the Energy to Lead

Research Partnership to Secure Energy for America

Subsurface Technology and Engineering Workshop

Topic 3: control of fractures and subsurface fluid flow

An Industry Perspective

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Presentation Outline

MOTIVATION: Present the industry perspective on critical subsurface knowledge and/or technology gaps

- Background
- Statement of problem
- Industry perspective of research needs

Background

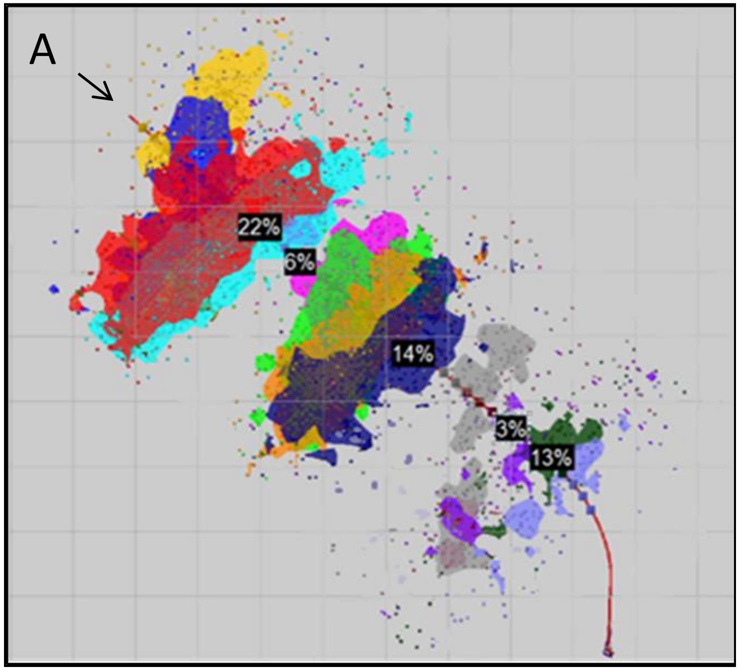
- GTI, with support from the Research Partnership to Secure Energy for America (RPSEA) conducted 3 workshops and 6 Webinars with over 40 hydraulic fracturing experts from 26 producing and service companies and research organizations to identify and rank research needs for development of environmentally safe and economically efficient hydraulic fracturing practices
- Results from these workshops are presented

Sate of hydraulic fracturing technology

Industry Challenge

> Public concerns about environmental safety of hydraulic fracturing are widespread.

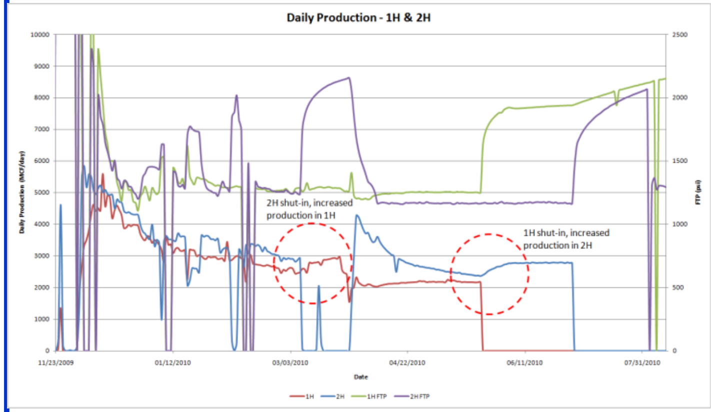
> Current practices are quite inefficient because in many cases the majority of production in a horizontal well comes from a few fracture stages.



> Clearer understanding of the fracturing dynamics are key to controlling fracture dimensions, vital to minimization of environmental impacts, and essential for enhanced productivity of fracture networks created in long horizontal wells.

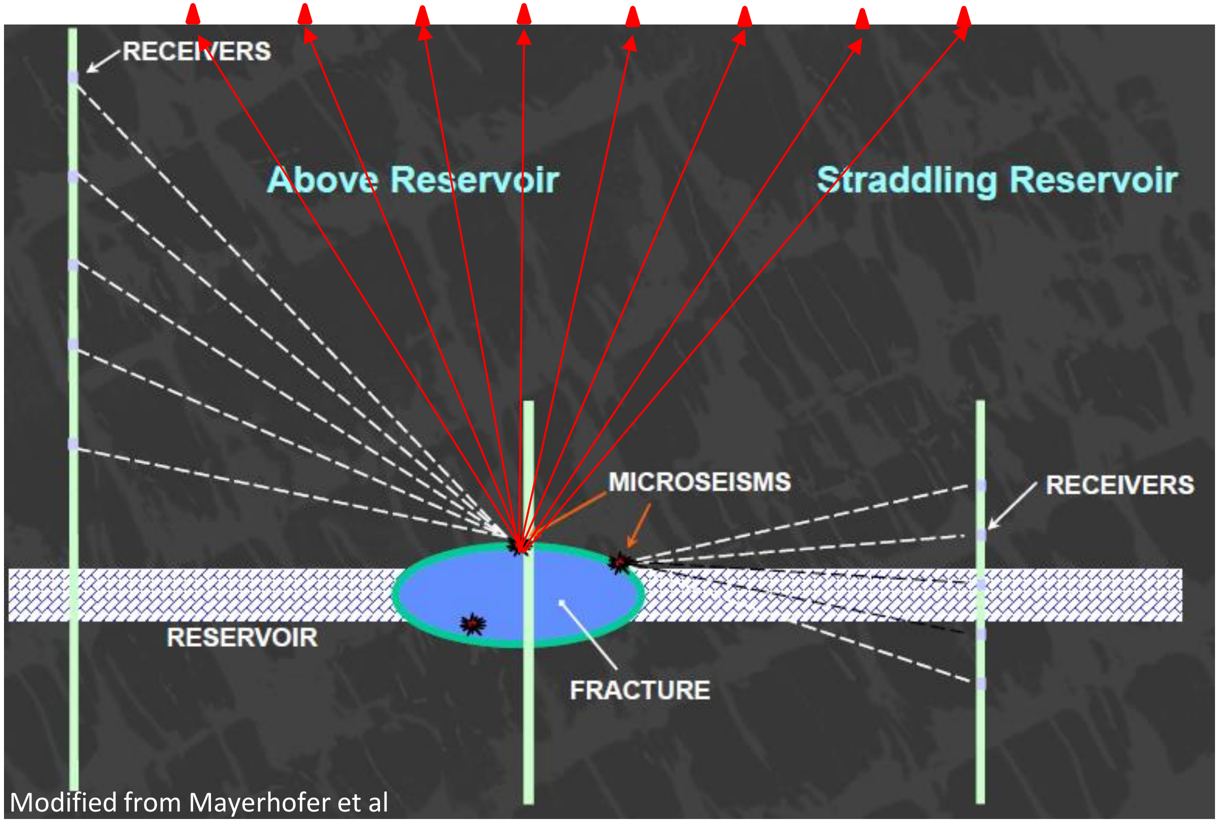
State of fracturing technology

- Interference between wells are common
- Hydraulic fracturing of horizontal well is unpredictable
- All fracture diagnostic data are after-the-fact measurements
- Real-time control needs:
  - Accurate, dynamic, and site appropriate model
  - Accurate diagnostic tools and technology
  - Real-time inversion

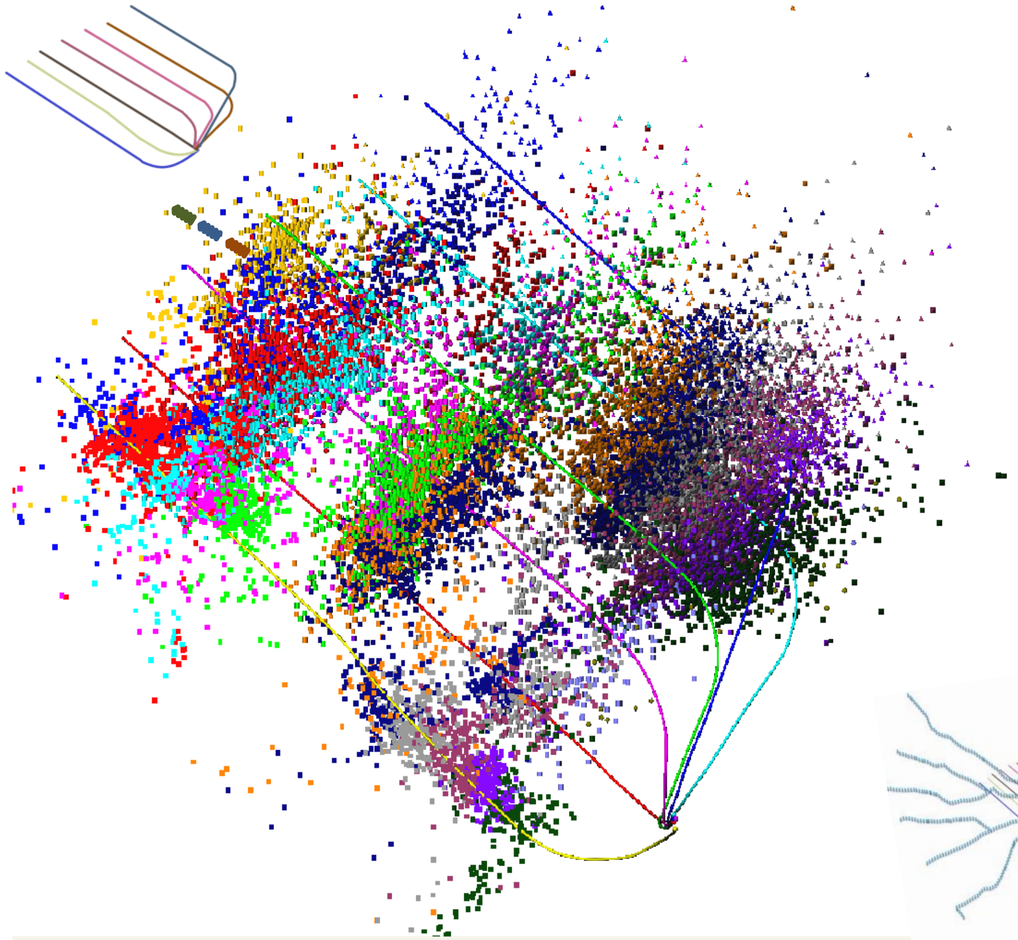


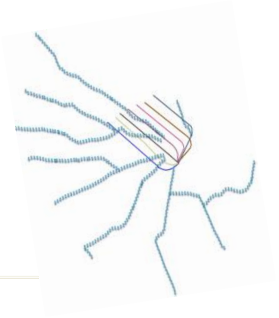
Example of in interference between two adjacent wells

Microseismic fracture imaging

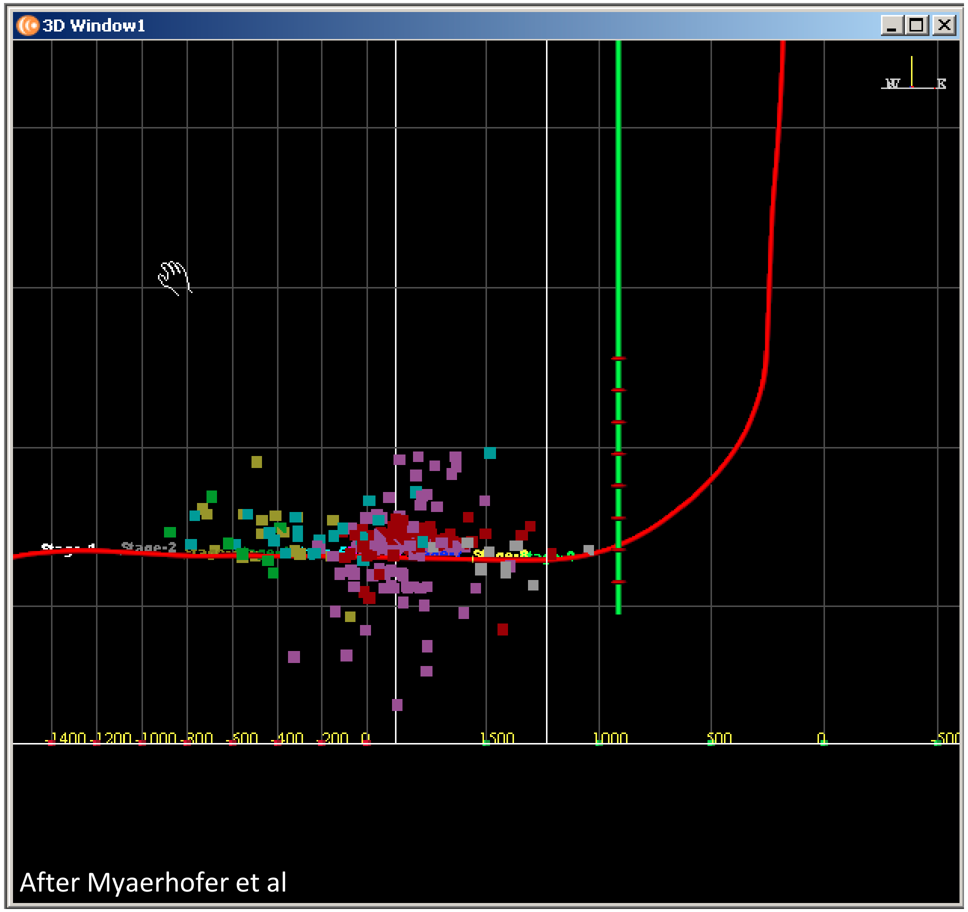


Microseismic fracture imaging





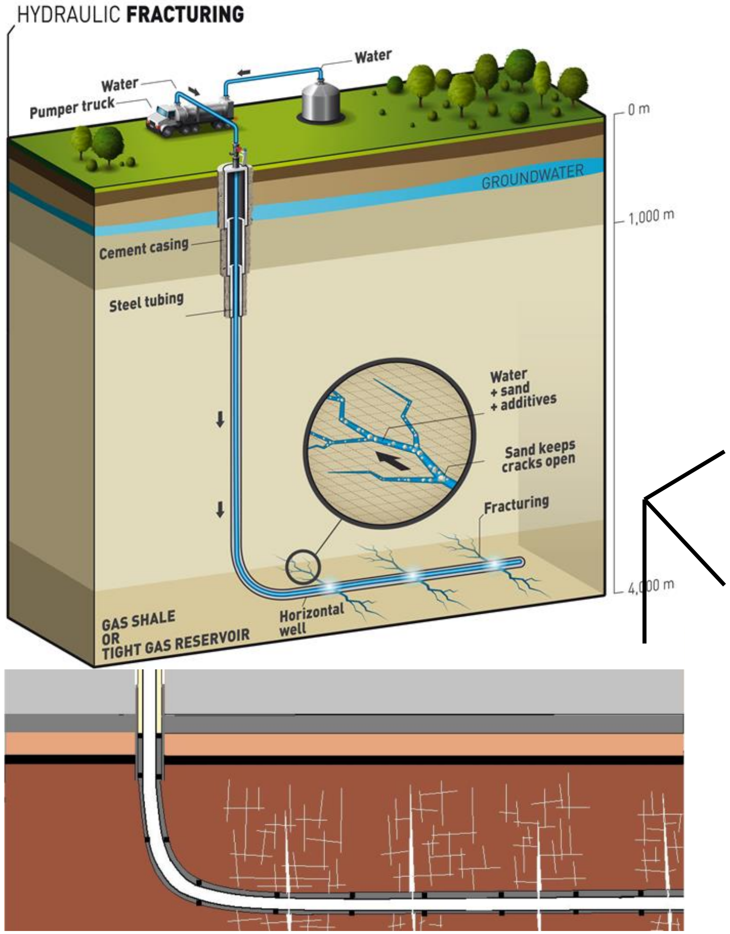
Microseismic fracture imaging

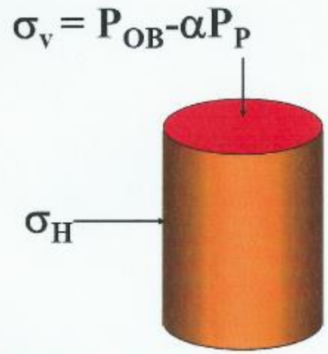


Microseismic fracture imaging

- Errors in event location can be as much as 30% due to:
  - Velocity errors
  - Event picking
  - Extraneous seismic events
- Most events are from rock shear failure
- Opening mode signals at microseismic frequencies are too weak to be detected

State-of-the-art in hydraulic fracturing design





$$\sigma_v = P_{OB} - \alpha P_P$$

Horizontal stress required to assure no lateral strain

$$\sigma_H = \left(P_{OB} - \alpha P_P\right)\frac{\upsilon}{(1-\upsilon)}$$

Complete Stress Equation

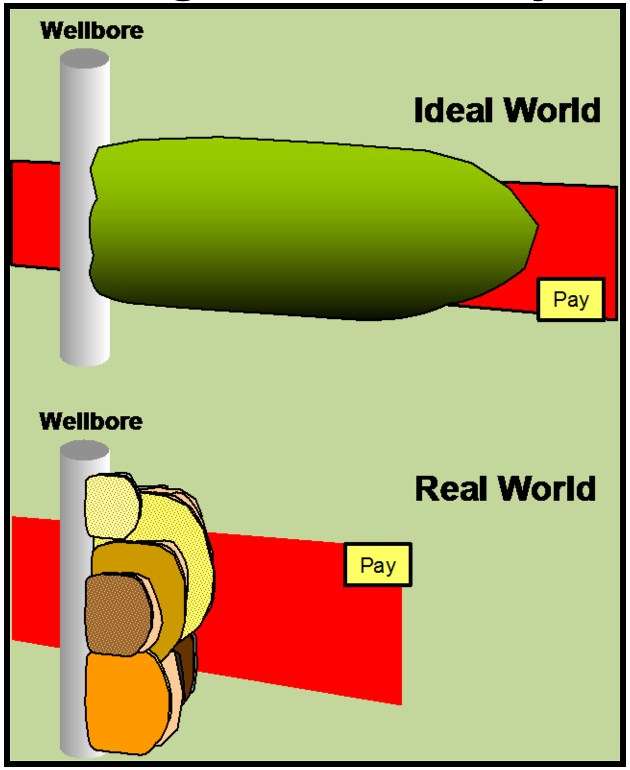
$$P_c = \frac{\nu}{(1-\nu)}\left[P_{ob} - \alpha_v P_p\right] + \alpha_h P_p + \varepsilon_x E + \sigma_t$$

- P_c = closure pressure, psi
- ν = Poisson's Ratio
- P_{ob} = Overburden Pressure
- α_v = vertical Biot's poroelastic constant
- α_h = horizontal Biot's poroelastic constant
- P_p = Pore Pressure
- ε_x = regional horizontal strain, microstrains
- E = Young's Modulus, million psi
- σ_t = regional horizontal tectonic stress

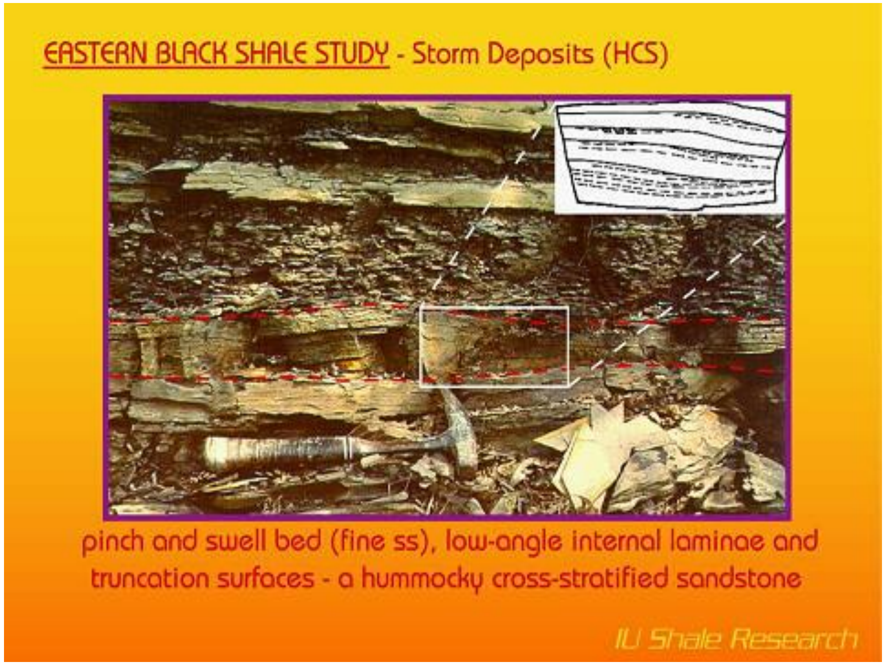
State-of-the-art in hydraulic fracturing design

- Data need for accurate fracture design:
  - Porosity and permeability
  - In-situ and dynamic stress values
  - Pressure in fracture
  - Natural fractures
  - Layering
  - Lithologic variations

Design v. Reality



Not all shales are created equal



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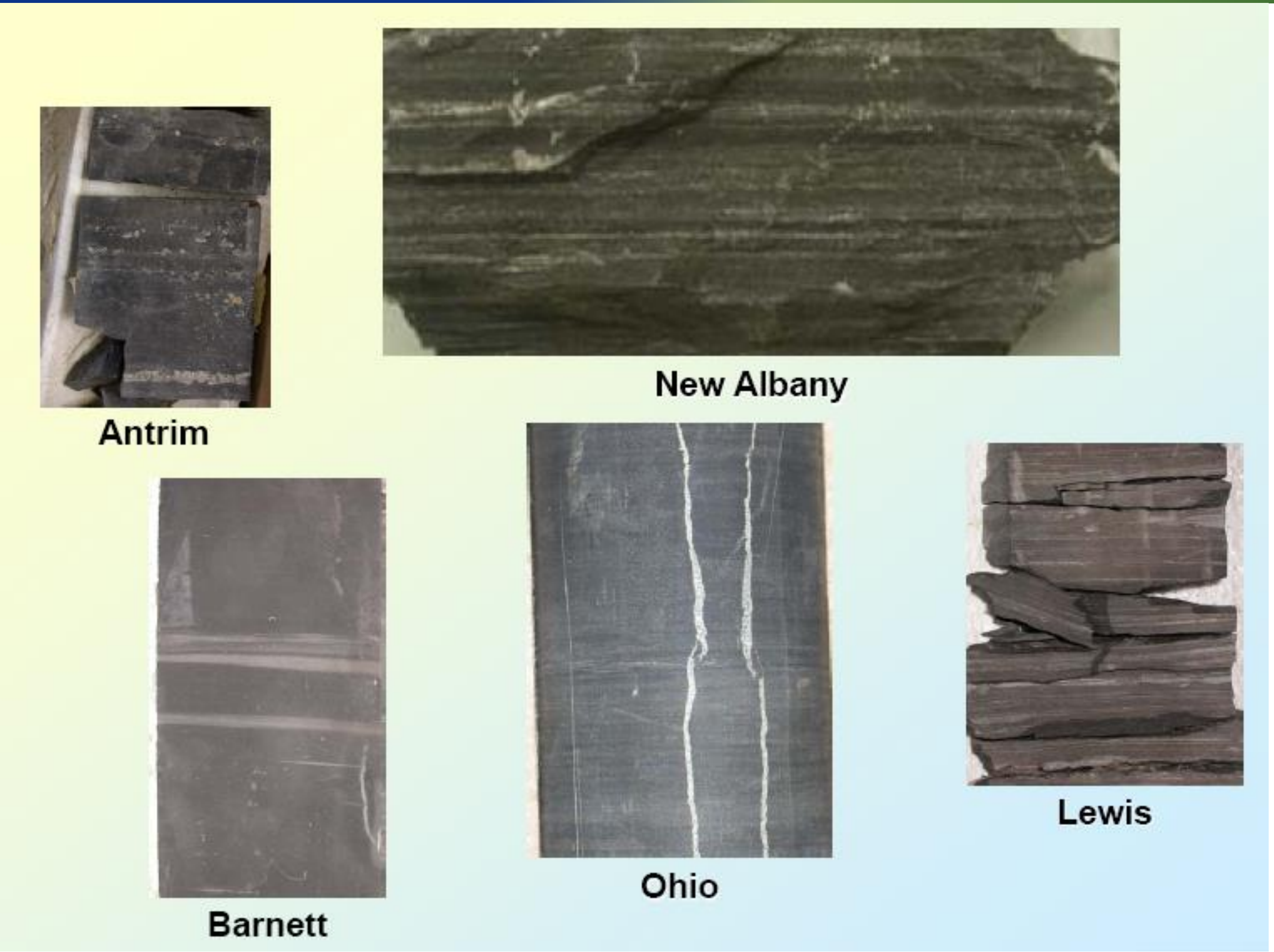

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Statement of problem

- Fracture design models are not adequate
- All fracture diagnostic measurements are after-the-fact
- The state-of-the-art hydraulic fracturing is very inefficient
- Real-time fracture control is impossible

- It is impossible to use equivalent homogeneous

rock to explain heterogeneous rocks.
This is especially true for clay-rich rocks,
ZOBACK & BEYERLEE (1975), BERRYMAN,
(1992)

- A new theory must be developed for fractured, heterogeneous rocks

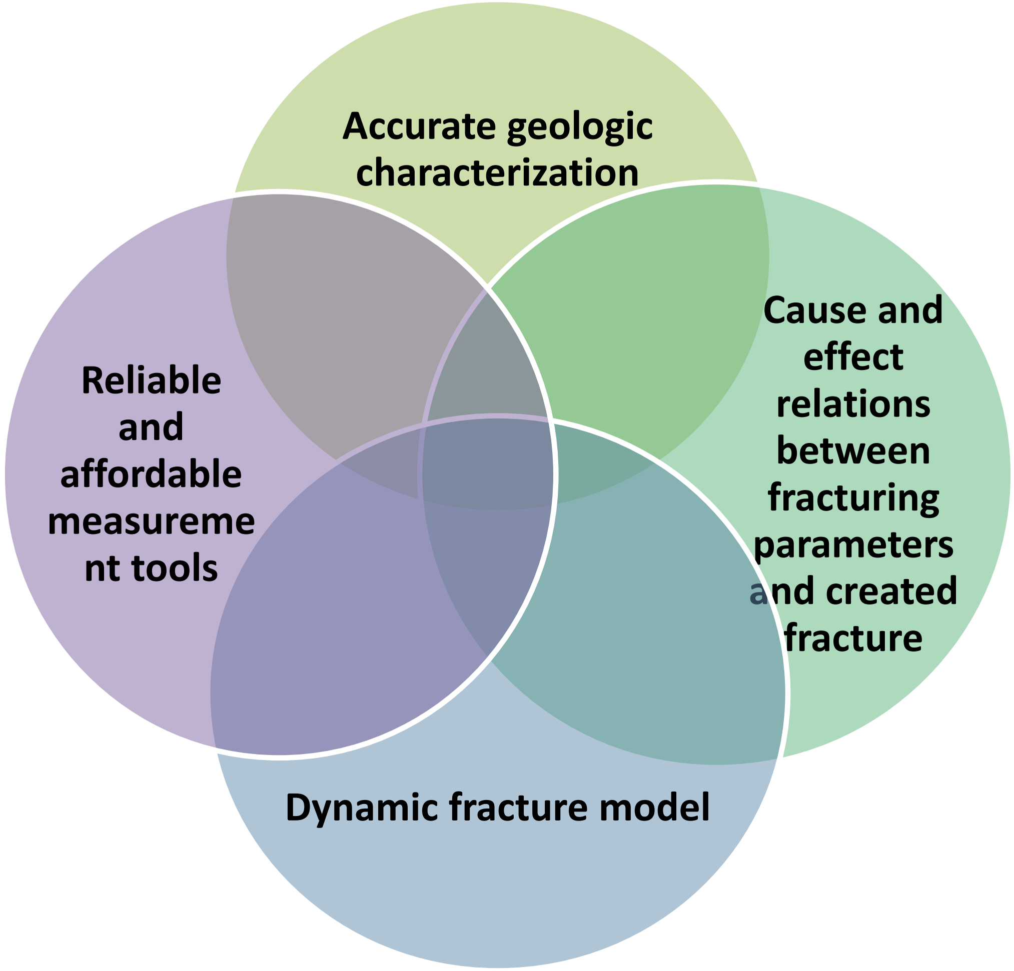
Top level industry needs

1. Improve fracture design.
2. Early detection of fracture efficiency.
3. Develop methods and techniques for real-time control of fracturing processes.
4. Optimal instrumentation to reduce the margin of error in interpretation of monitoring/measuring.
5. Evaluate new technologies for increasing the efficiency of fracture treatments.
6. Determine environmental impacts and develop mitigation strategies.
7. Demonstrate safe and reliable hydraulic fracturing operations.
8. Quantify the value of diagnostics, testing, data collection, and analysis.

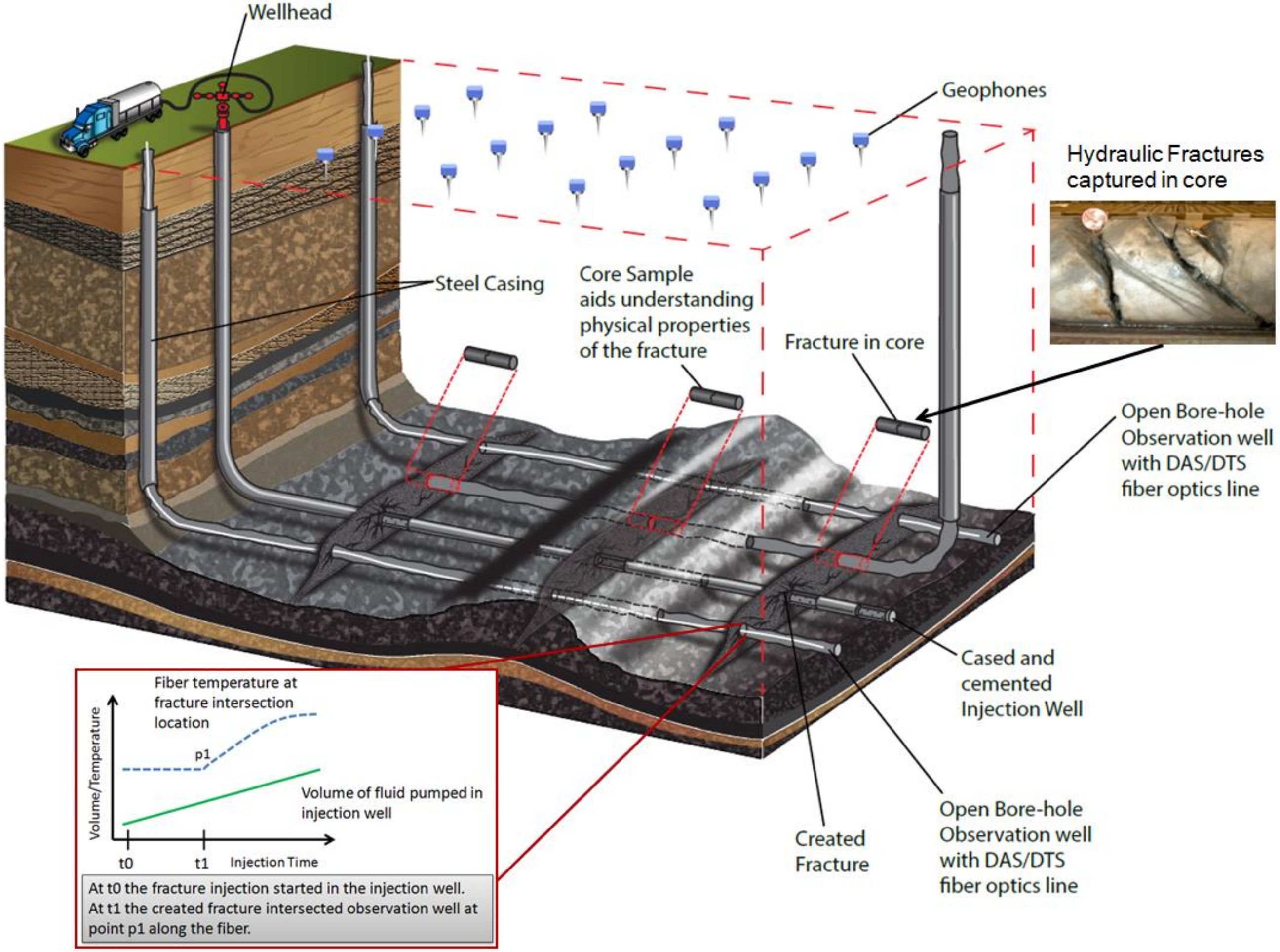
Industry ranked HF Tech Priorities

1. Effects of **fluid injection points** on fracture geometry
2. Effects of **natural fractures** on fracture geometry
3. Effects of **pump rates** on fracture geometry
4. Effects of connected fracture network **conductivity** on stimulation efficiency
5. Effects of **fracture interference** on fracture geometry
6. Effects of created fracture network **connectivity** on stimulation efficiency
7. Effects of **formation lithology** on fracture geometry
8. Effects of created fracture network **complexity** on stimulation efficiency
9. Effects of **fluid properties** on fracture geometry
10. Understanding **fracture height growth**
11. Effects of **proppants** on fracture geometry
12. Effects of **stress anisotropy** on fracture geometry
13. Testing **alternative stimulation techniques**

Needs for accurate fracture design



Coupled lab/analytic/field tests



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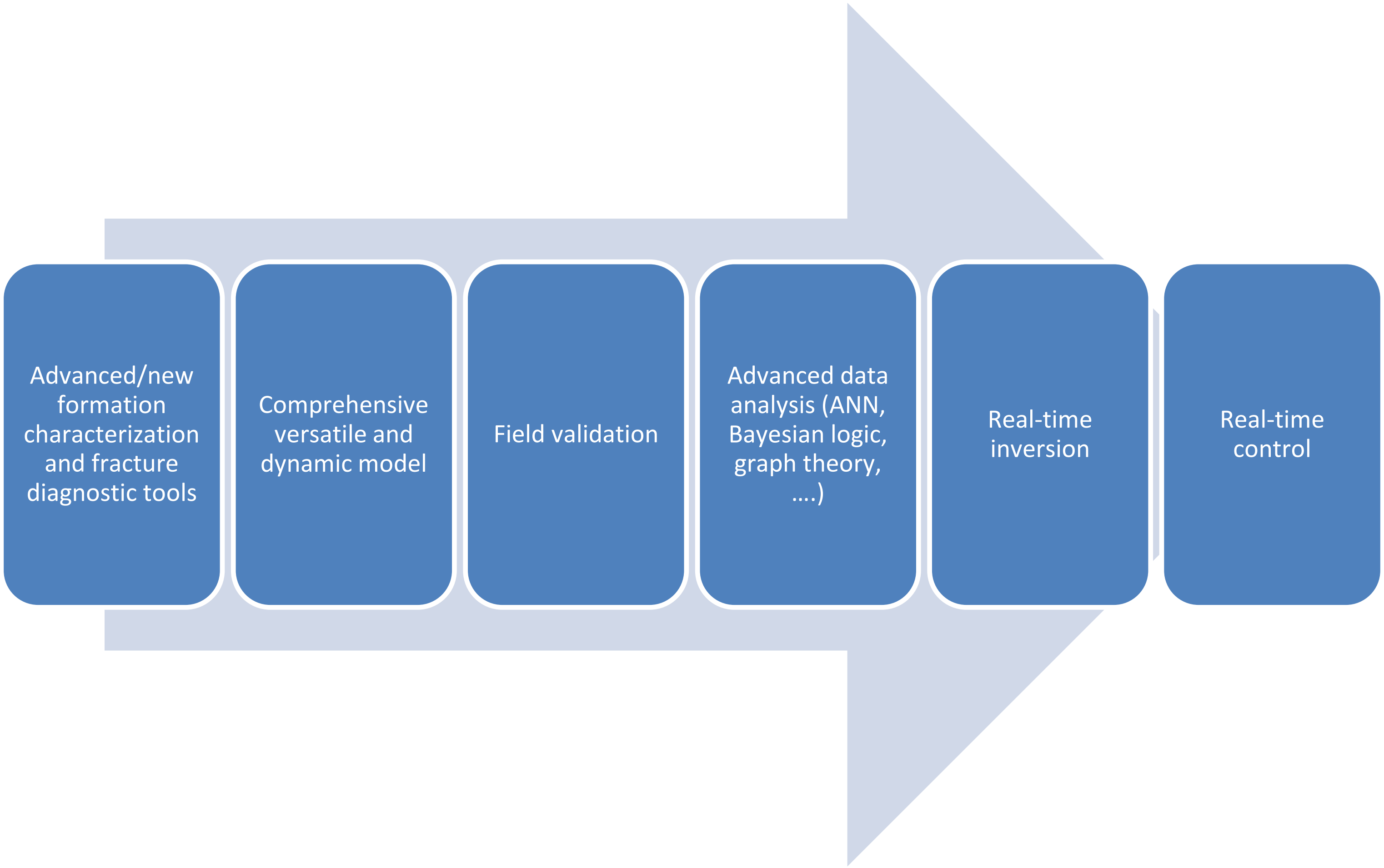
Future of hydraulic fracturing



Answers to questionnaire

- *What are the most important challenges associated with fracture and control of subsurface fluids?*
  - *Determination of cause-and effect relation between fracturing parameters and fracture attributes*
- *What are the major uncertainties and knowledge gaps?*
  - *Fracture dimensions and connectivity*

Answers to questionnaire

- *Will improving our knowledge of this area significantly improve our ability to control fractures and fluid flow in real time? Or, will the improvement be incremental?*
  - Improvements will be incremental at first leading to real-time control
- *Within the challenges and uncertainties that you have identified in this area, which are best tackled through computational modeling versus technology R&D versus field based initiatives?*
  - Coupled lab/analytic/field-based approach

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Answers to questionnaire

- *What are the barriers to industry collaboration with government initiatives to address these challenges?*
  - *Sharing of results with competitors*
  - *Stringent terms and conditions*
- *Would you be interested in or willing to cost-share in government research in this area?*
  - *Yes*

Answers to questionnaire

- *Are you investing in this area?*
  - *Some companies are (e.g., Noble, Shell)*
- *What degree of fracture and flow control do you envision in 5 years and 10 years with limited government involvement?*
  - *Depends on the level involvement*
- *Will government support get you to your goals faster or help you to exceed those goals?*
  - Yes

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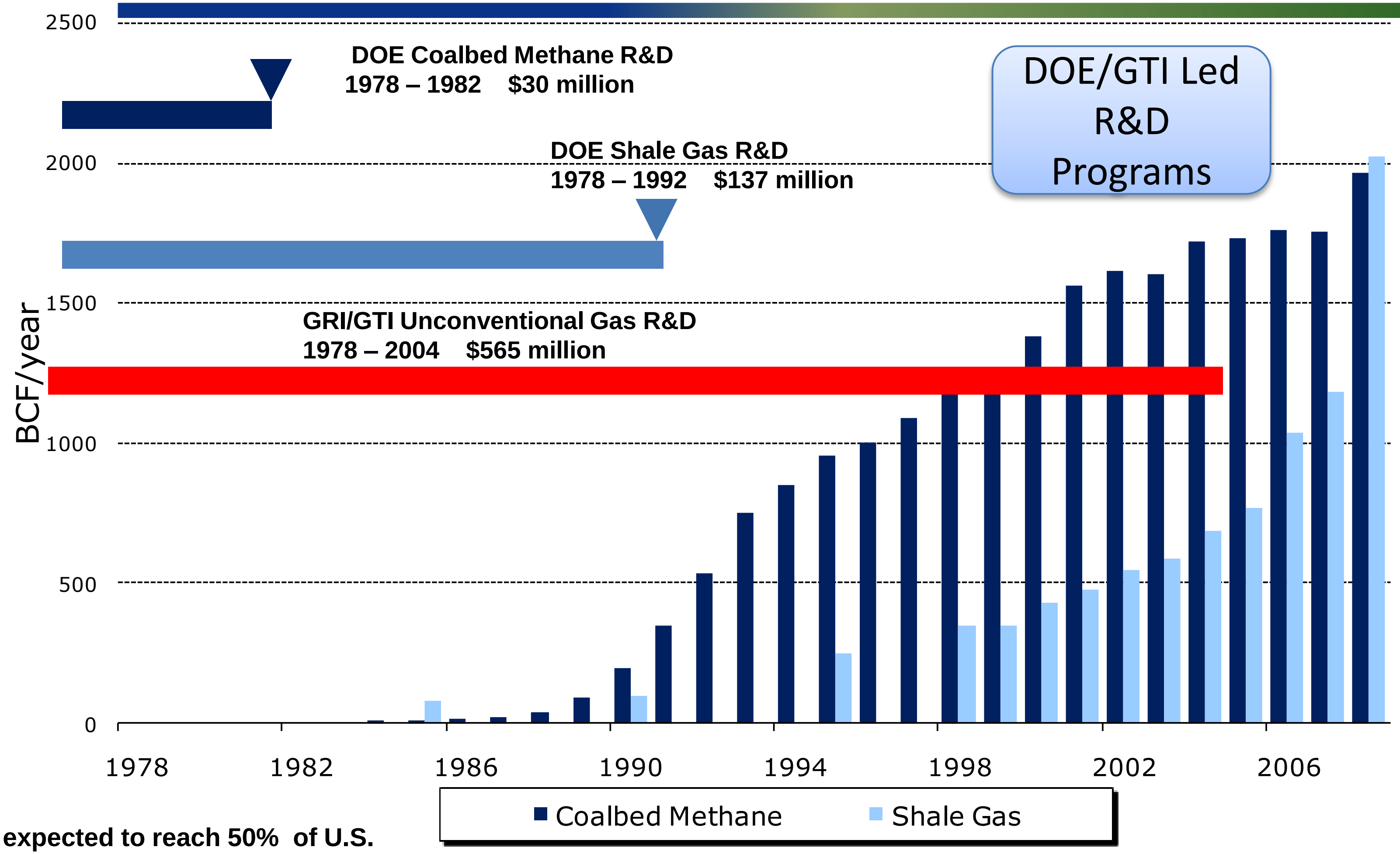
Impacts of public funding on development of unconventional resources



Shale expected to reach 50% of U.S. gas production by 2035

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