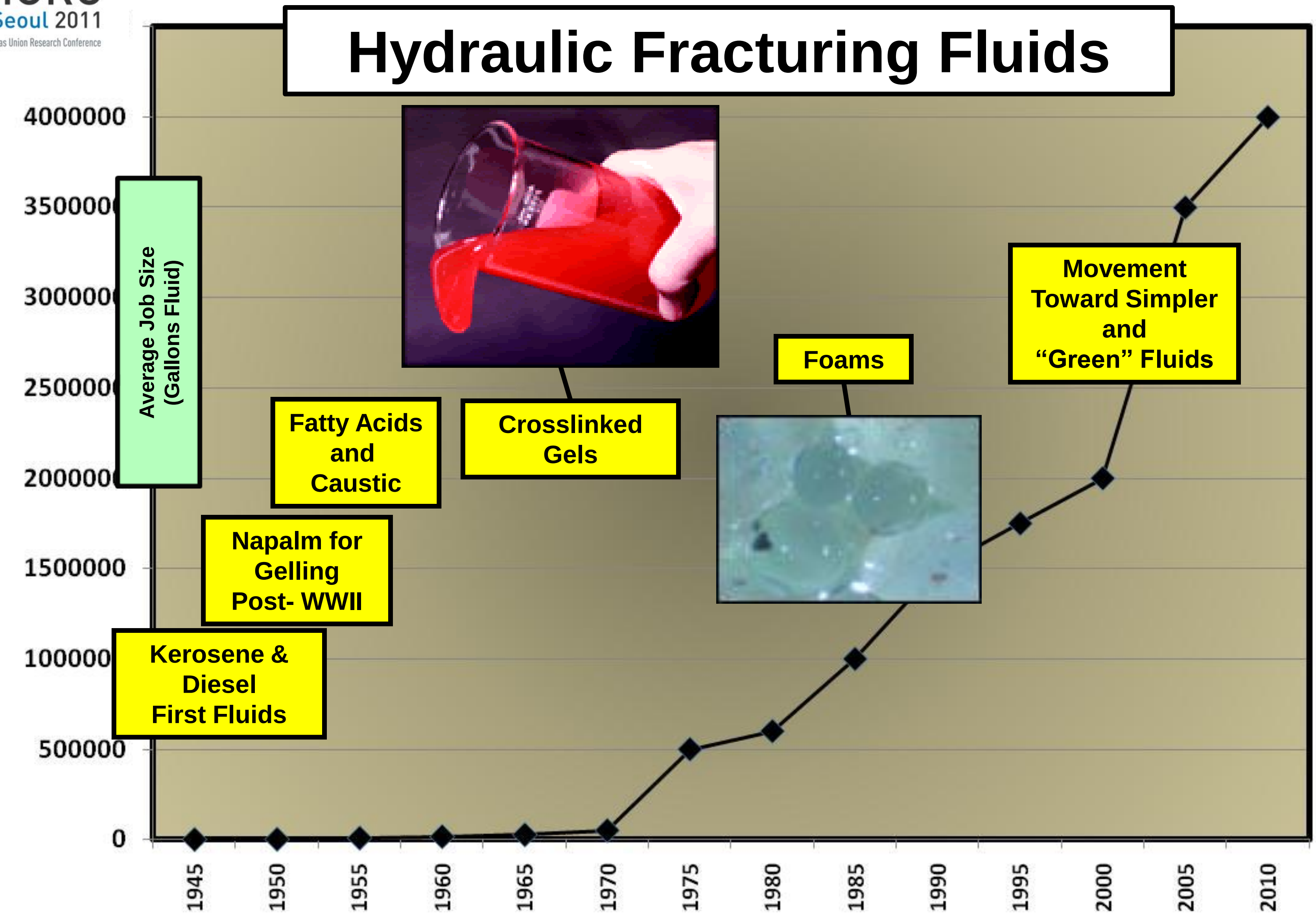
Hydraulic Fracturing



Hydraulic Fracturing Timeline

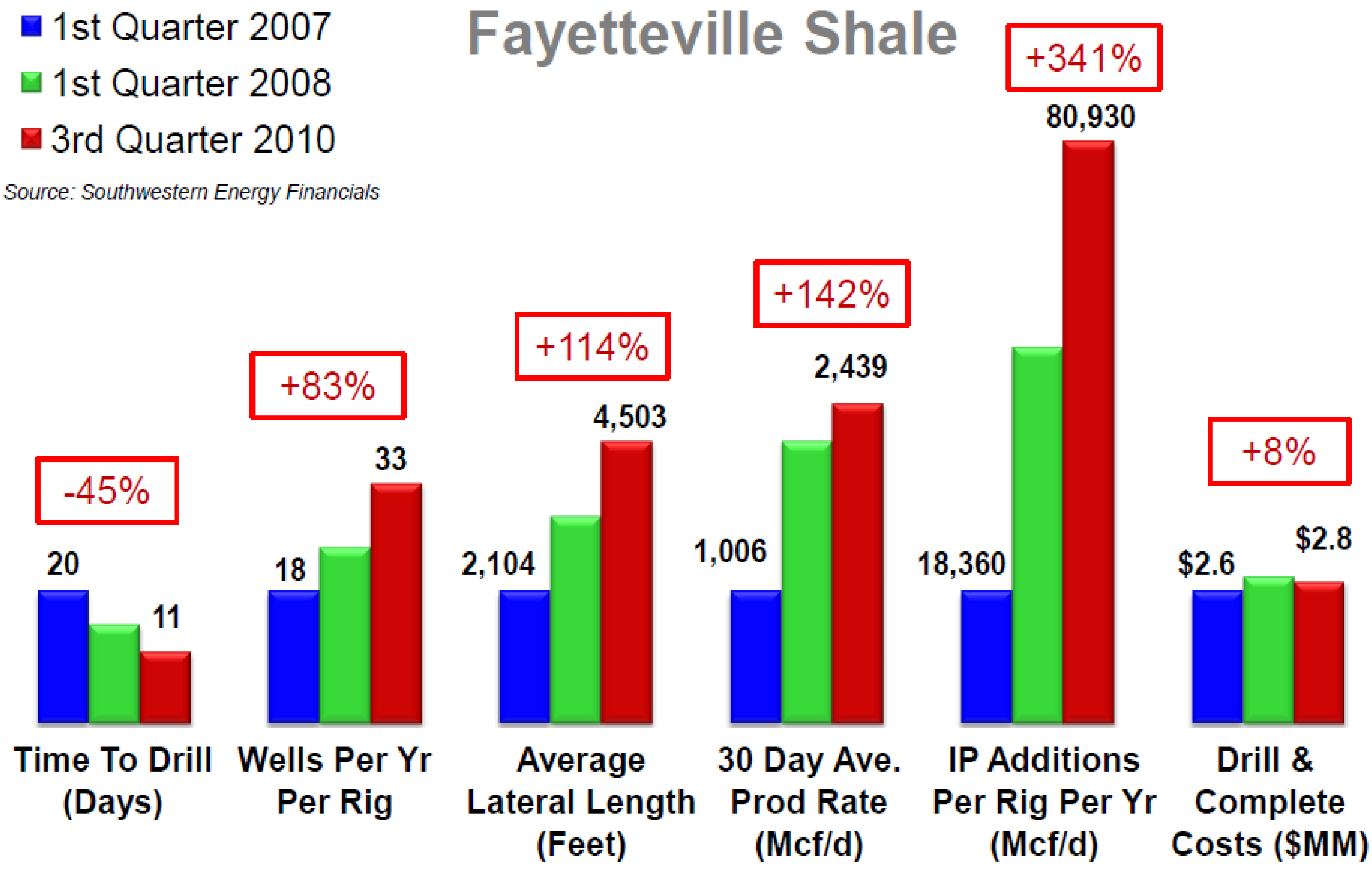


SPE Papers 801, 22392, 36166, IOGCC, Halliburton



SPE Papers 22392, 36166, Halliburton

Southwestern Energy's Rig Productivity



IGRC Seoul 2011
International Gas Union Research Conference

Hydraulic Fracturing Research

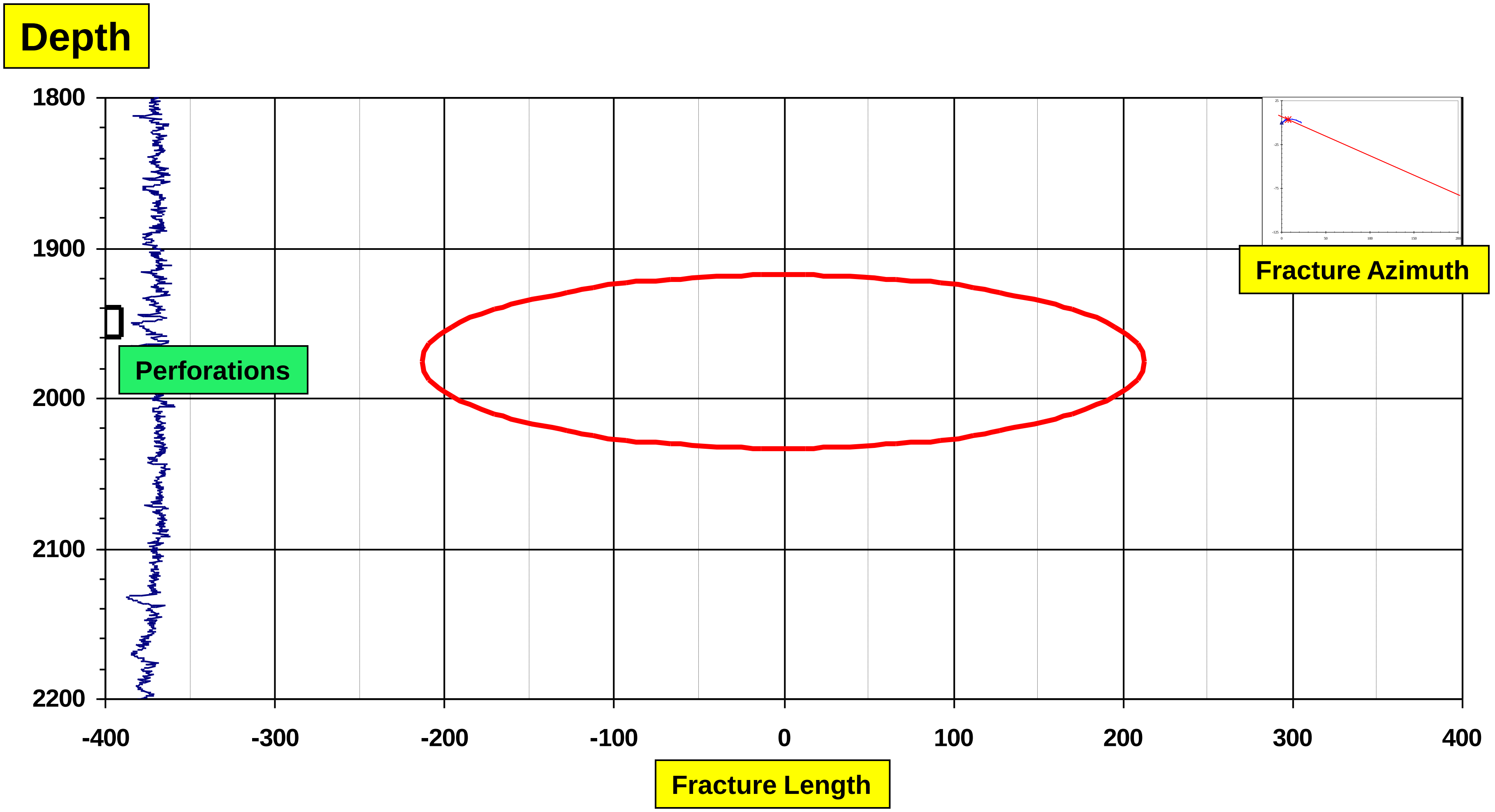
Staged Field Experiments

M-Site Hydraulic Fracturing Research

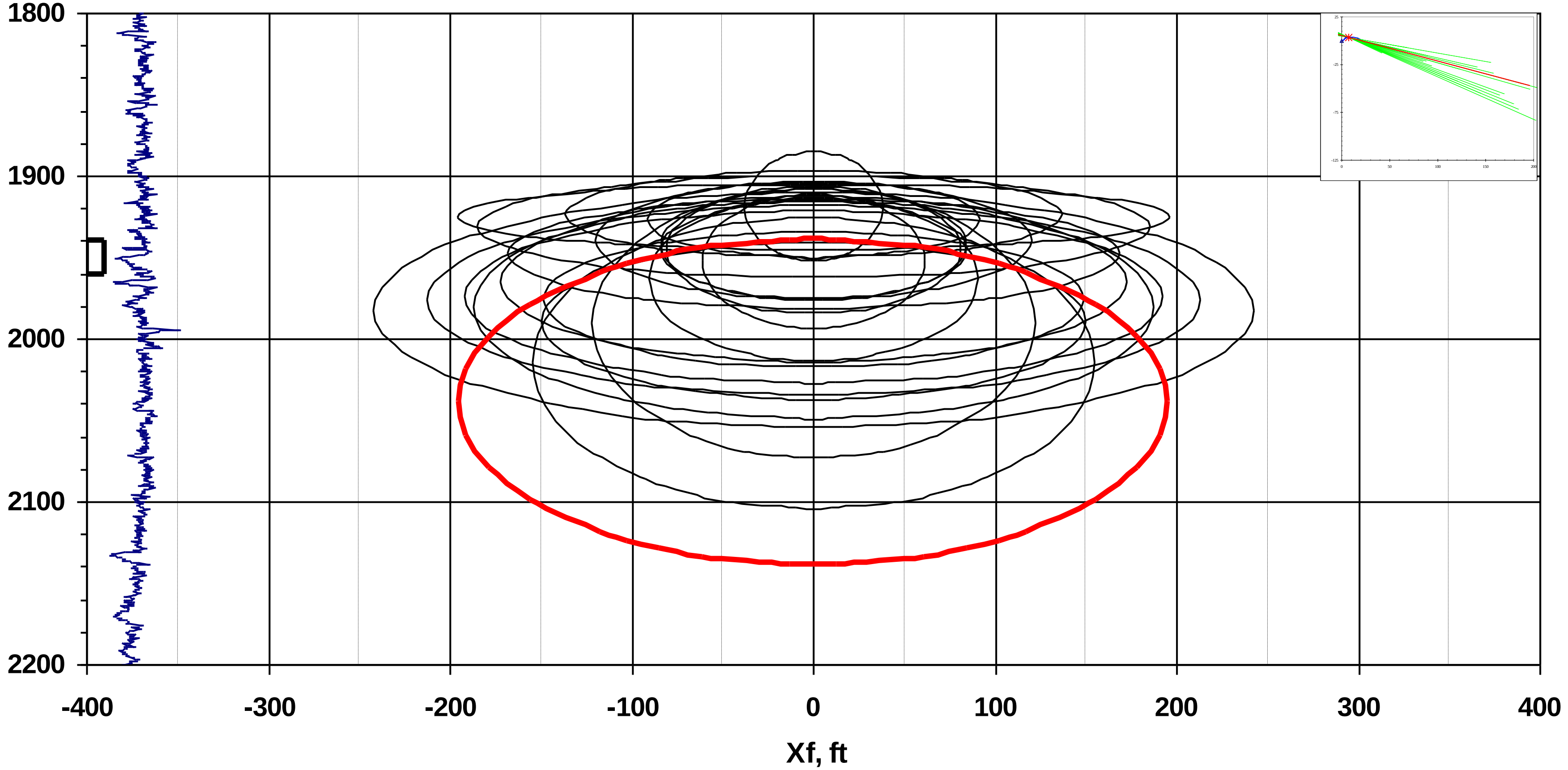
Mounds Hydraulic Fracturing Research Experiment

- **Multiple Wells**
- **Tilt meters**
- **Inclinometers**
- **Coring of Created Fractures**
- **Modeling**
- **Microseismic**
- **Full Geologic Characterization**
- **Multiple Fracture Treatments**
- **Seismic**
- **Colored Proppants**
- **Tracers**

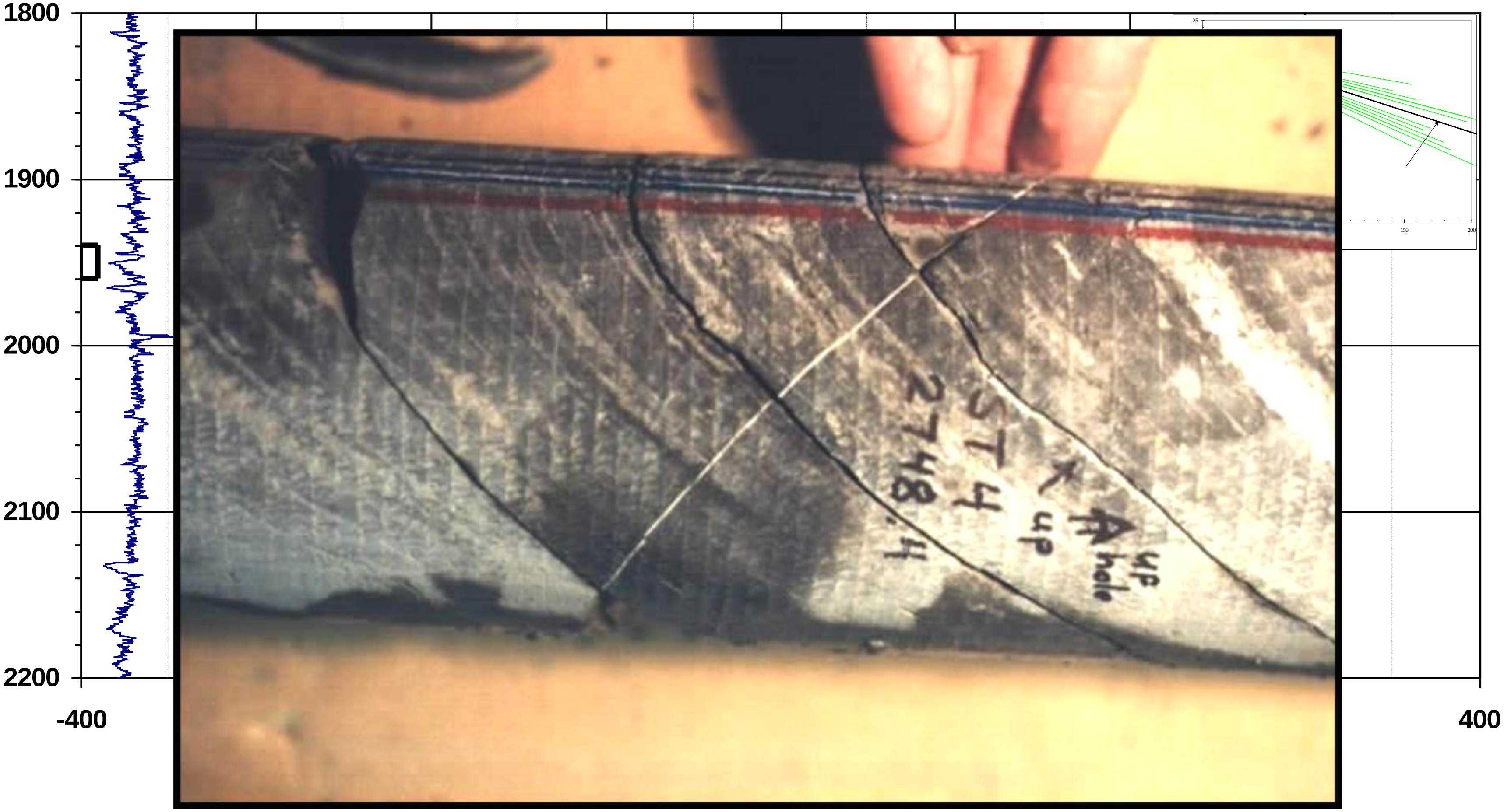
Atoka Shale Stage OA



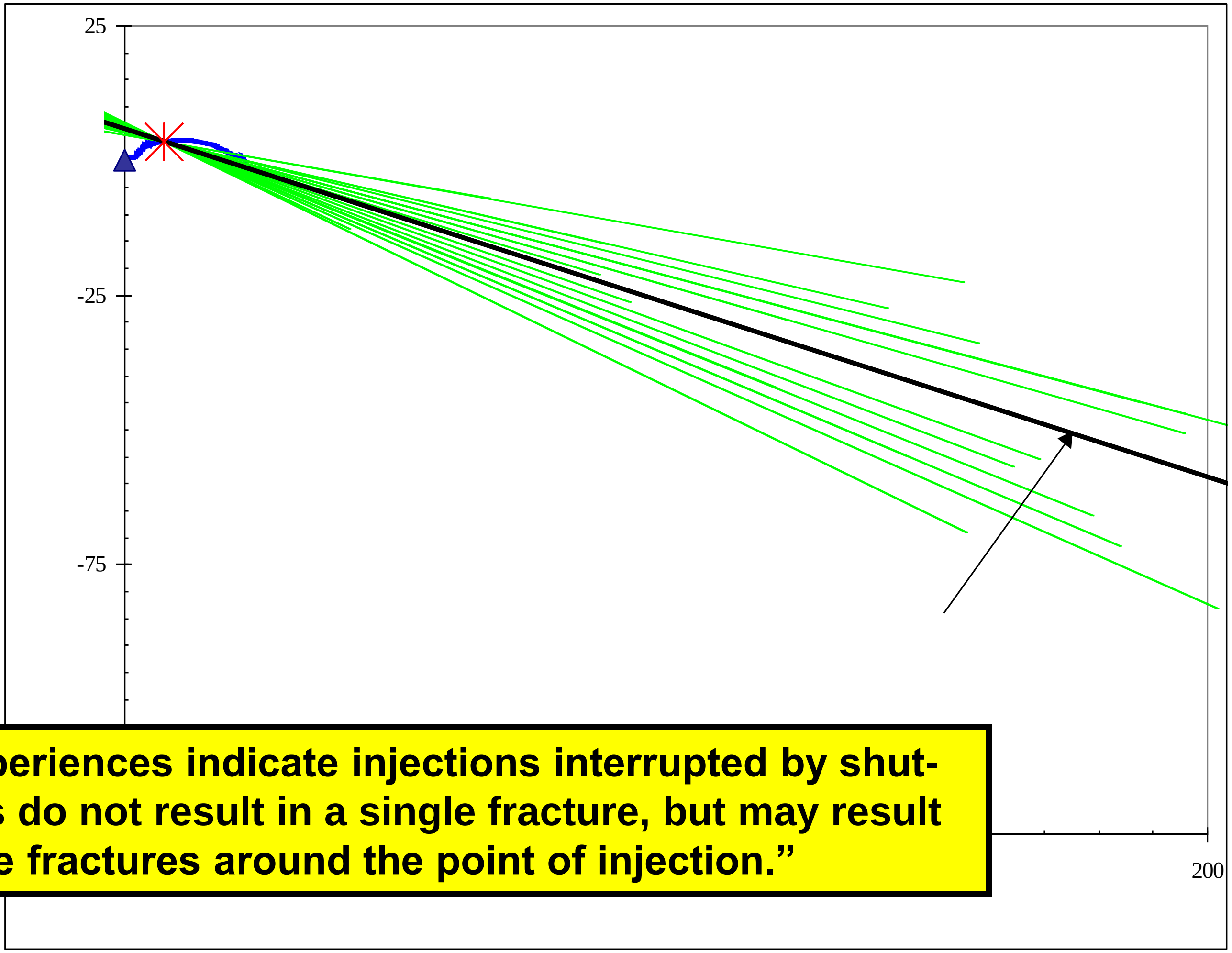
Atoka Shale Stage 19



Atoka Shale All



Multiple Fractures Created



"Field experiences indicate injections interrupted by shut-in periods do not result in a single fracture, but may result in multiple fractures around the point of injection."

Gas Shale—Two Rocks

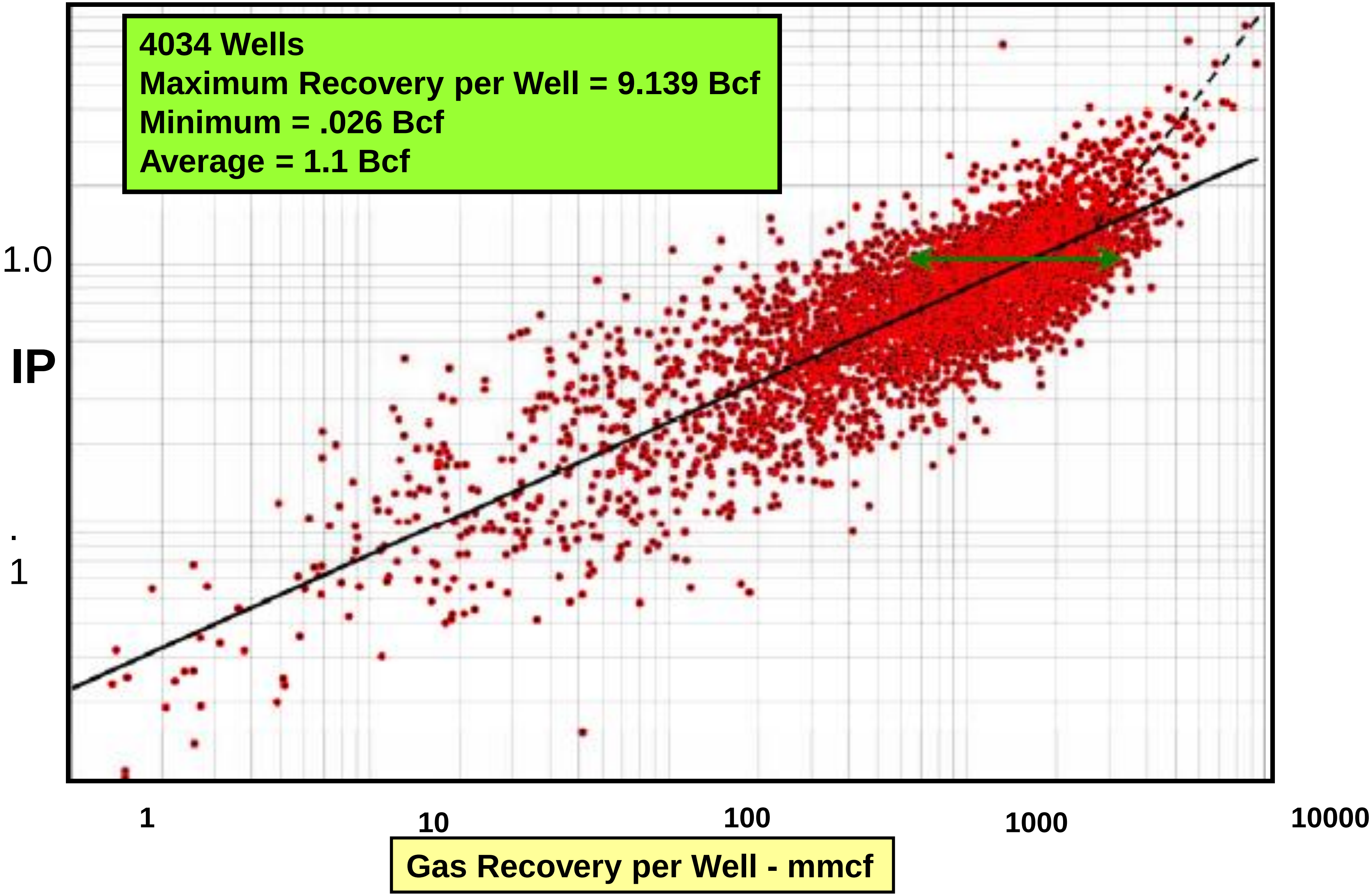
Organic Clay Rich Shale
Produces adsorbed gas

Quartz Rich Shale
Produces free gas

They may look the same, but they have very different production performance profiles.

Gas Shales and Other Unconventional Gas Resources

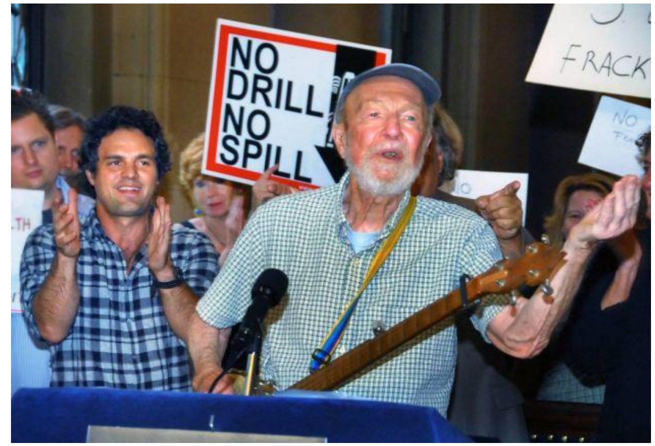
Barnett Shale Gas Recovery per Well

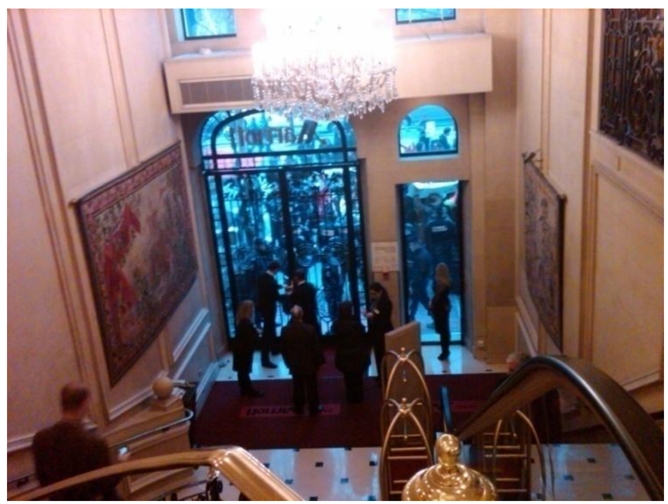


IGRC Seoul 2011
International Gas Union Research Conference

NOT SO FAST!

Negative Media and Public Sentiment

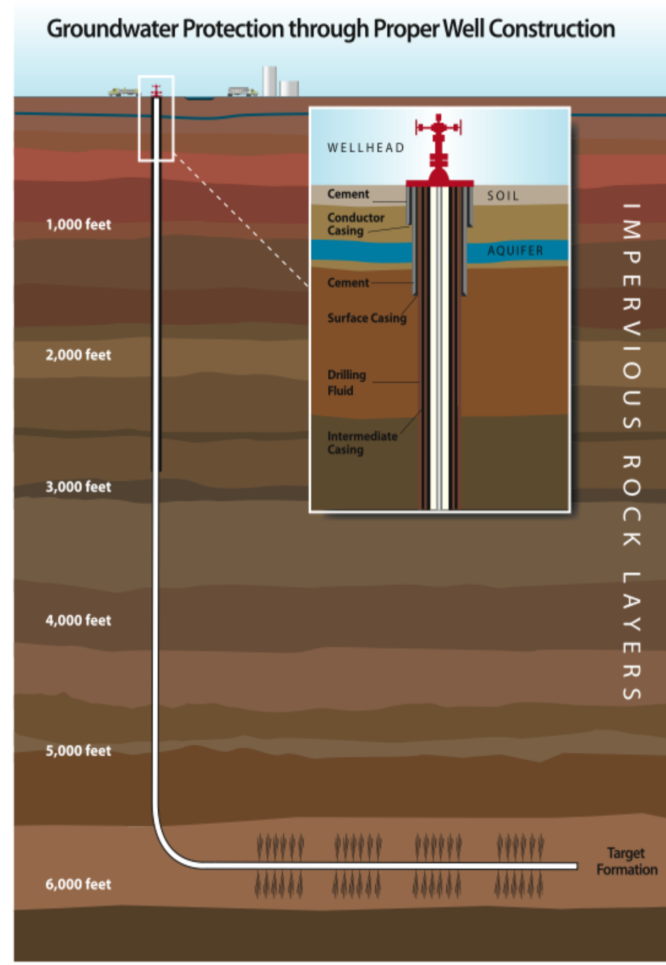




The New York Times

Shale Gas Concerns…Not Just Water

- Water quality and availability
- Air quality
- Noise
- Truck traffic & CO2 produced
- Surface disturbance
- Methane emissions
- Solid waste generation
- Induced seismicity

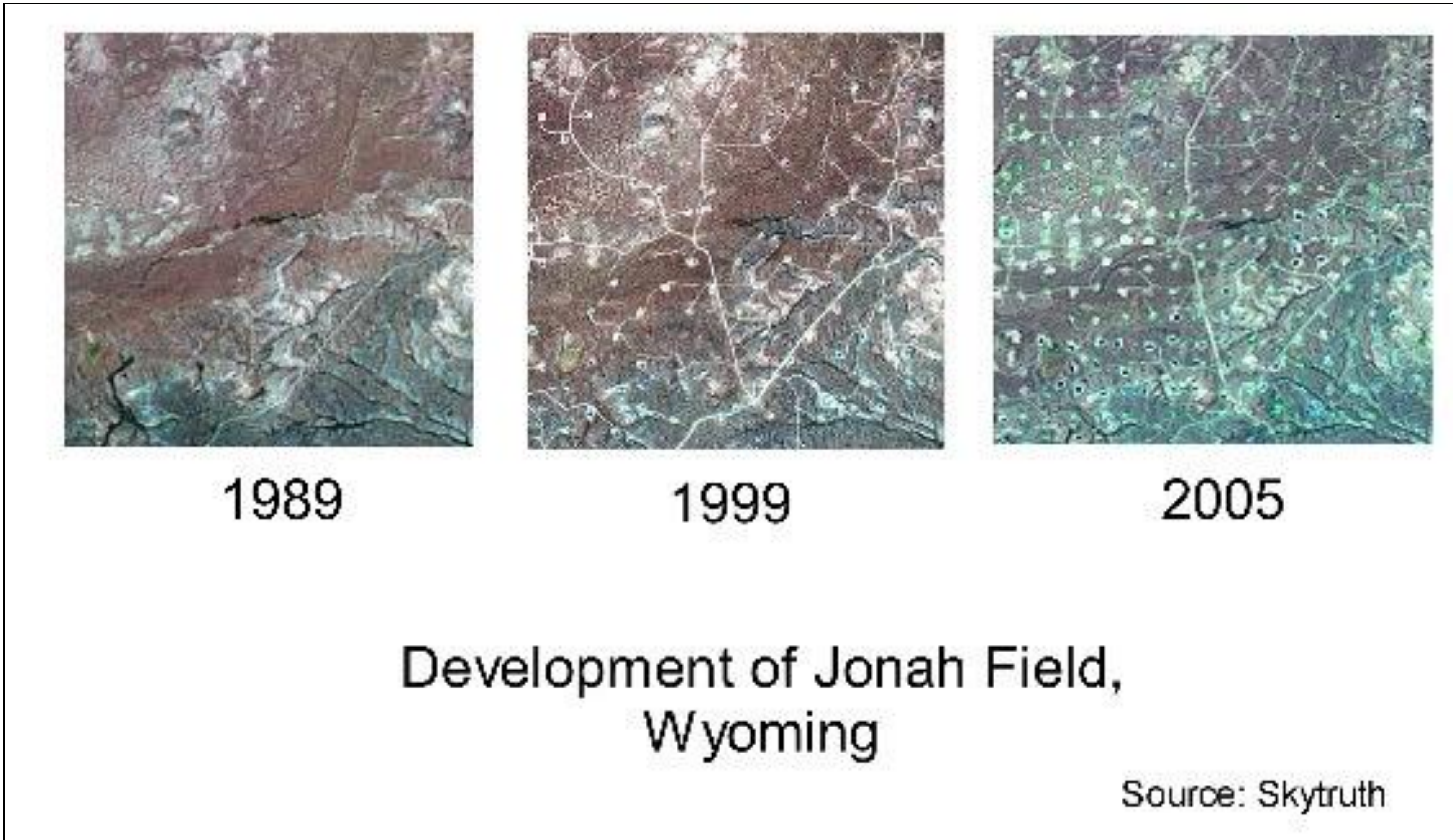


Issues—Why Now?

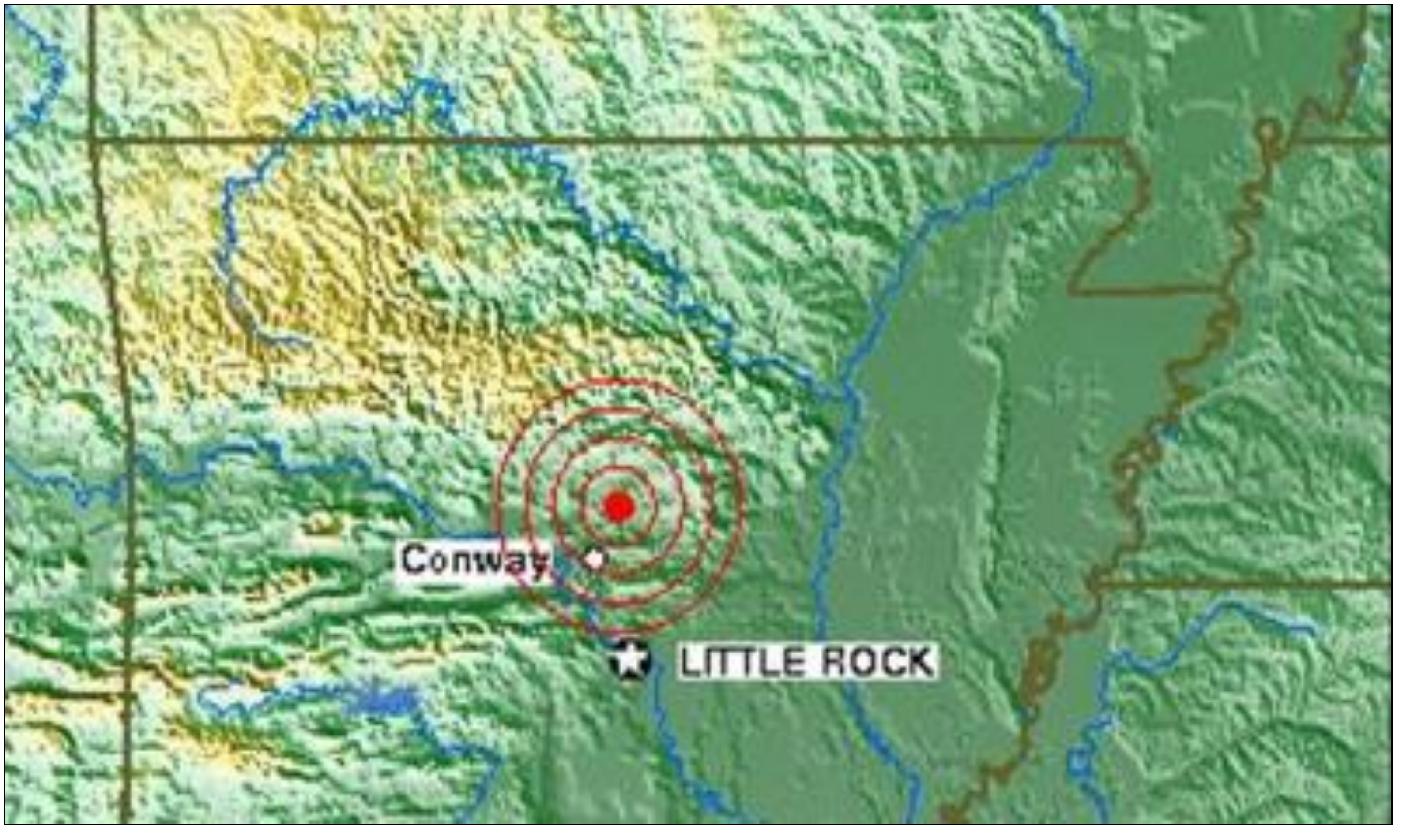
- Significant Activity in New and Populated Areas
- Complex Process
- Environmental Concerns
  - Water Usage
  - Chemicals
- Press—Good News is not News
- Internet
- Solution = Good Science, Transparency and Information that is Easy to Understand

The Science of Human Behavior as Much as the Science of Fluid Rheology

Drilling Footprint



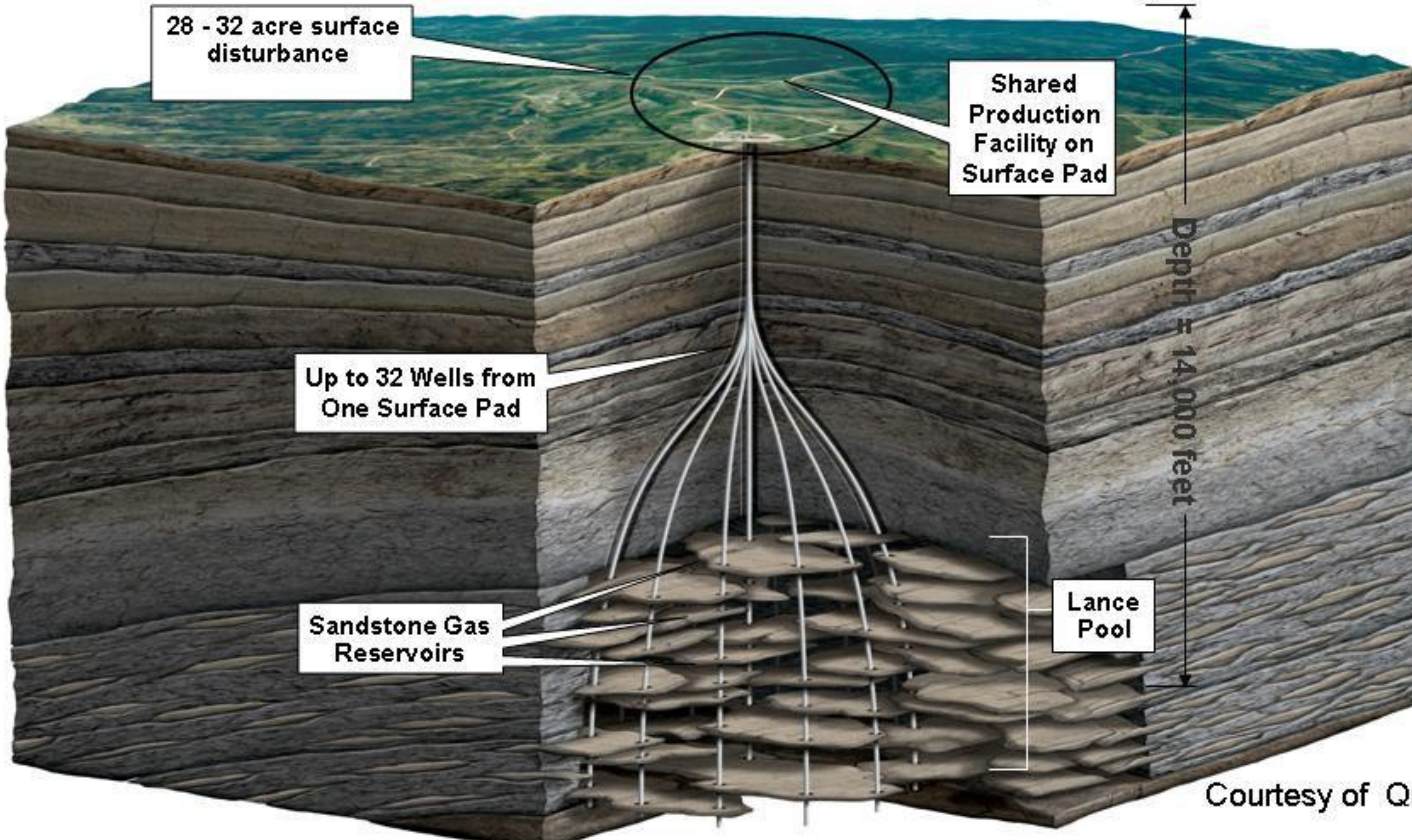
Induced Seismicity



Responsible Energy Development = It can be done

Multiple directional wells from one pad:

- Minimizes surface disturbance
- Identical surface disturbance for 20 or 40 ac. bottom-hole spacing



Courtesy of Questar

IGRC Seoul 2011
International Gas Union Research Conference

Wellheads on Pad Location Prior to Fracing

Opportunities for Environmental Mitigation

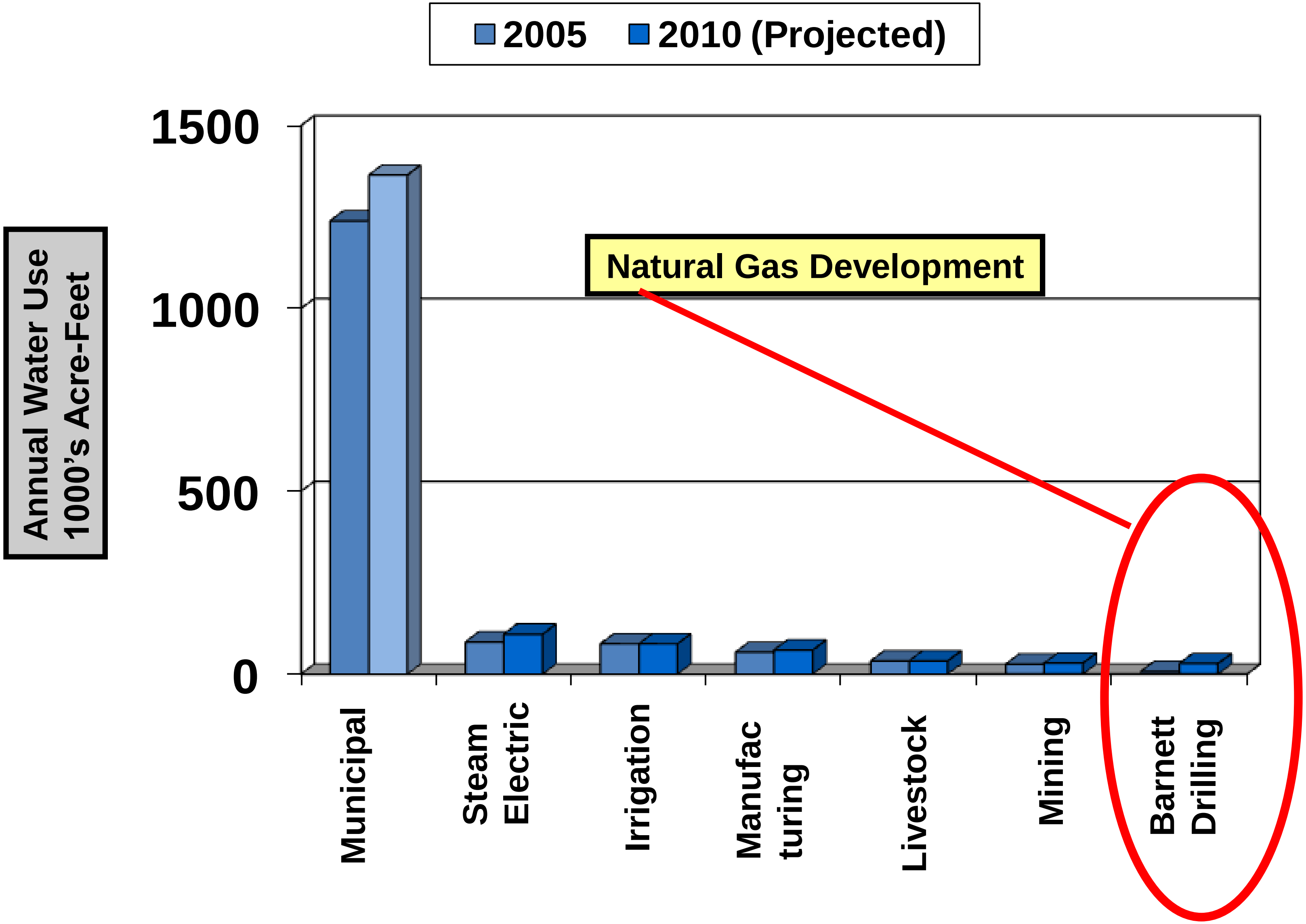
- Good Science
- Transparency
- Base Lining
- Pad Drilling Technology
- Unitization
- Technology—All Areas
- Information to Offset Misinformation
- Social Networking

Groundwater Contamination Where is the Risk?

- Hydraulic fracturing—Unknown: Occurrences and risk factors likely very low and localized.
- Septic systems—Known: Occurrences and risk factors likely high and localized but also cumulative.
- Storm water—Known: Occurrences and risk factors not fully quantified but likely high and widespread.
- Pesticides and nutrients—Known: Occurrences and risk factors not fully quantified but likely very high and widespread

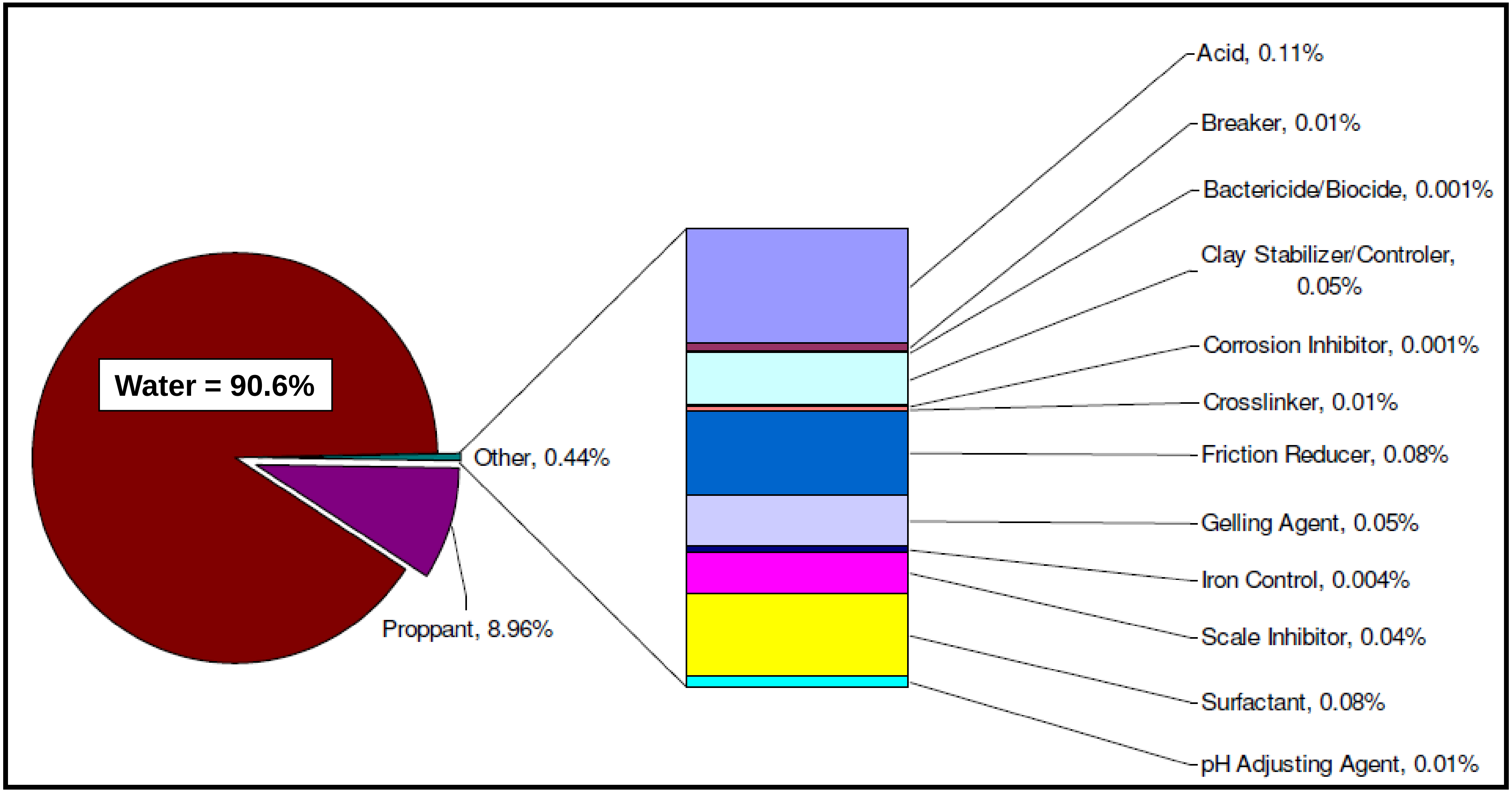
Ground Water Protection Council (GWPC)

Freshwater Users in the Barnett Shale Region



Hydraulic Fracturing

What Goes In?



NYSERDA - 2009

Fracturing Fluid Additives and Usage

Additive	Main Compound	Common Use
Diluted Acid	Hydrochloric or Muriatic Acid	Swimming Pools
Biocide	Glutaraldehyde	Dental Disinfectant
Breaker	Ammonium Persulfate	Bleaching Hair
Crosslinker	Borate Salts	Laundry Detergents
Iron Control	Citric Acid	Food Additive
Gelling Agent	Guar Gum	Biscuits
Scale Inhibitor	Ethylene Glycol	Antifreeze
Surfactant	Isopropanol	Glass Cleaner
Friction Reducer	Polyacrylamide	Water and Soil Treatment

Selected Metals in Flow Back Water—Samples from Two Locations

Metal **	Location A 14-d FB	Location B 14-d FB
Chromium (Cr^{3+})	ND	ND
Copper	ND	0.023
Nickel	ND	0.033
Zinc	0.06	0.18
Lead	ND	ND
Cadmium	ND	0.002
Mercury	0.000049	0.000027
Arsenic	0.05	0.017

* mg/l; ND=Non Detect

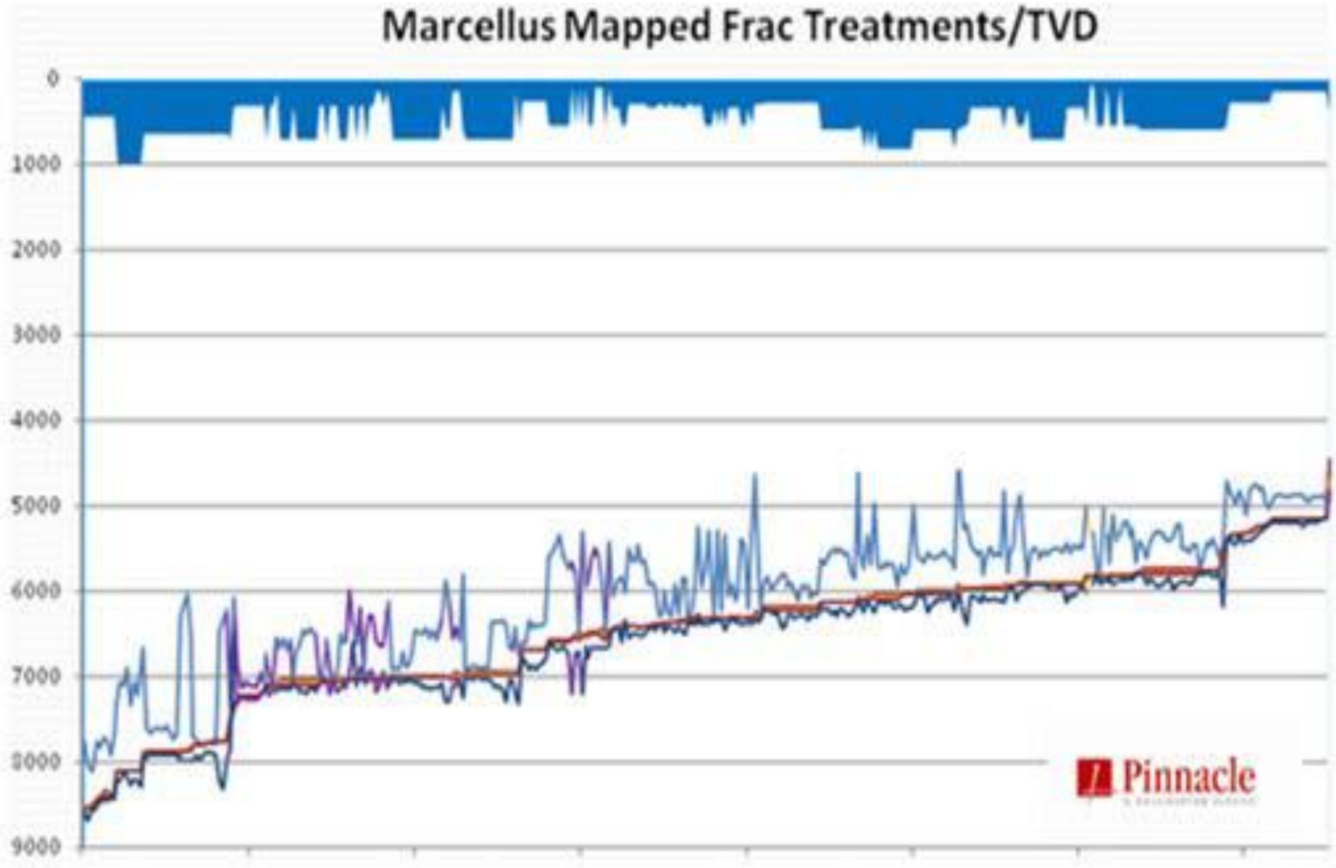
IGRC Seoul 2011
International Gas Union Research Conference

Selected Metals in Flow Back Water—Samples from Two Locations

	Location A	Location B	POTW Sludges**	
Metal **	14-d FB	14-d FB	Median	95th % ile
Chromium (Cr^{3+})	ND	ND	35	314
Copper	ND	0.023	511	1,382
Nickel	ND	0.033	22.6	84.5
Zinc	0.06	0.18	705	1,985
Lead	ND	ND	65	202
Cadmium	ND	0.002	2.3	7.4
Mercury	0.000049	0.000027	1.5	6.0
Arsenic	0.05	0.017	3.6	18.7

* mg/l; ND=Non Detect

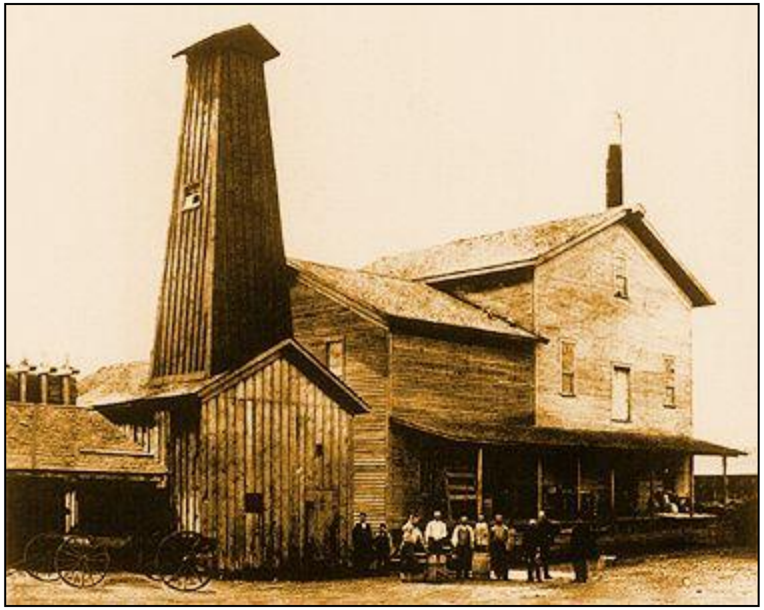
** Penn State, 2000



Fracture height relative to groundwater aquifers (feet)

Beneficial Use

Deep under the flatlands of Midland, Michigan, lie *salt-rich rocks*, rich in magnesium, chlorine, calcium, sodium and bromine. Inside these rocks, Herbert Dow found the raw materials of creative chemistry (1897).



Road Salt –	**$56 per ton**
Road Brine –	**$.63 per gallon**
Bromine -	**$1,128 per ton**
Fresh Water	**$?**

Multiple Benefits Stemming from Water Reuse

- Greatly reduced potential for environmental impact
- Reduced ton-miles in water transportation
- Decreased air emissions
- Decreased carbon footprint
- Lower truck traffic densities
- Reduced road wear
- Greater stakeholder acceptance

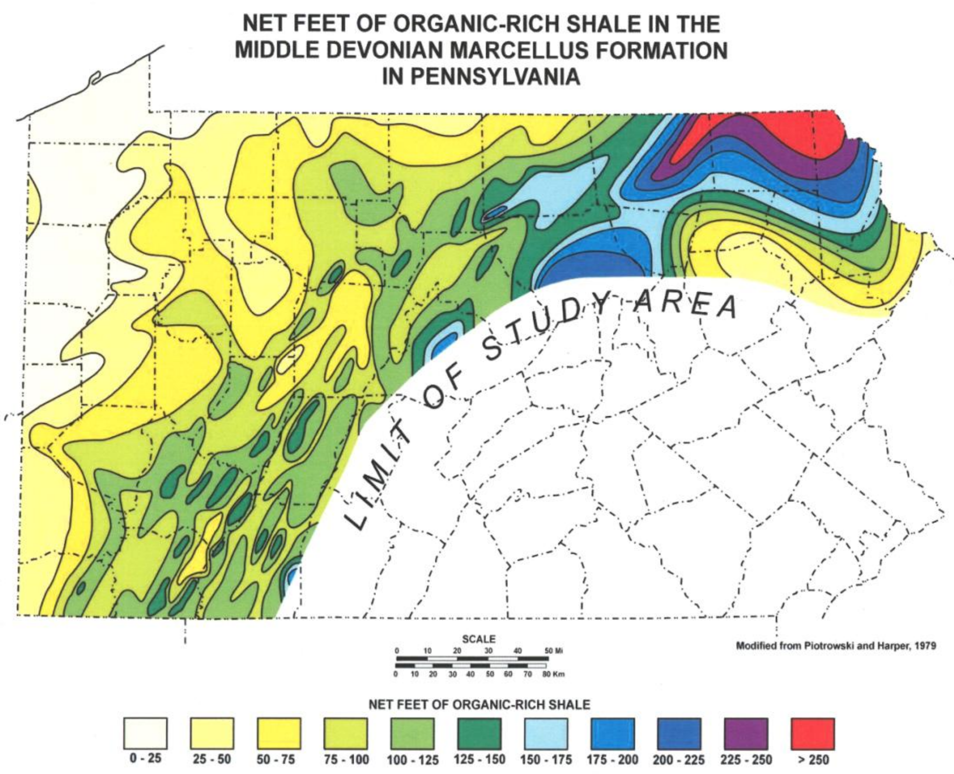
New Developments Under Way

- New concepts in high efficiency thermal systems for water reuse applications
- Novel coatings for improved membrane process performance
- New electrocoagulation designs with expanded capabilities for pretreatment
- Electrodialysis processing for economical partial demineralization
- New friction reducing compounds that perform well at high salt concentrations
- Combining processes to reduce costs

What's Still Missing

- Information sharing to help minimize costs, reduce commercial risk, and minimize environmental impacts
- Strategic partnerships to enable comprehensive solutions
- Identification and consistent application of sustainable operating practices
- Consideration of full life cycle costs
- Further reductions in impact and improvements in effectiveness

Example—Marcellus Shale Play



Reservoir Depth 1,500-8,000 ft
Thickness 50-300 ft
Total Organic Content (TOC) 5.3% - 7.8%
Thermal Maturity (Ro) 0.6%-3.0%
Average log porosity 5.5% - 7.5%
Pressure (psi/ft) 0.42-0.7
Water saturation (Sw) 12% - 35%
Gas in place (bcf section) 30-150
AnticipatFactor ~30%
Average EUe recovery R / Hrztl well (bcf) 3.75

Source: Engelder, 2008

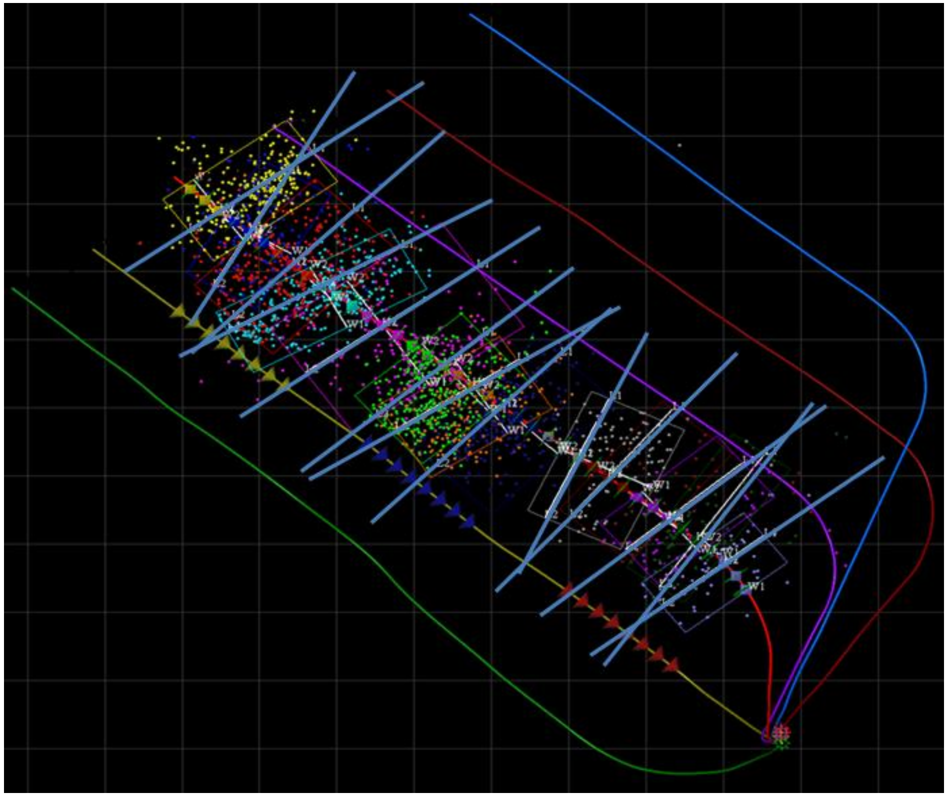
Hydraulic Fracturing—Diagnostics

Hydraulic Fracturing
Fracture Diagnostics

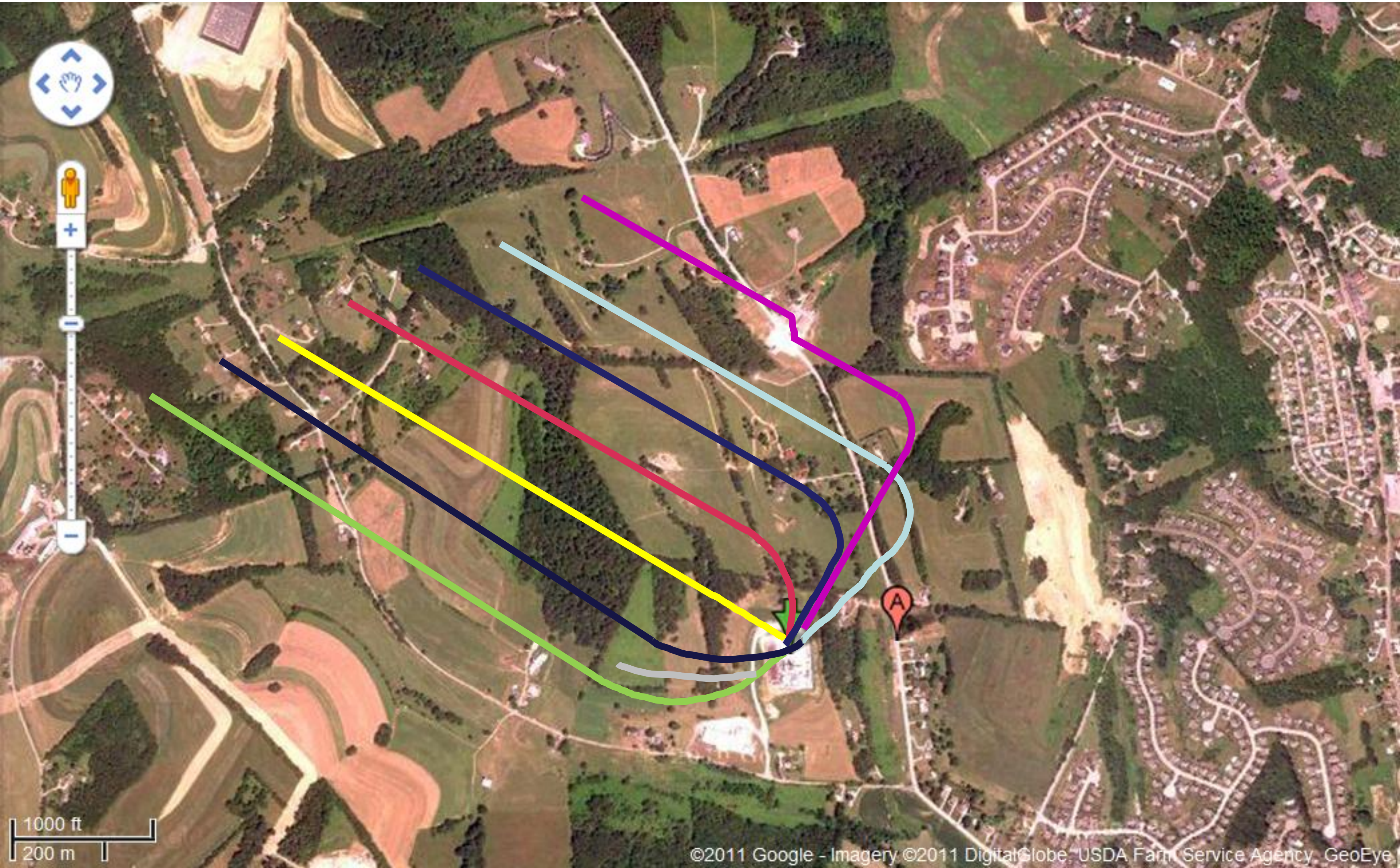
Effectiveness of hydraulic fracturing based on microseismic imaging (SRV), pumping diagnostics, and production results

•Quality control of surface and borehole microseismic analysis—velocity model calibration, fracture geometry and attributes, SRV comparison, check shots

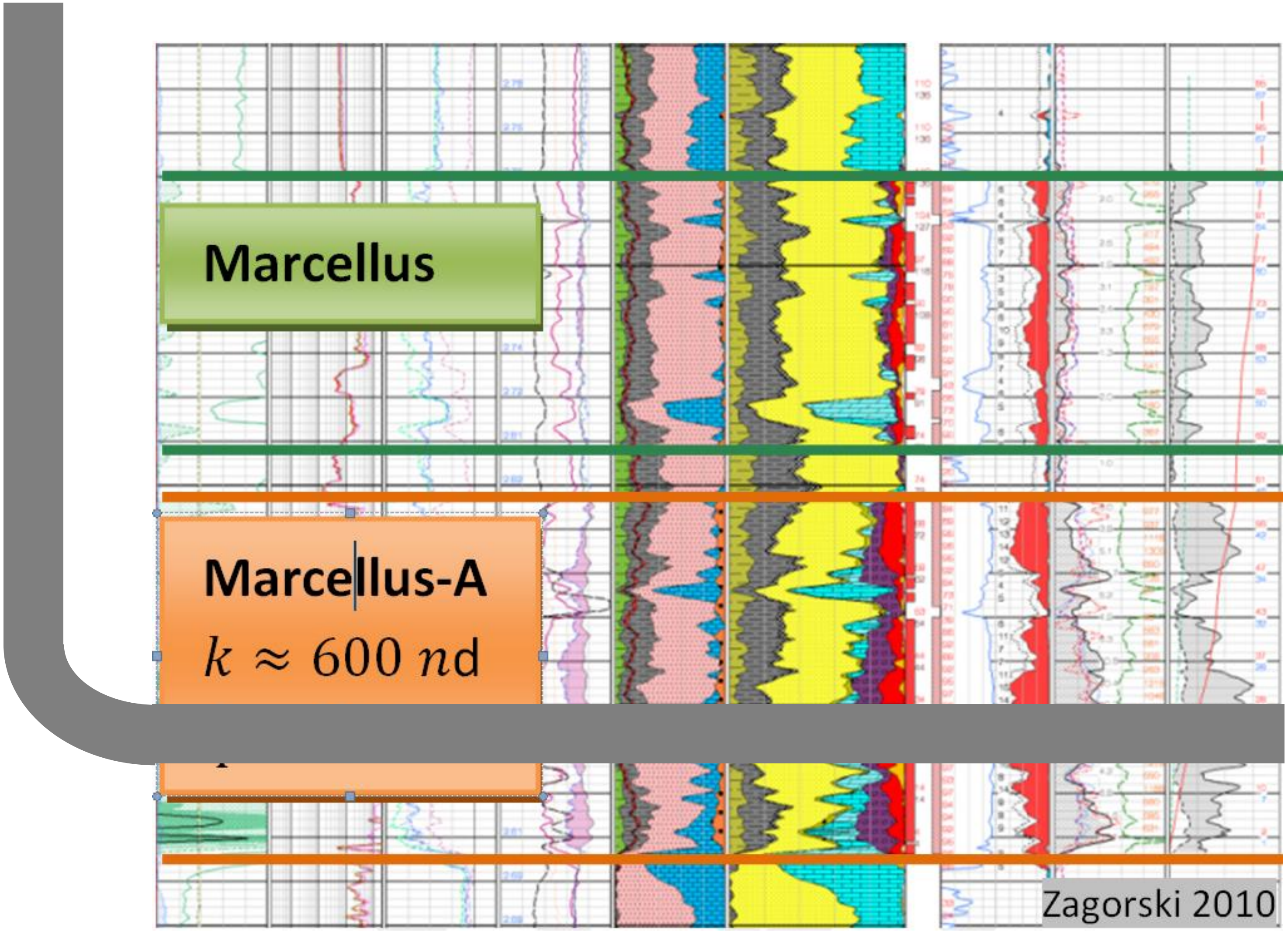
•Optimization of hydraulic fracture treatments through examination of created fracture geometry and complexity, coupled with production results



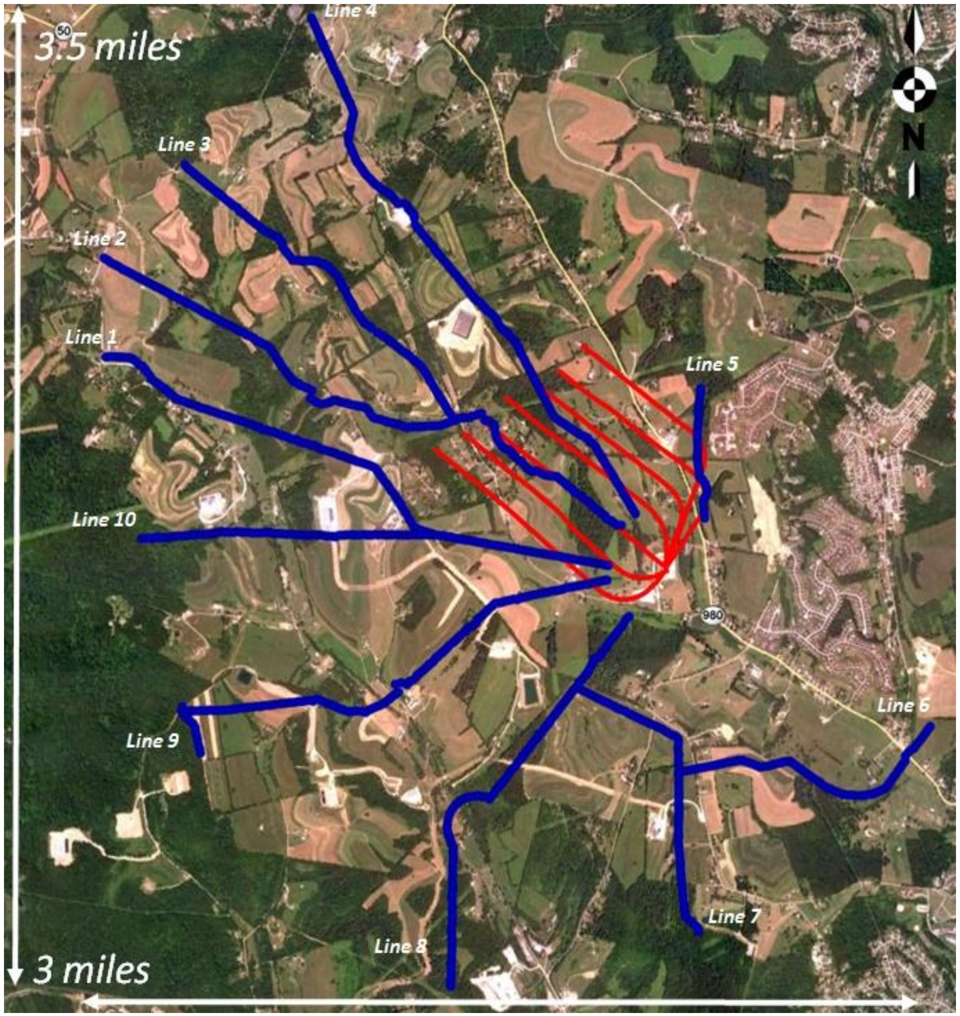
Local Setting



Well Placement

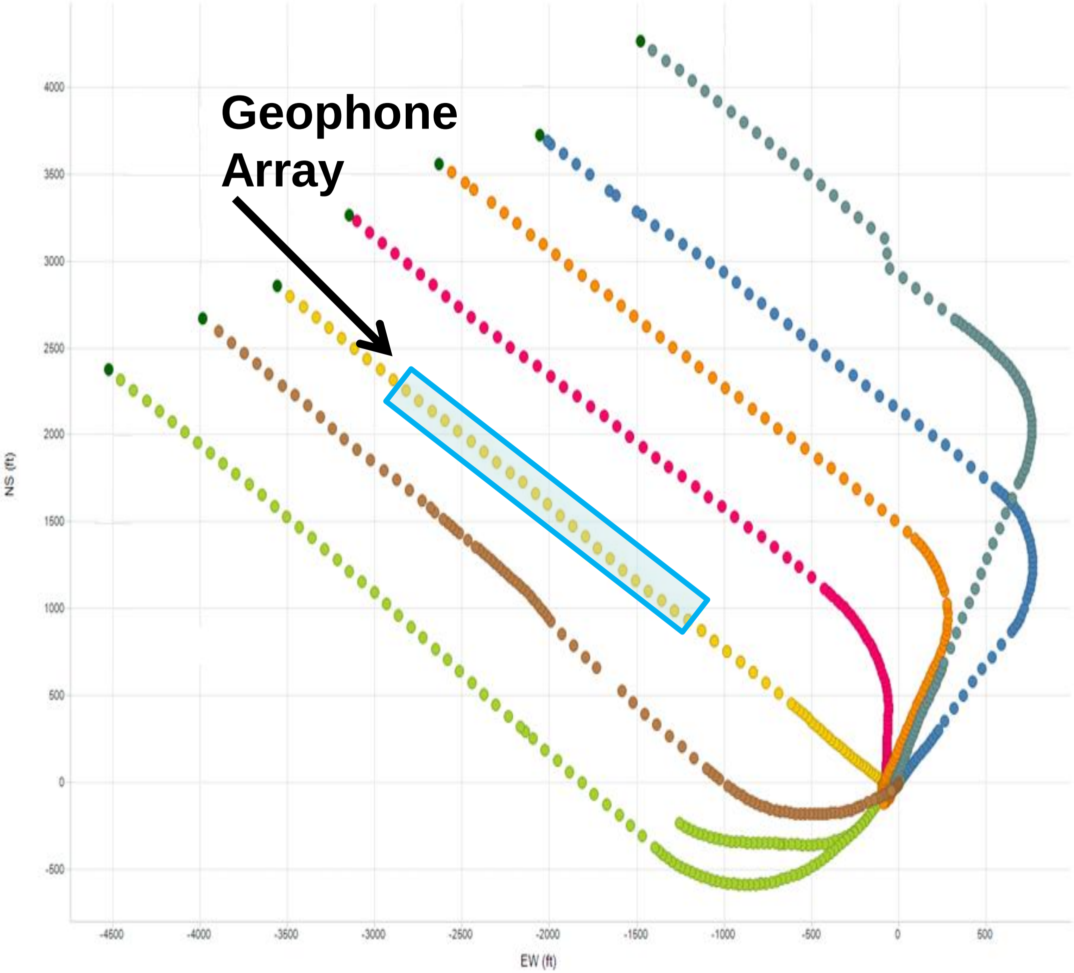


Surface Microseismic



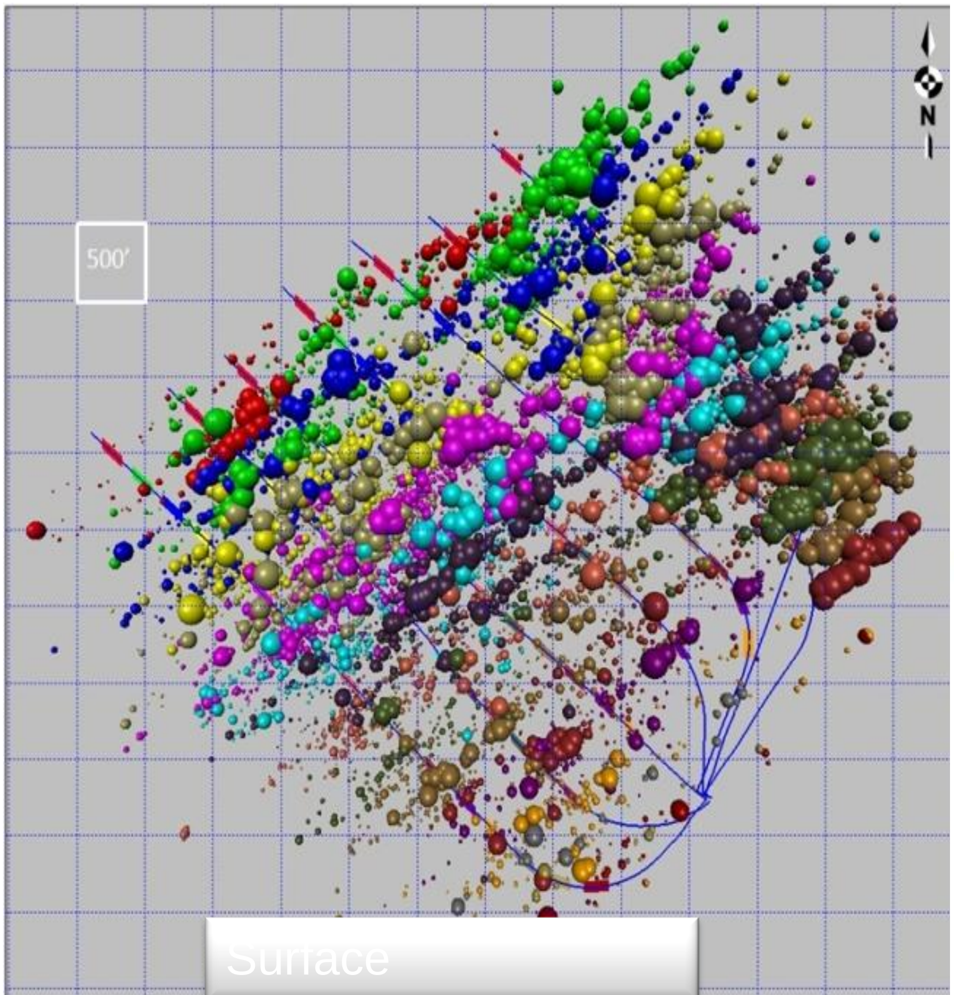
- 1082 stations in the array. They are represented as blue spheres.
- The array consists of 10 lines radiating away from the well head.
- Wells A through G are shown in red.
- Data was acquired with the GSR recording system at 2ms sample rate.
- VSP used for seismic velocity profile

Borehole Microseismic



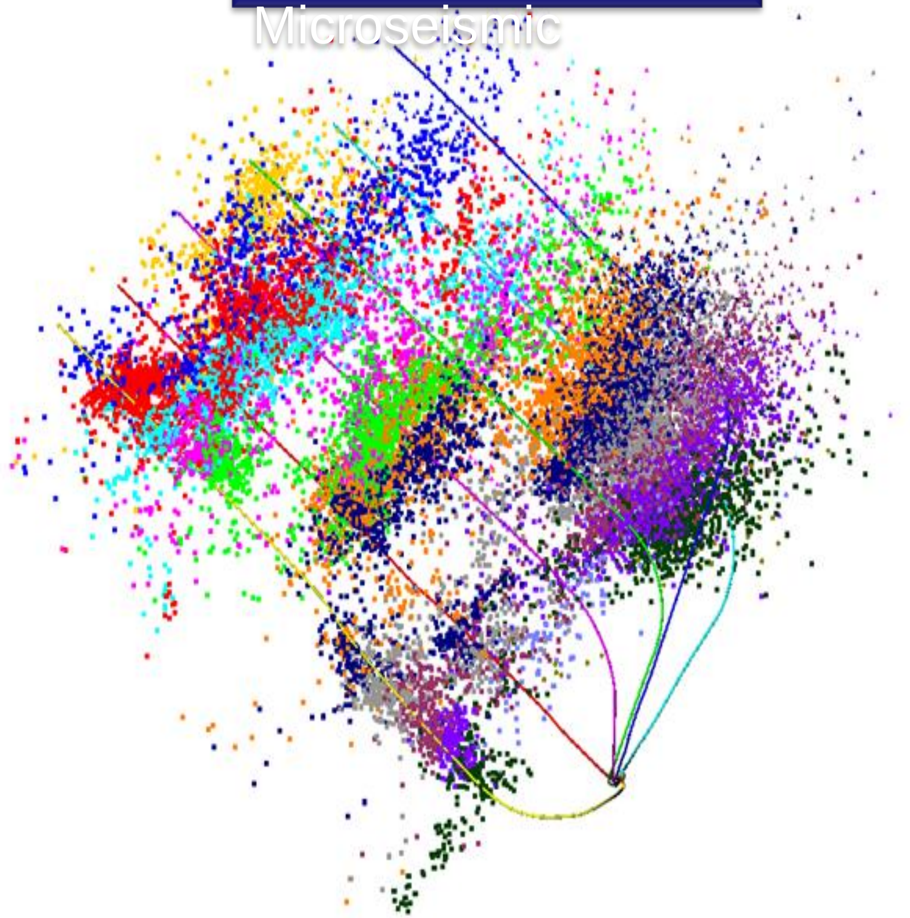
- Horizontal Array—8 Shuttles spaced 100 ft. apart
- Array positioned in Well-C
- Array moved to 5 positions during course of zipper-frac treatments.
- VSP used for velocity profile & Perforations check shots used to re-calibrate velocity model

Microseismic Results

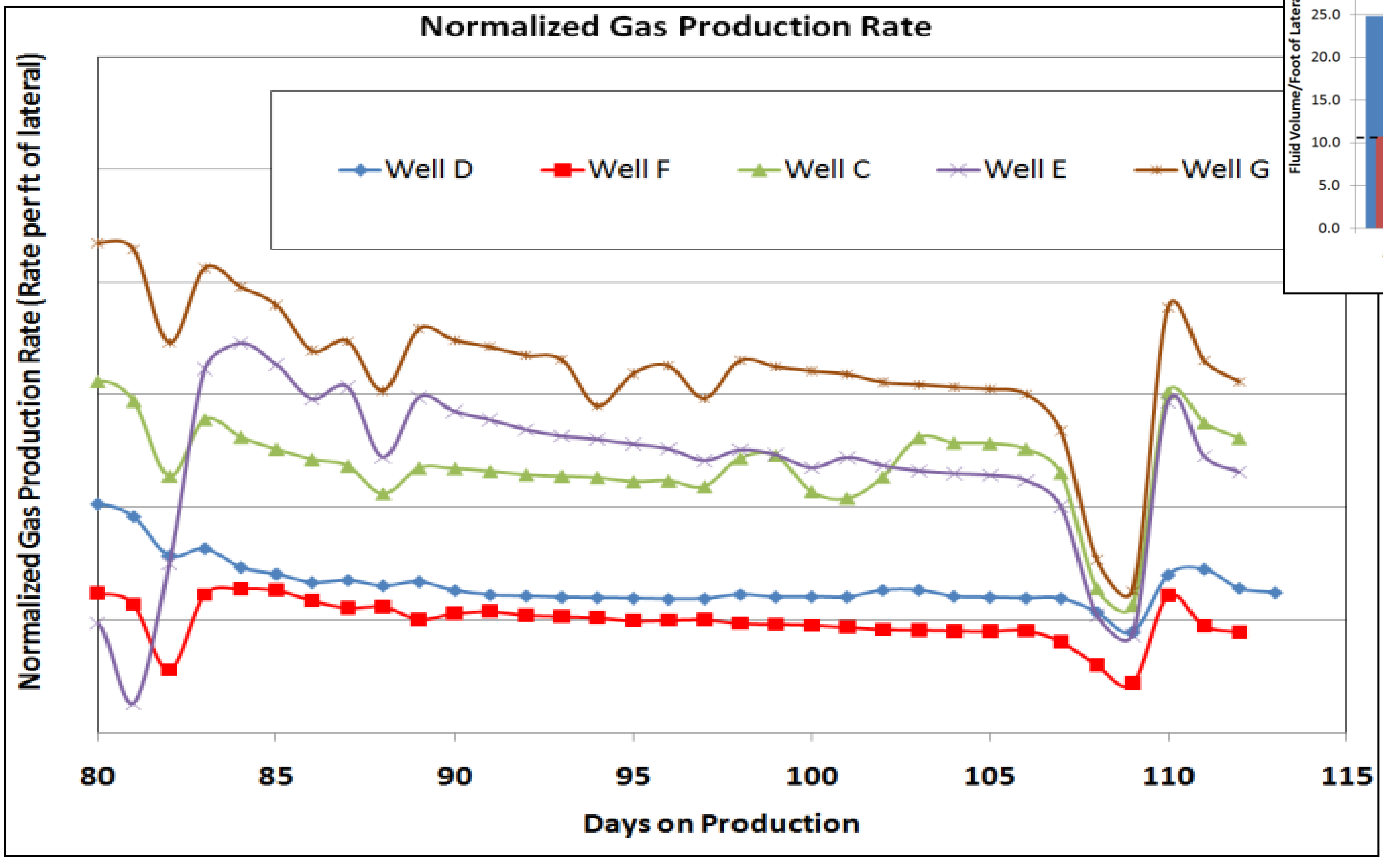


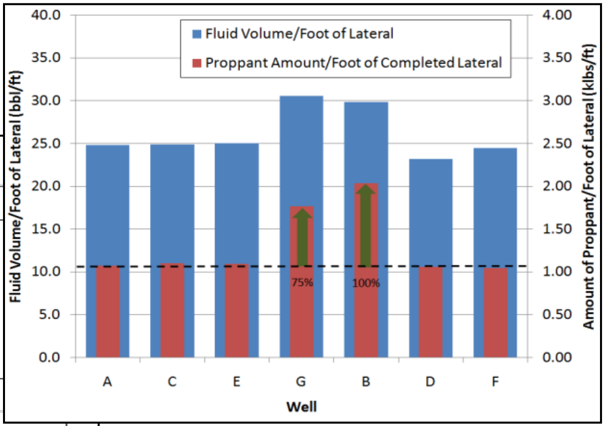
Surface Microseismic

Borehole Microseismic

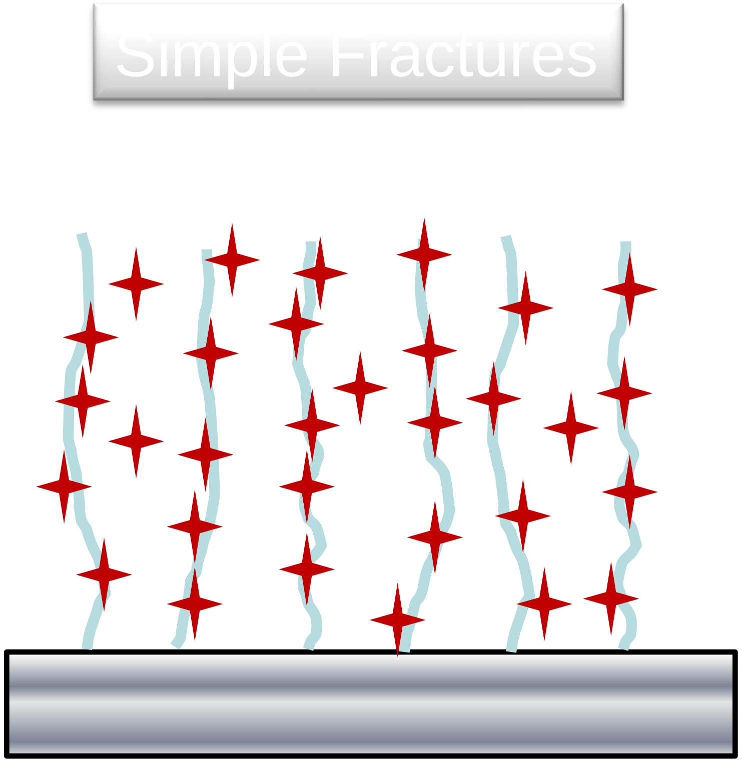


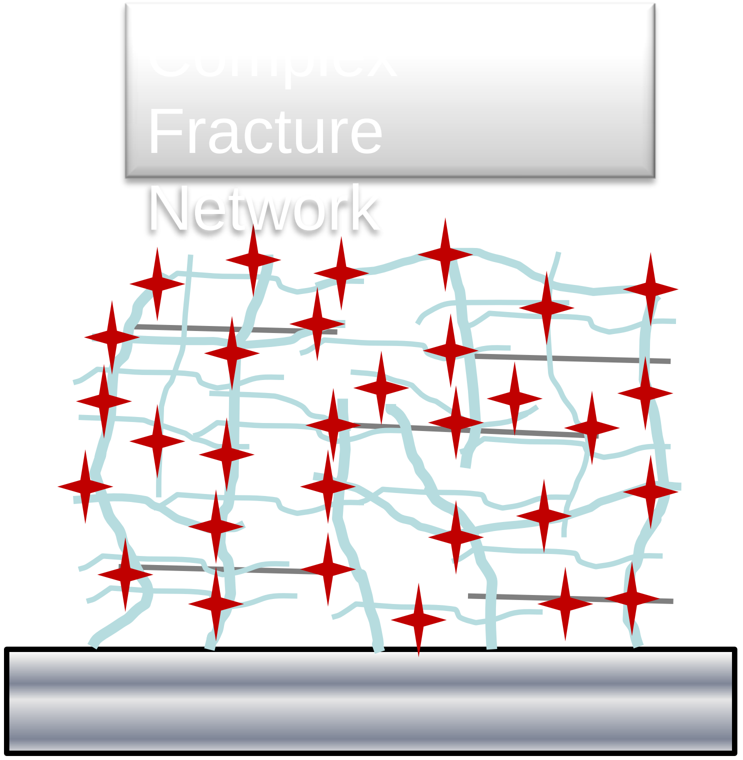
Frac Design Optimization—Normalized Gas Production Rates





Fracture Characteristics Derived from Microseismic Survey

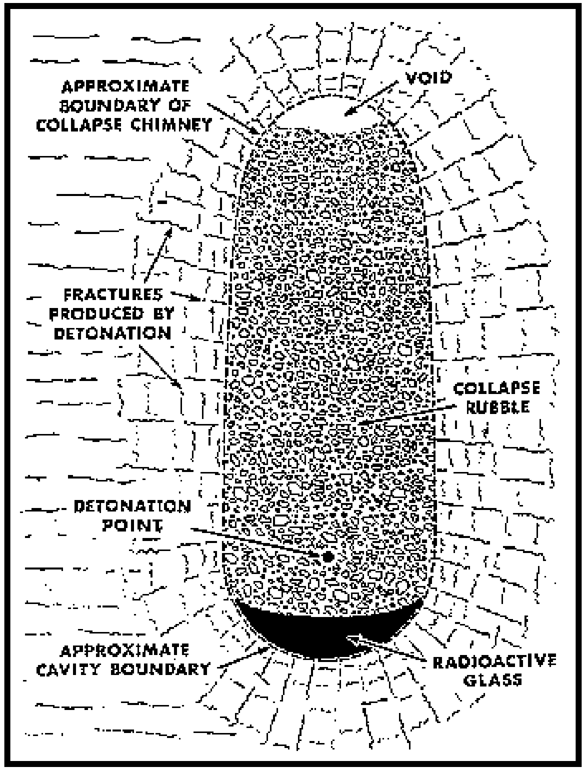




IGRC Seoul 2011
International Gas Union Research Conference

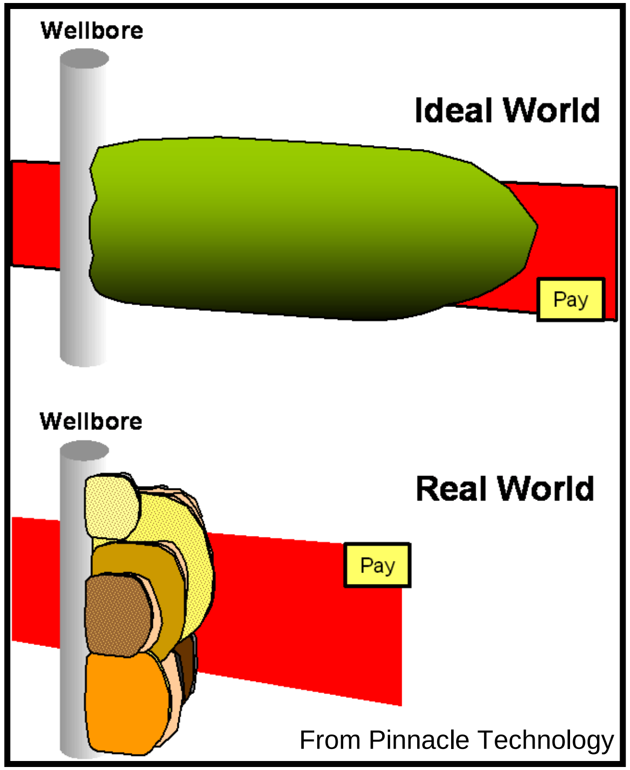
Creating Permeability

1960's



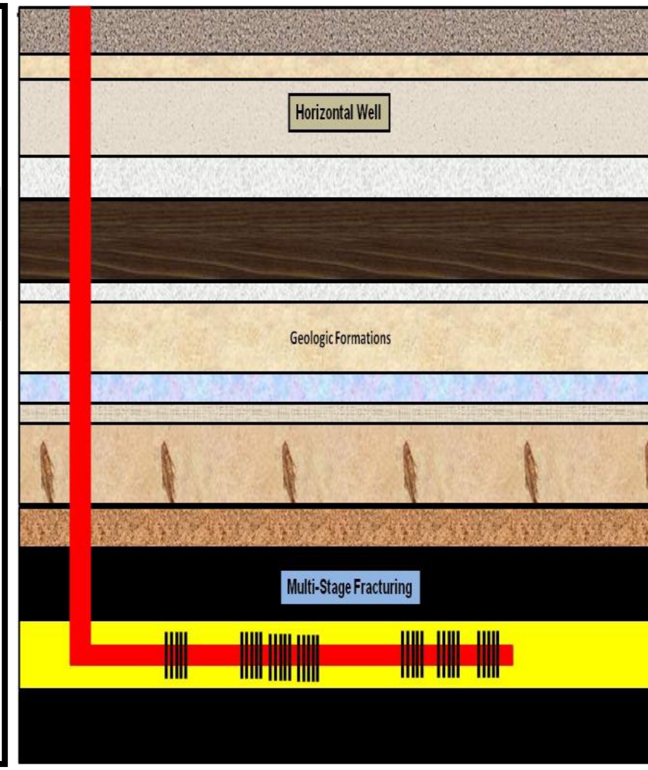
Nuclear Stimulation

1980's



Massive Hydraulic Fractures

2000's



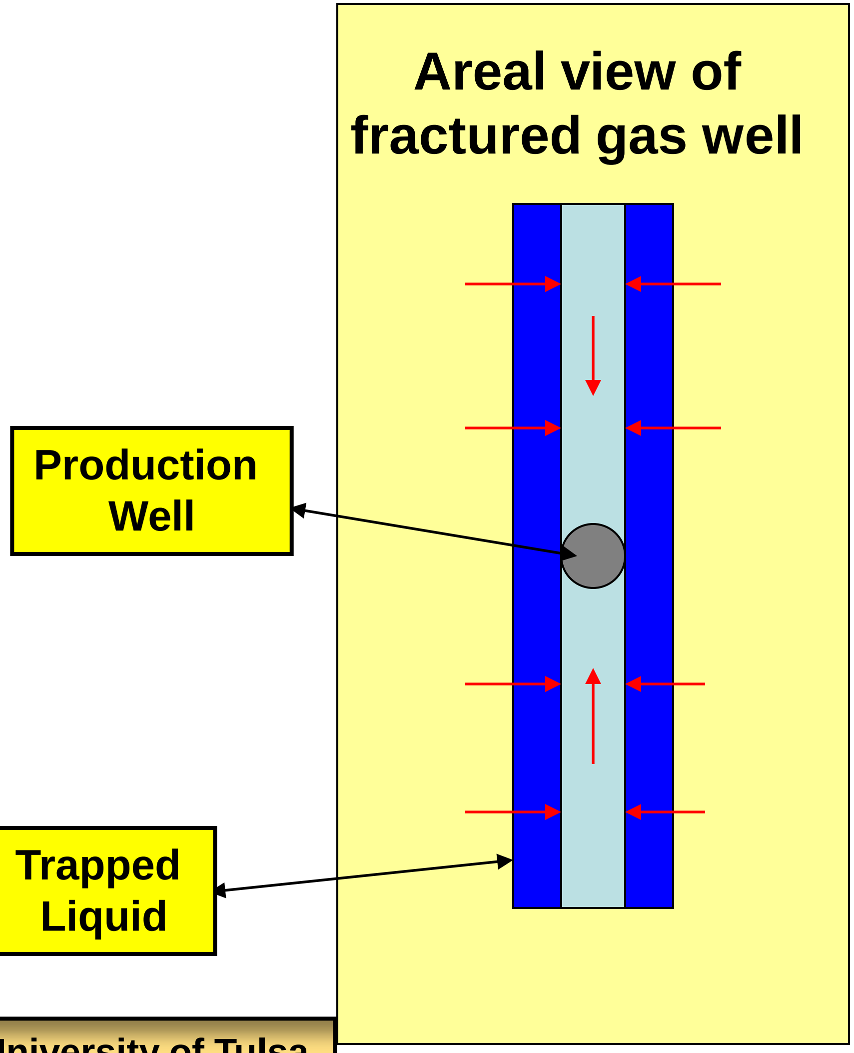
Precise Size & Precise Placement

Why Some Treatments Do Not Work as Well as Expected

- Fracture treatment grew out of zone.
- Propping agent settled to the bottom of the fracture.
- Propping agent was crushed or was embedded into the formation.
- Fracture fluid did not break.
- Fracture fluid broke too soon.
- Treatment volume was too small.
- Reservoir quality is less than expected.

Productivity Loss Due to Fracturing Induced Damage

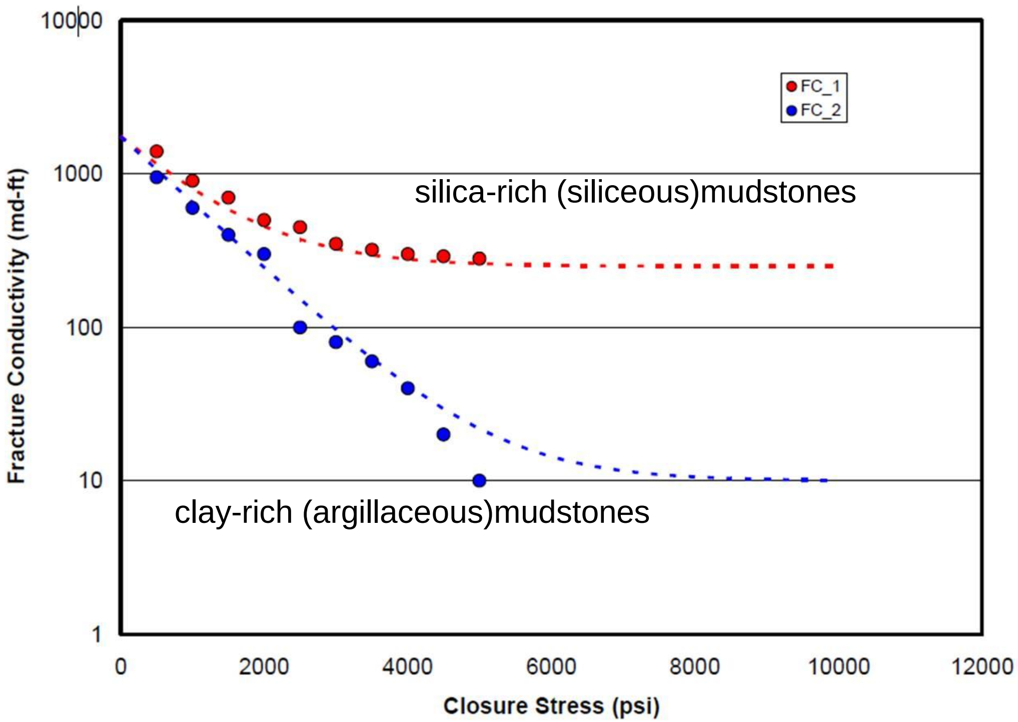
- Liquids Invade the Near Wellbore/Fracture Region
- Use of Polymer Gels Can Aggravate Loss in Well Deliverability
- We Aim to Understand Factors Affecting Cleanup of Gel Induced Damage
- Lab Testing—Model Development and Field Verification



University of Tulsa

Sustaining Fracture Area and Conductivity of Gas Shale Reservoirs for Enhancing Long-term Production and Recovery

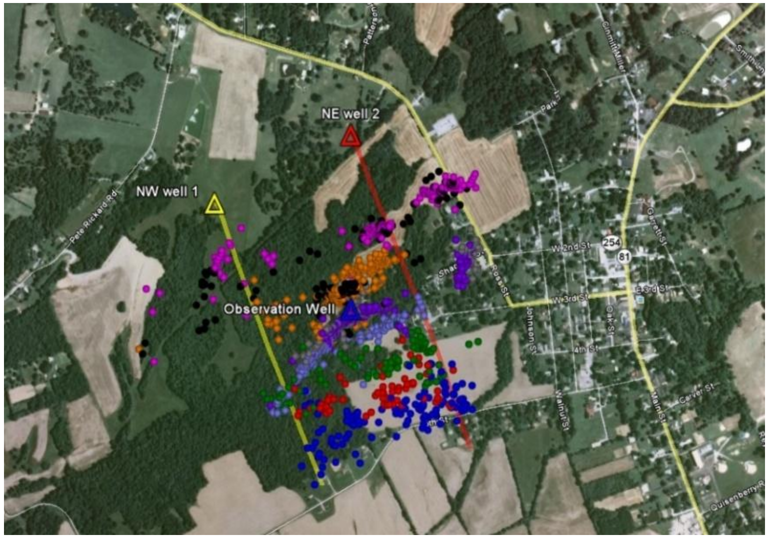
- Theoretical and experimental project to understand the multiple causes of loss of fracture area and fracture conductivity
- Define solutions to mitigate the resulting loss of production
- Identify optimal proppants, fracture fluids, and pumping schedules for the rock being produced



Texas Engineering Experiment Station/Texas A&M University System And TerraTek a Schlumberger Company

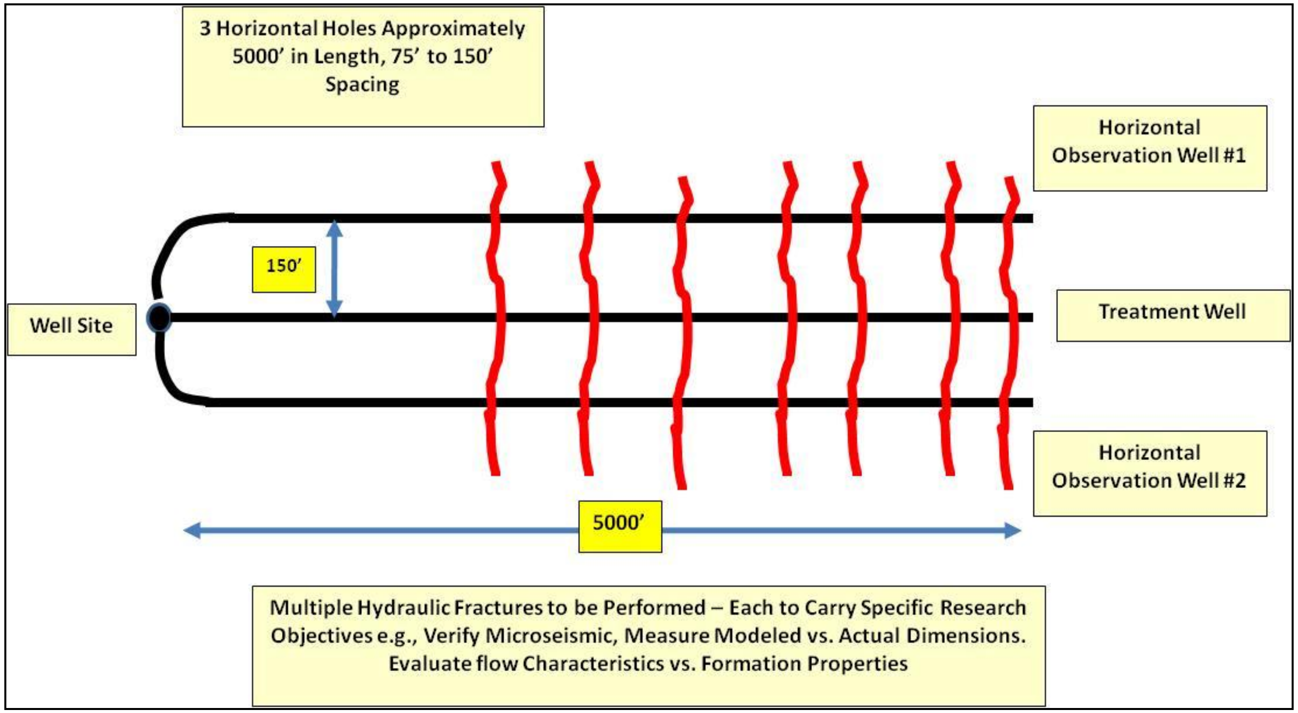
Improving Fracturing Effectiveness

- Inadequate design
- Wrong proppant loadings
- Poor fluid selection
- Proppant embedment
- Poor fracture fluid clean-up
- Water blockage of permeability
- Poorly understood reservoir compartmentalization



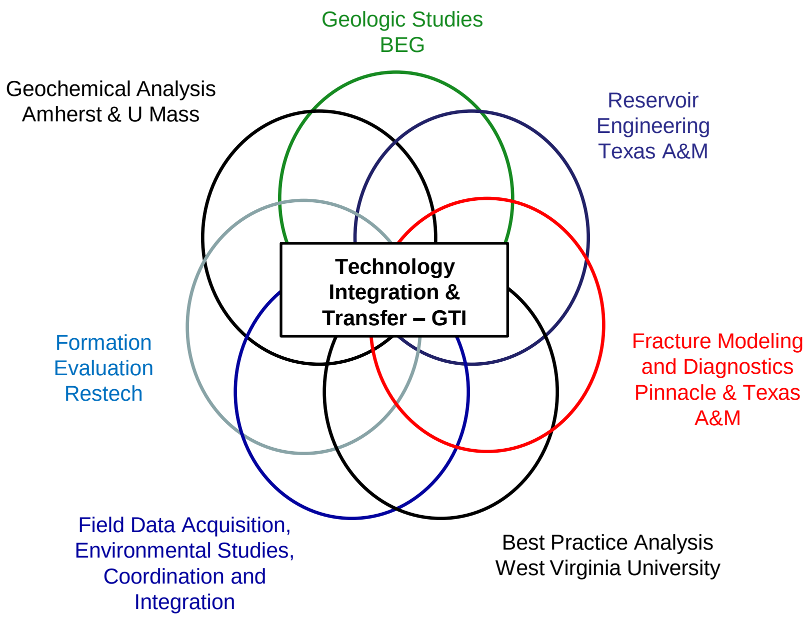
Expensive process with 50% fractures sub-optimal

Potential Experimental Procedure

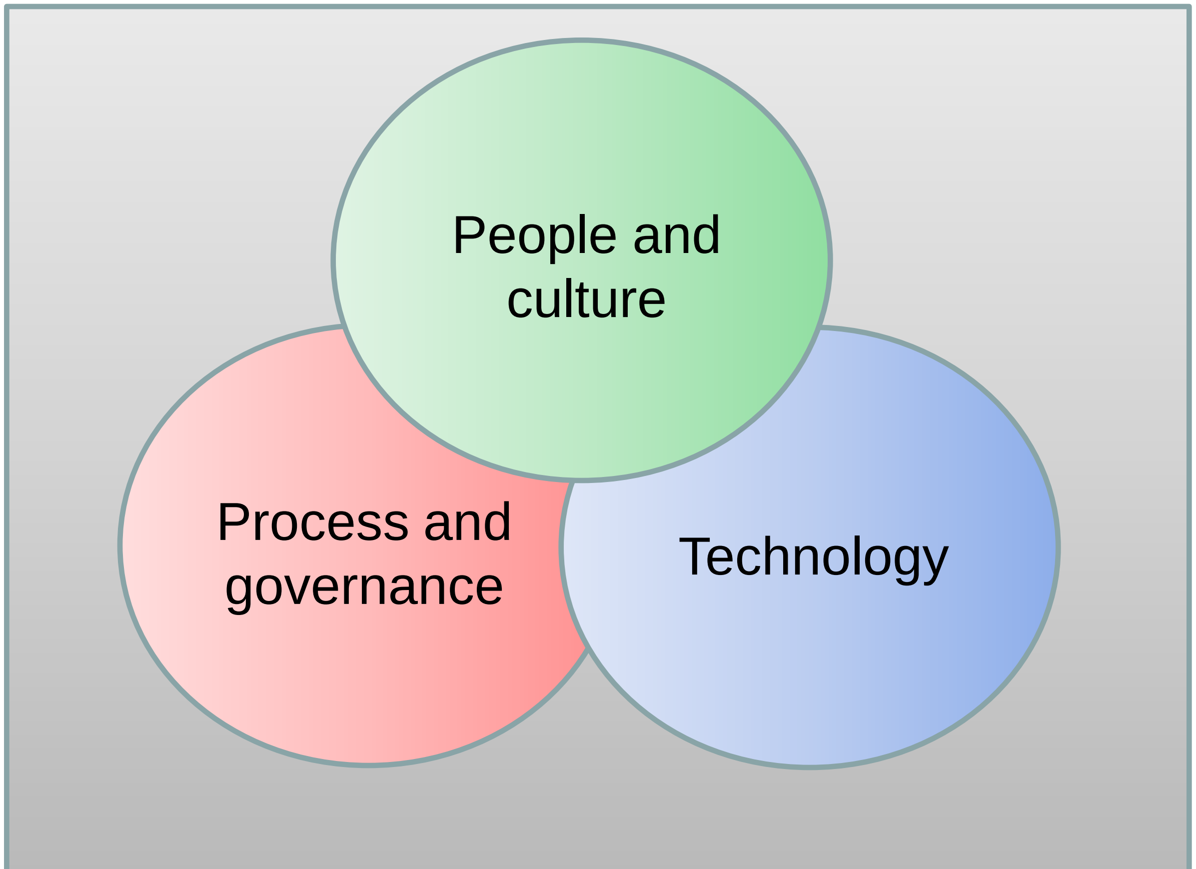


Collaborative Development

- Bringing together the right partners and technology-based solutions
  - Government and Regulators
  - E&P Operators
  - Service Companies
  - Universities
  - Consulting Firms
  - Private Research Organizations
  - Energy Associations
  - Geological Surveys



Collaboration Requirements for Shale Gas Development



Addressing Fracing Issues

- Acknowledge that lack of trust is an issue
- Public is seeking information from a knowledgeable and credible source
- Facts alone may not be sufficient
  - How stakeholders are engaged as important as the facts
  - Not an “academic” scientific discussion

IGRC Seoul 2011
International Gas Union Research Conference

Transforming our Energy Future

- Abundant supplies
- Enhanced security
- Price stability
- Smaller carbon footprint
- Economic benefit