KUALA LUMPUR 2012 WORLD GAS CONFERENCE

25th world gas conference

"Gas: Sustaining Future Global Growth"

Advances in Unconventional Gas Technologies

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Level 3—Room 302/3

Patron

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Introduction

- There has been a huge shift in natural gas production over the past decade toward unconventionals
- Unconventionals have low permeability and require fracture stimulation for economic production
- They include coalseam gas (CSG), shales, and tight sandstones/carbonates
- This shift has been accompanied by rapid advances in three key areas, which will be covered in this talk
  - Reservoir characterization
  - Drilling and completions
  - Well production and forecasting

Reservoir Characterization

- Several fractured zones in Pinedale Field (tight sands) were identified by mud losses during drilling
- An AVAZ analysis from 3-D seismic showed that these losses coincided with zones of significant anisotropy interpreted as open natural fracture swarms
- Well produced 1.7 BCF (about 50 MMm^3) of gas over a 3-year period

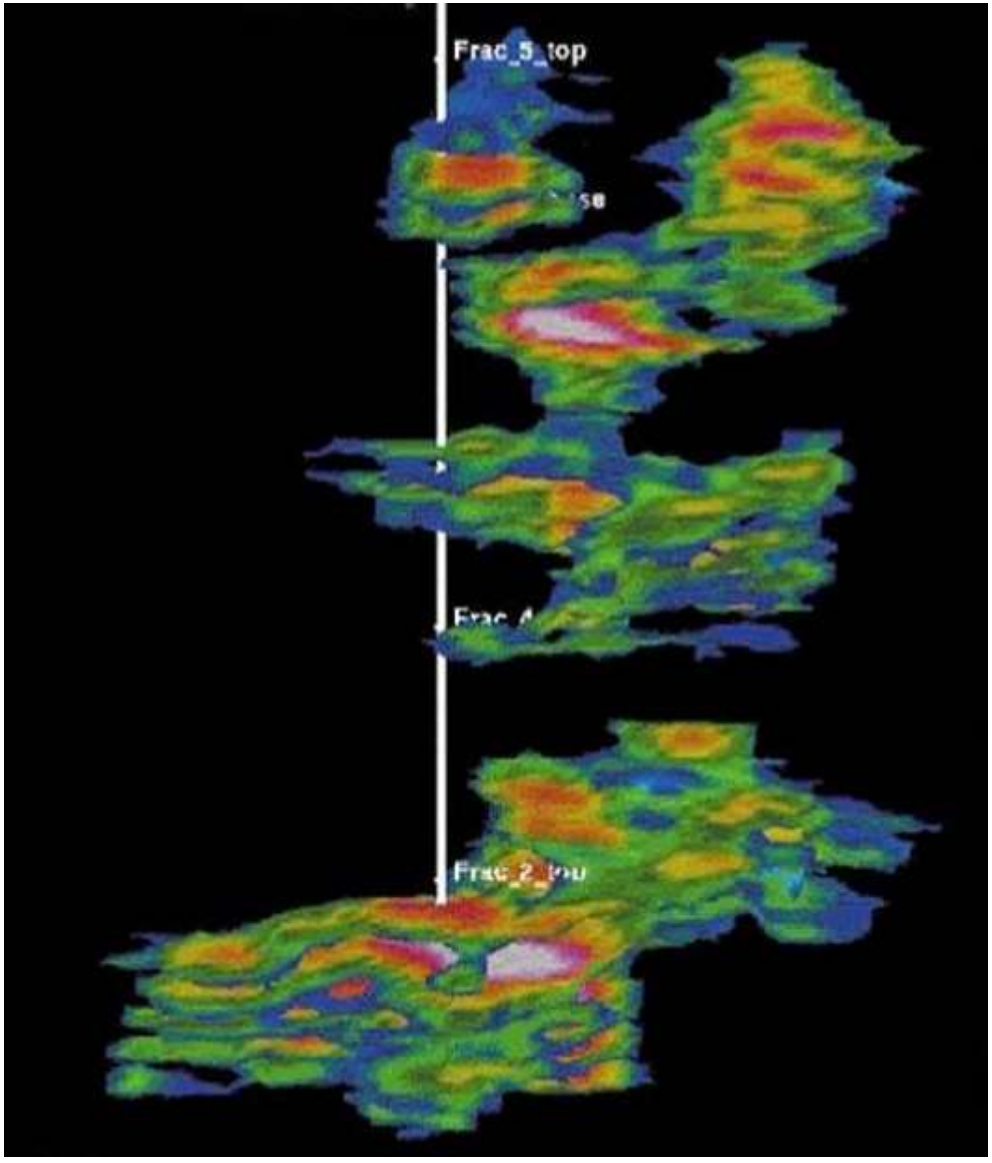


Figure from David Gray, Graham Roberts, and Kim Head, 2002, *Recent advances in determination of fracture strike and crack density from P-wave seismic data*, The Leading Edge, March 2002, pp. 280-285.

Reservoir Characterization

- SEM image from the Barnett Shale shows organic matter (dark gray) that contains pore spaces (black)
- These pores formed when solid organic matter was converted to hydrocarbons during burial

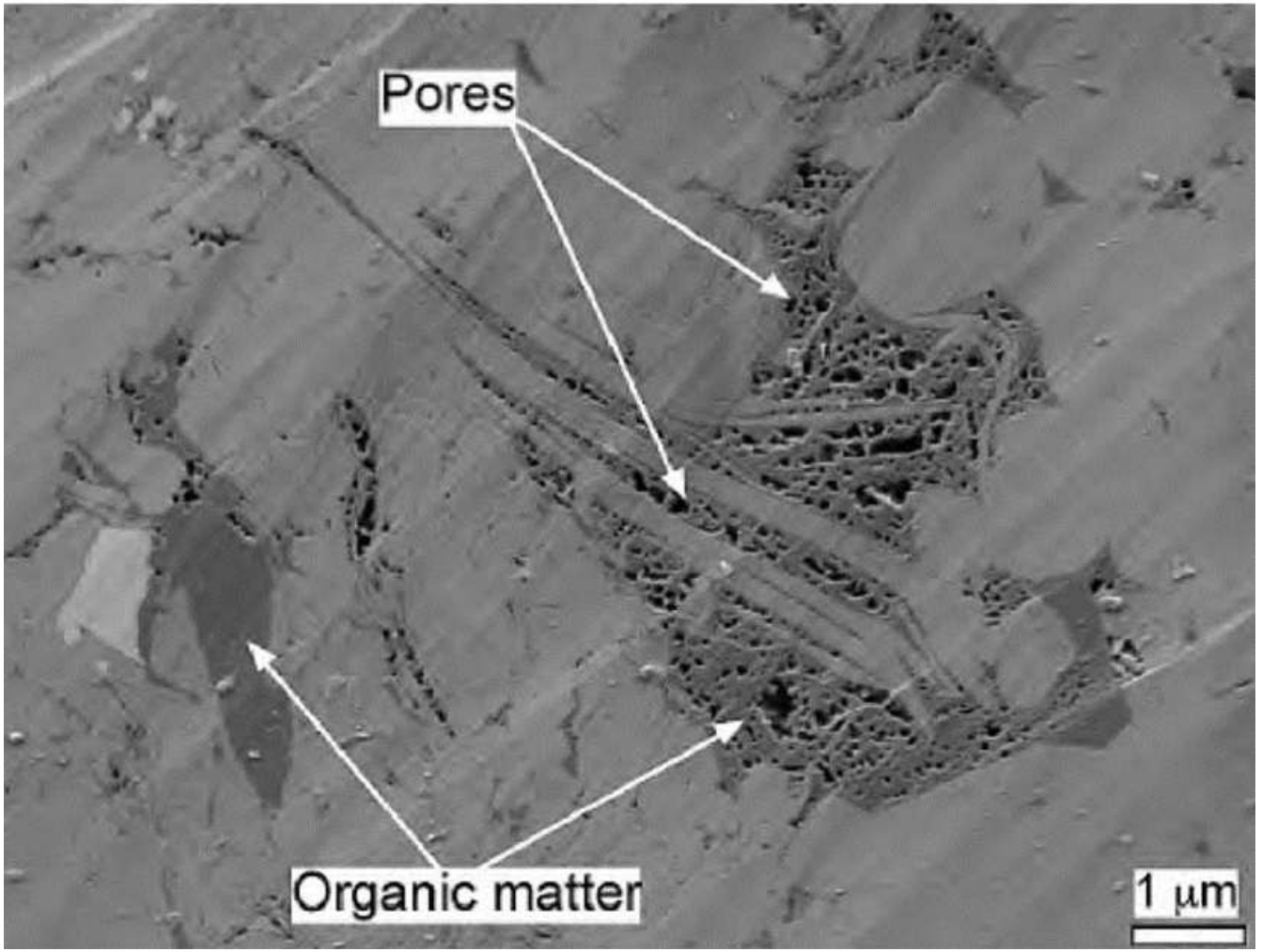
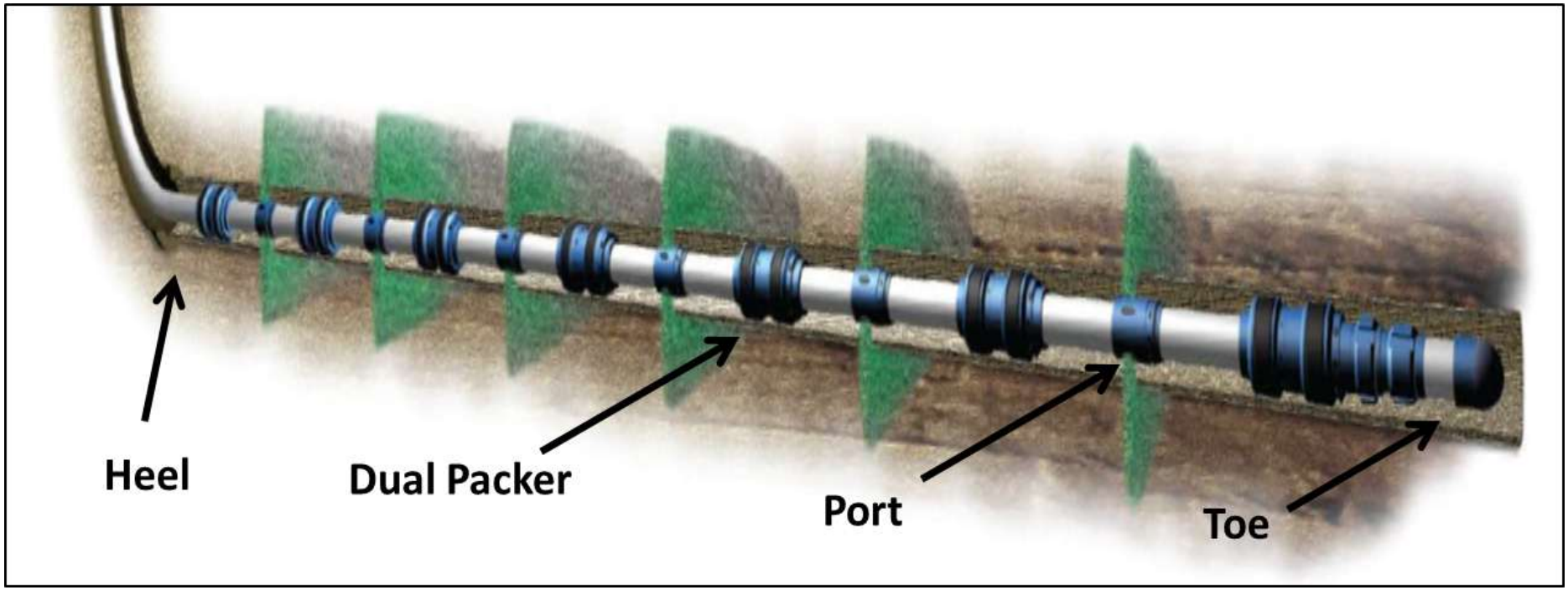


Figure from Stephen C. Ruppel and Robert G. Loucks," *Black Mudrocks: Lessons and Questions from the Mississippian Barnett Shale in the Southern Midcontinent*", The Sedimentary Record, June 2008

Reservoir Characterization

- Additional work is needed to…
  - Improve vertical seismic profiling (VSPs), tomography, 4-D seismic, and other geophysical techniques to locate sweetspots and avoid geo-hazards
  - Apply the interpretations of mineralogy, mechanical properties, and natural fracturing to decision target intervals and well completion types
  - Refine existing petrophysical techniques to more accurately determine porosity, permeability, and saturations
  - Determine how reservoir properties at the nanometer level can be upscaled for use in modeling work

Drilling and Completions



- Liner segmented by packers is run in the well. Ports between them have progressively smaller diameters from the toe to the heel of the well.
- A small ball is dropped from the surface that seats itself in the last port and opens it so that the stage can be fracture-stimulated.
- This is repeated with successively larger balls until all stages are fracture stimulated

Drilling and Completions

- Microseismicity in the Montney Shale was recorded from a vertical monitoring well during the fracture stimulation of multiple stages in 3 horizontal wells
- Linear microseisms extend from Wells A and B into areas with lower Poisson's Ratio
- Large microseisms clustered along Well C follow an existing fault that has been reactivated

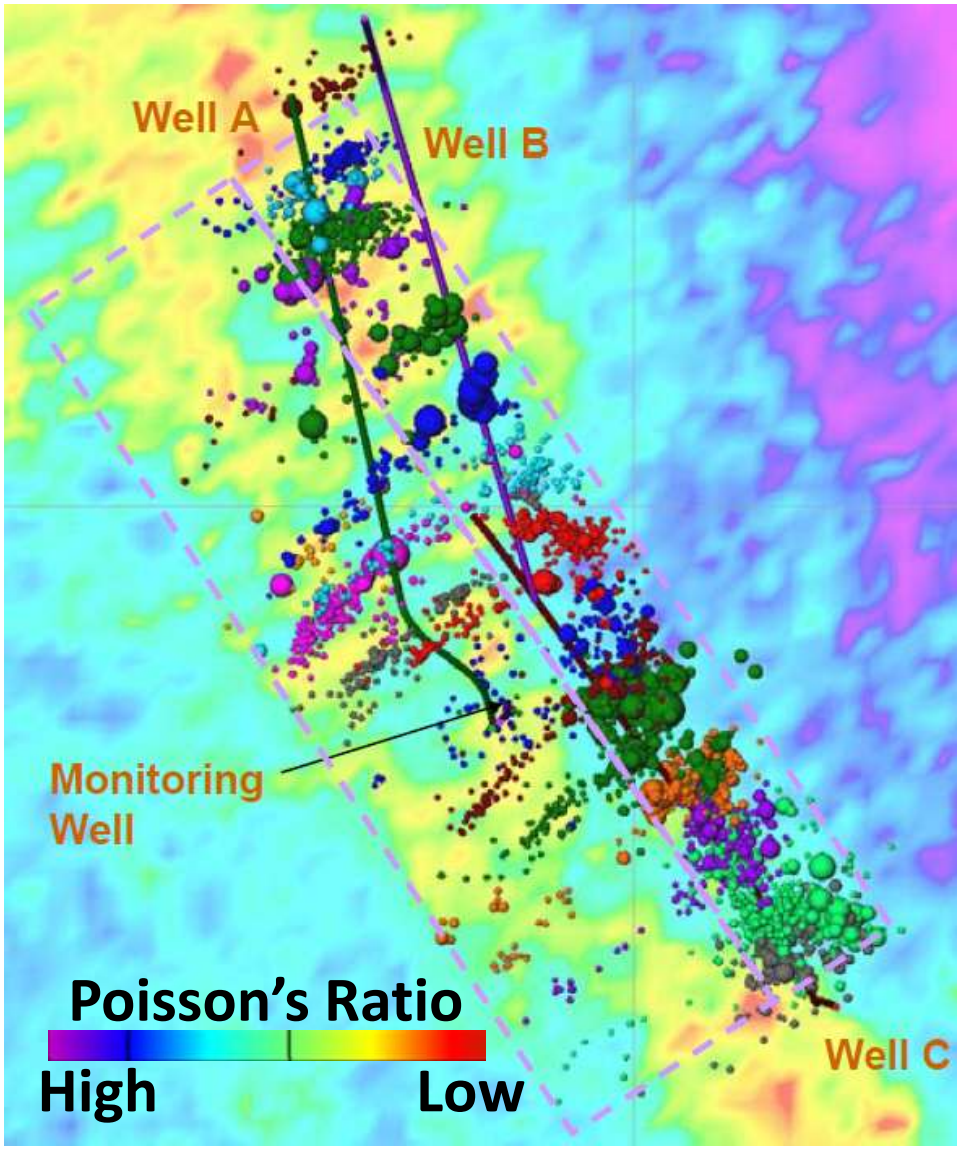
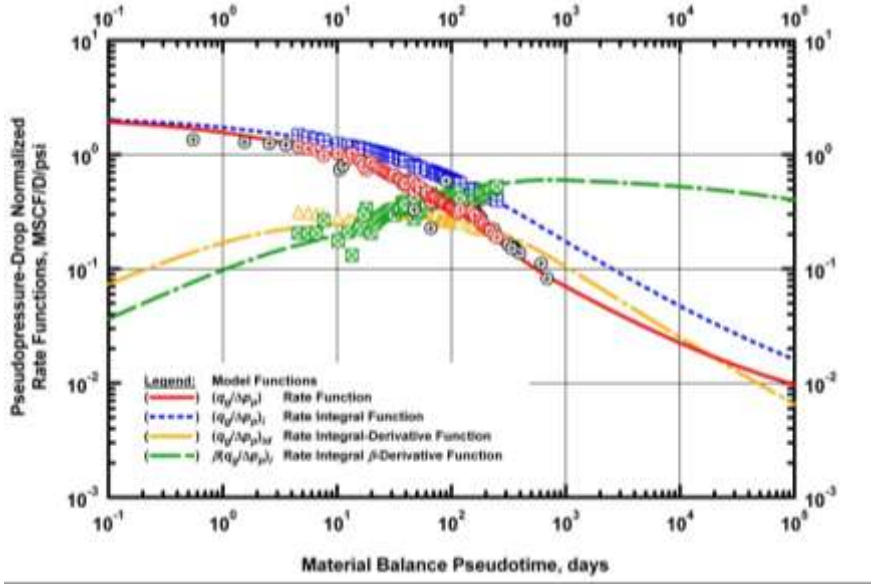


Figure from S.C. Maxwell et al, *Understanding Hydraulic Fracture Variability Through Integrating Microseismicity and Seismic Reservoir Characterization*, SPE 144207.

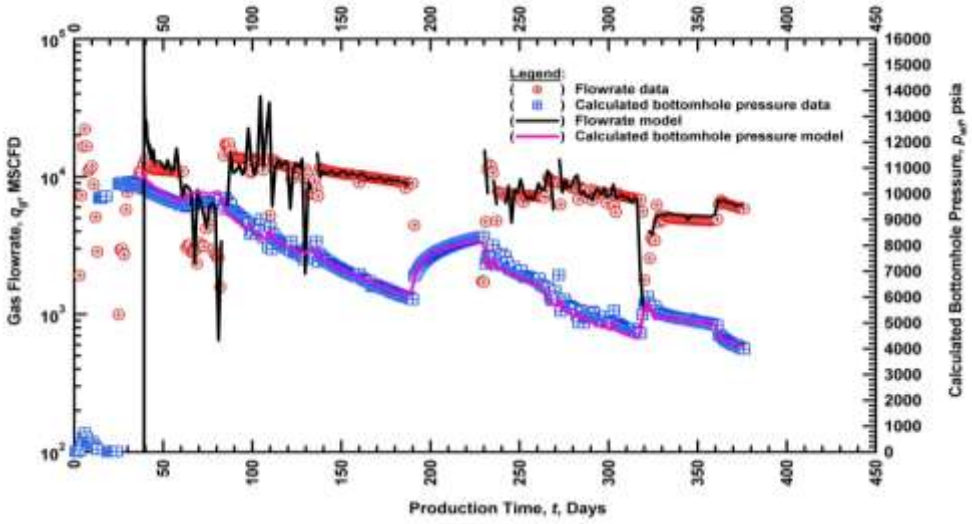
Drilling and Completions

- Additional work is needed to…
  - Develop techniques for propping narrow hydraulic fractures using smaller and/or buoyant proppants
  - Design fracture stimulations that both drain the tips of fractures and maximize near-wellbore conductivity
  - Develop fracturing fluids that can be mixed with brines, are compatible with formation fluids, and are non-toxic
  - Understand what portion of the stimulated reservoir volume is being effectively drained to optimize well spacing, well length, and fracture stage spacing
  - Obtain information from production logs, temperature surveys and chemical tracers regarding which frac stages are contributing and why

Well Production and Forecasting



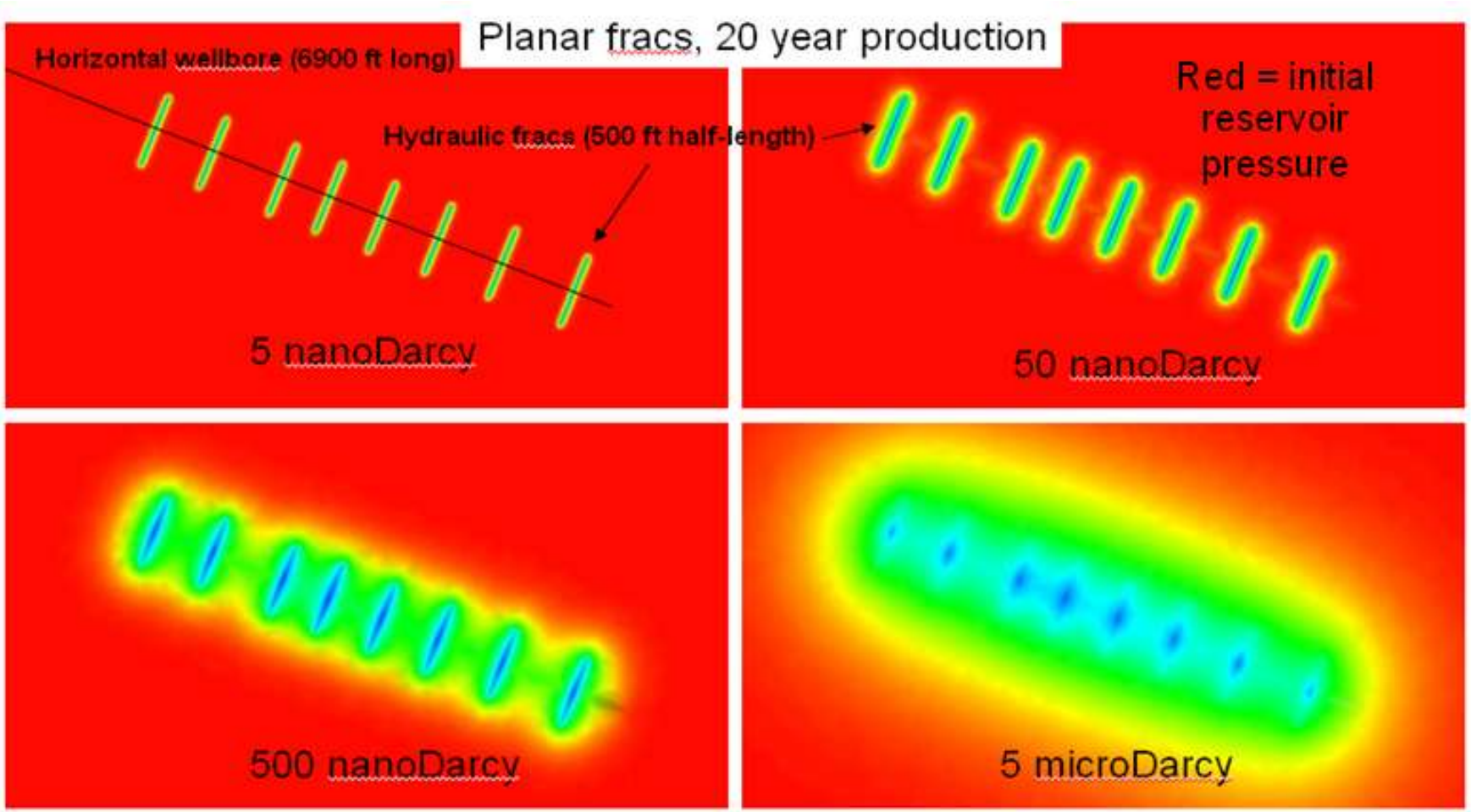
Match of the data functions with a multiple transverse fractures solution.



Production history plot showing the match between data and model

- Using model-based production analysis, one year of rate and pressure data are matched assuming a horizontal well with 47 contributing fractures, a permeability of 600 nanodarcies, a fracture half length of 210 feet, and a skin factor of 0.01
- The model is then used to forecast future well performance

Well Production and Forecasting



- Modeled pressure distributions for different permeabilities show the volume drained in a shale gas reservoir after 20 years of production

Figure courtesy of Object Reservoir

Well Production and Forecasting

- Additional work is needed to…
  - Improve forecast models by incorporating multiple layers, natural fractures, and realistic hydraulic fracture geometries
  - Quantify risks and uncertainties through the use of experimental design, Monte Carlo analysis, or other techniques in the reservoir modeling process
  - Develop inexpensive and minimally-disruptive techniques to collect periodic information about which intervals are contributing fluids and how this is changing with time
  - Improve the durability of downhole data collection equipment to endure high temperature and pressure conditions

Conclusions

- Technology continues to play a vital role in the identification and commercial production of gas from unconventional reservoirs
- Additional improvements and innovations will be critical for developing future unconventional opportunities, most of which will be outside of North America
- Investment incentives, partnerships between government-industry-academia, reasonable regulatory policies, and technology transfer protocols will all be needed to identify, grow, and implement these new leveraging technologies