Unconventional Resources

Society of Mining, Metallurgy, and Exploration
Midwest Groundwater Association

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STEPHEN R. BRAND

What defines an "unconventional" play?

Specific definitions vary but basically they are…

- **Extremely low production capability, i.e., low permeability (6-9 orders of magnitude lower than conventional systems)**
- **Organic rich systems, i.e., high organic content**
- **Large volumes of reserves in place**
  - Due to the low producing efficiency, must start with a large volume in place (recovery factors can be as low as 1-2%)

- **Cannot be produced at economic flow rates without assistance from massive stimulation treatments (hydraulic fracturing) or other enhanced recovery methods (EOR)**

Technical Challenges

Reservoir engineering

- A “shale isn’t a shale”
- How to manage/evaluate nano-Darcy perms

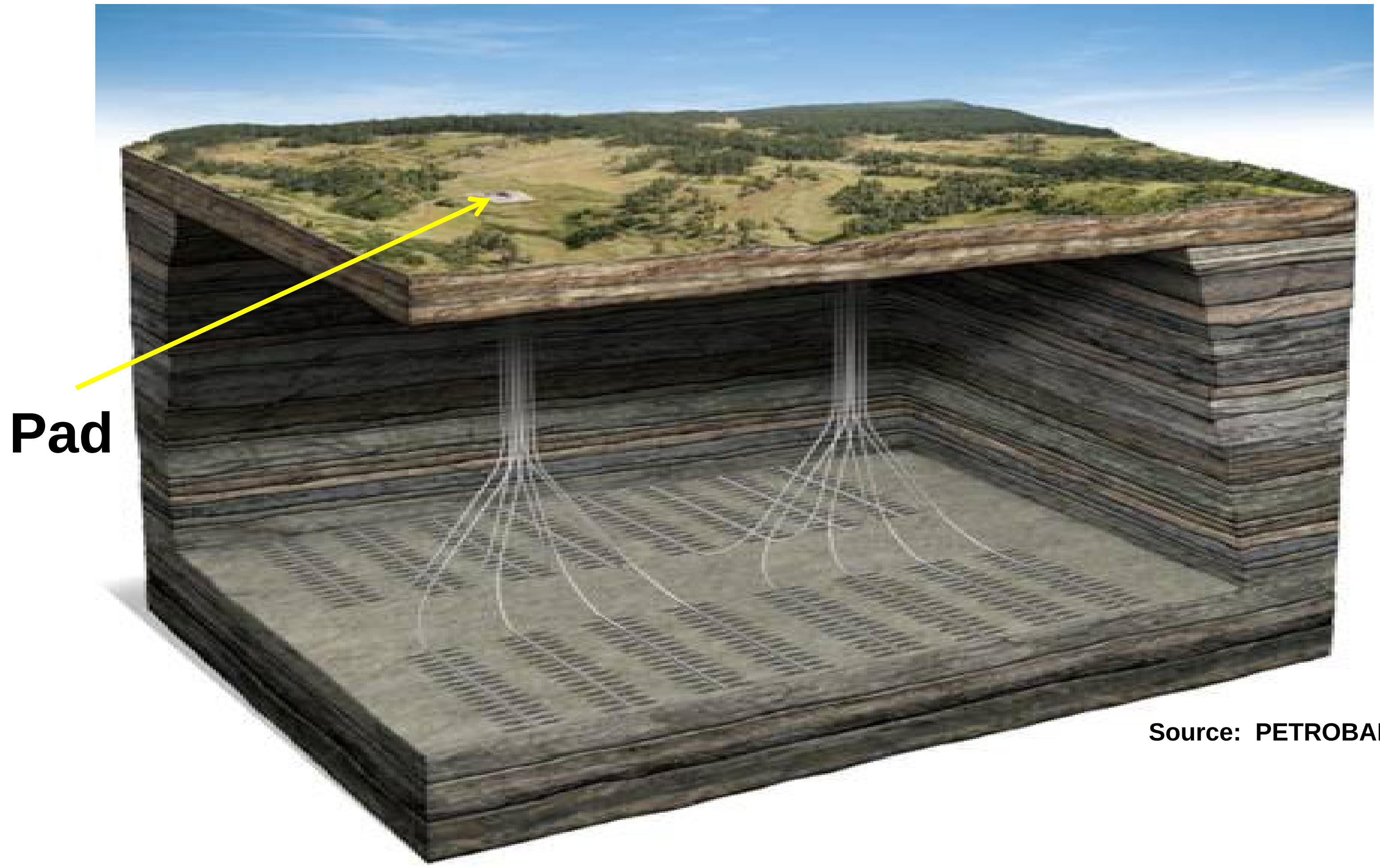
Stimulation and completion

- Rock characterization
- Complexity of hydraulic fracturing
- Horizontal well development and associated tools

Need to identify the best rock

- Listen to what the rocks are saying

Horizontal Wells



Source: PETROBAKKEN

- Earliest development occurred in 1940's in California
- True development and deployment began in the USA in the mid-1970's

Oilfield Stimulation History

Acidizing / nitroglycerin main stimulation services provided until late 1940’s

In 1947, the first intentional fracture treatment took place in the Hugoton gas field of western Kansas.

Klepper Gas Unit No. 1 well and was called a “hydrofrac”

+60 year technique used worldwide

From J.L. Miskimins, March 2006

Technology Drivers

Smaller "footprints" (pad drilling; horizontal wells)

Reduce stimulation costs

Material developments

- Proppants for hydraulic fracturing (nanotechnology)
- "Greener" fracturing fluids
- Reuse / recycling of fracturing fluids

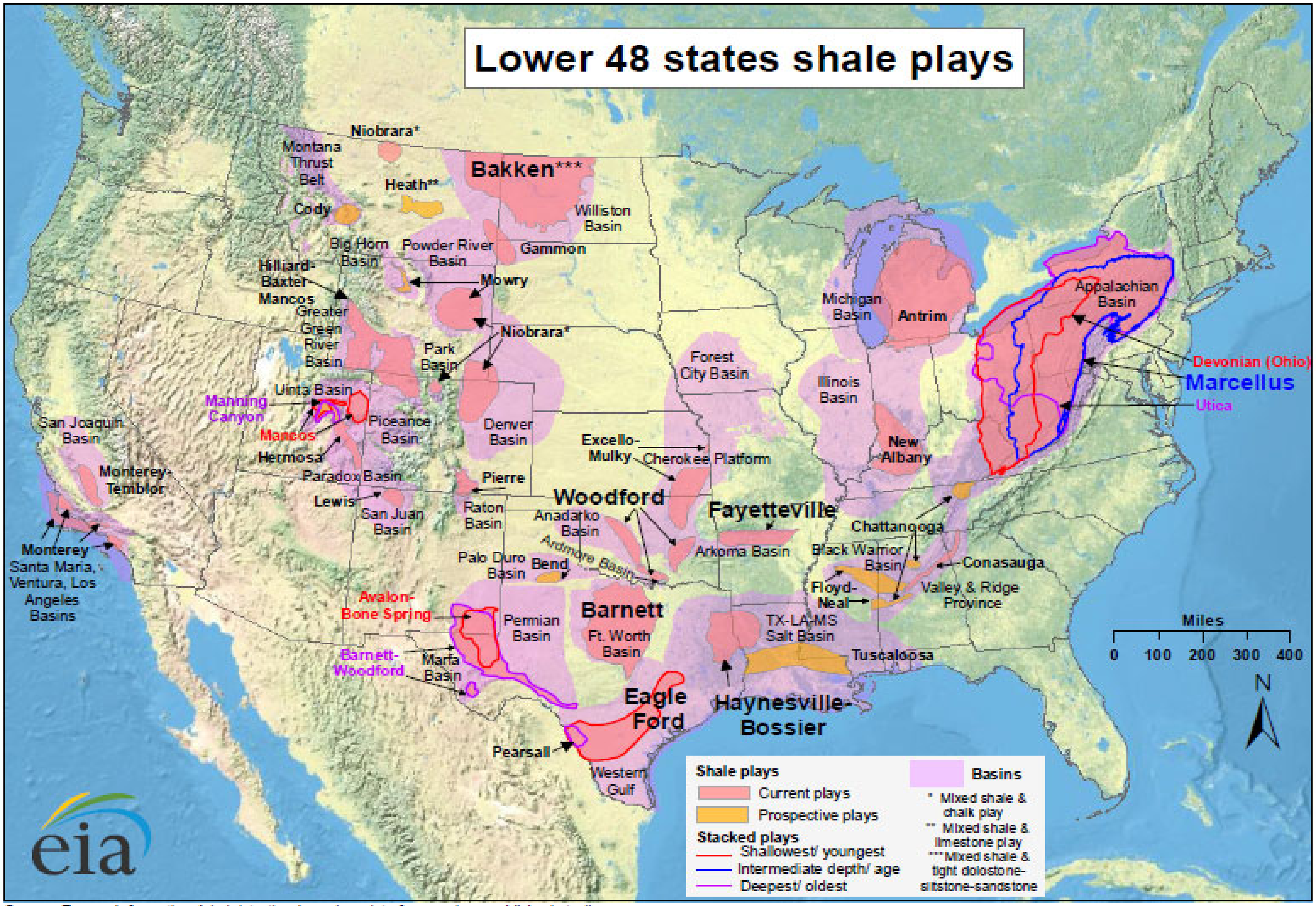
Overall mitigation of environmental impacts (traffic, noise, land use, aesthetics, etc.)

Technology Improvements – Fayetteville example

- Drill time has decreased by 59% (from 20 days to 8 days)
- Number of wells per year per rig has increased by 144%
- Average lateral length has increased by 122%
- Average 30-day production rate has increased by 162%
- Initial production additions per rig per year have increased by 538%
- Drilling and completion costs have increased by 4% (only an additional $100,000)

Source: Rusty Braziel, Bentek Energy

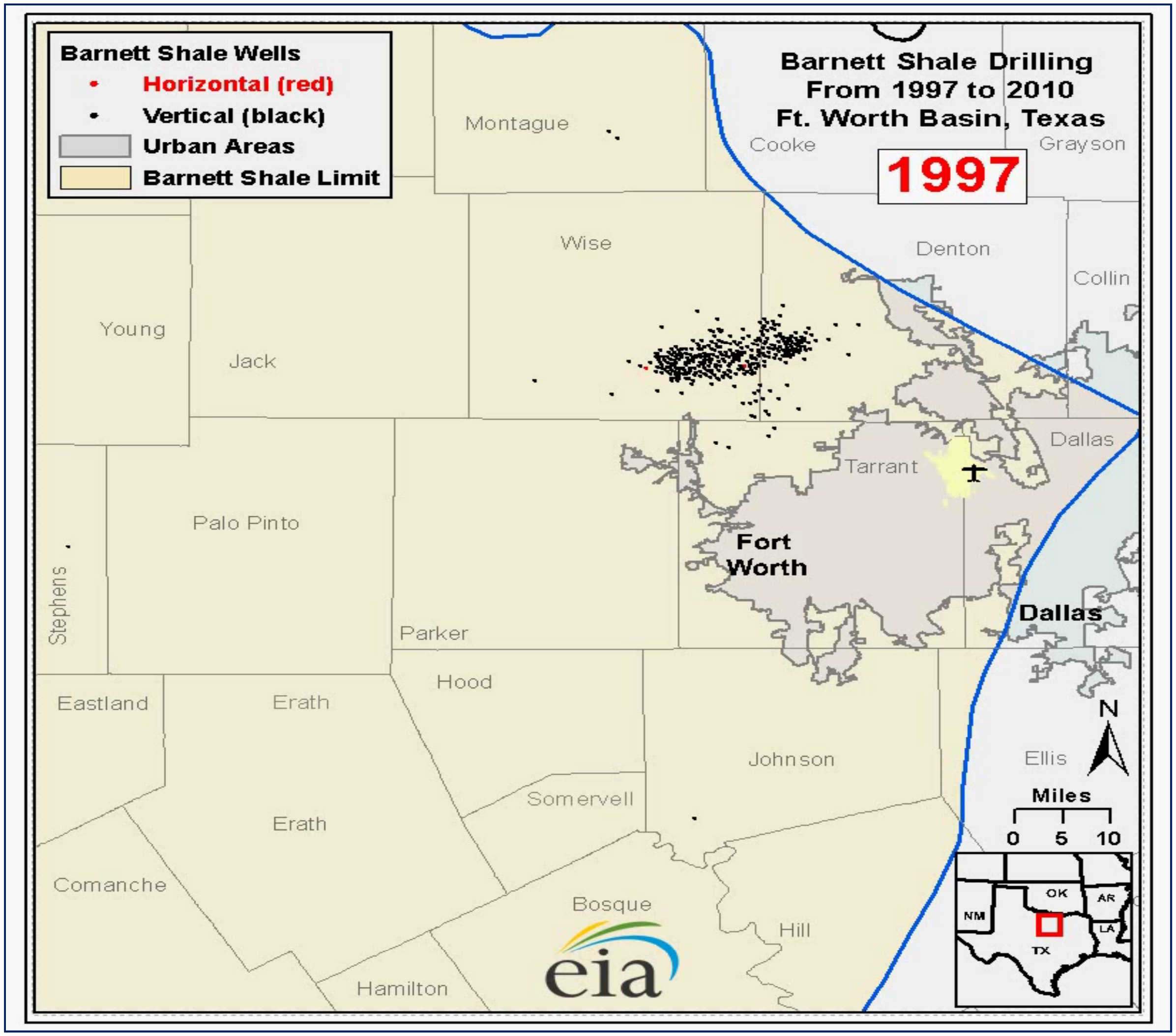
North America Shale Basins



Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

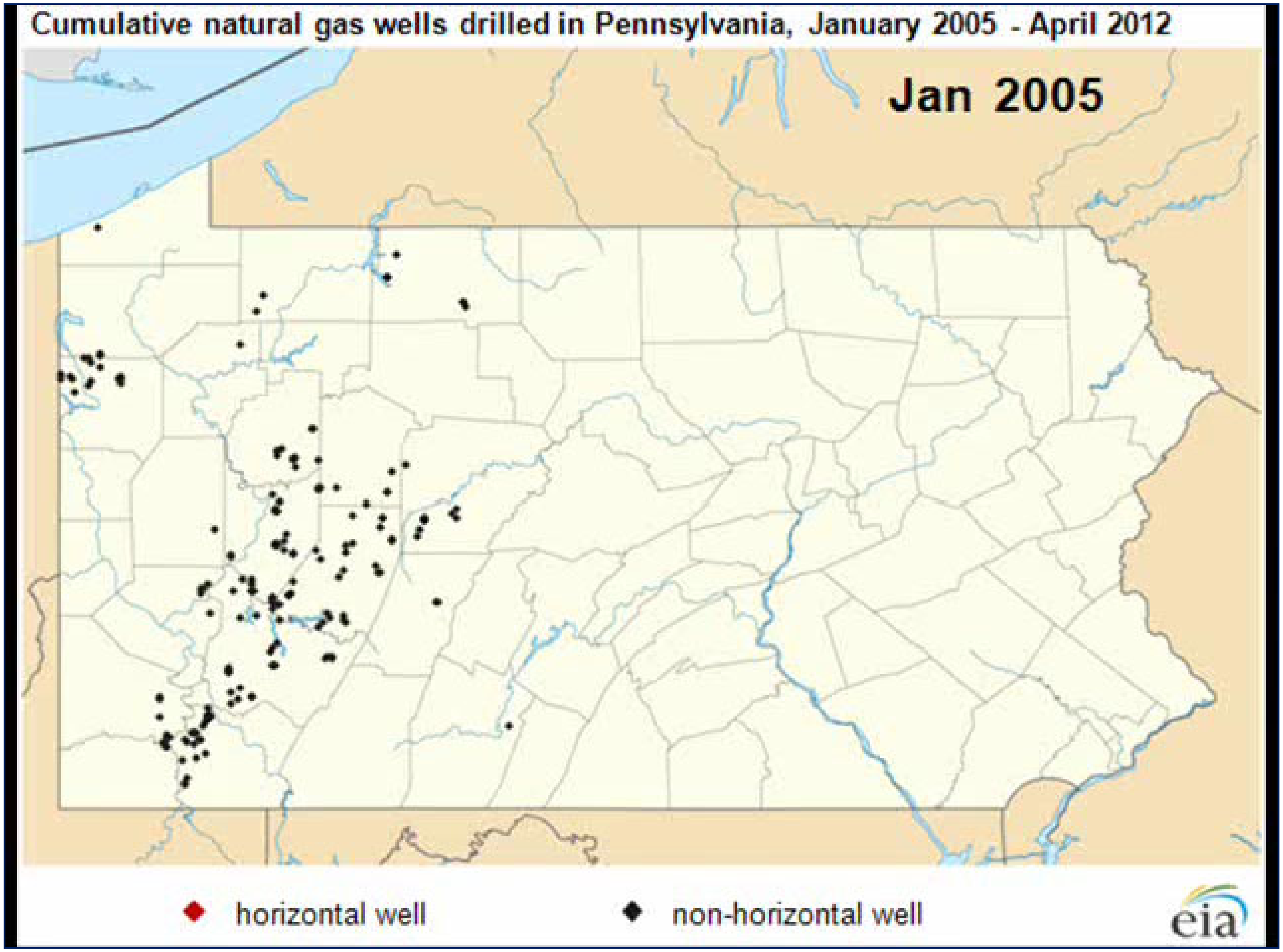
Barnett Shale

Ft. Worth Basin, Texas 1997 - 2010

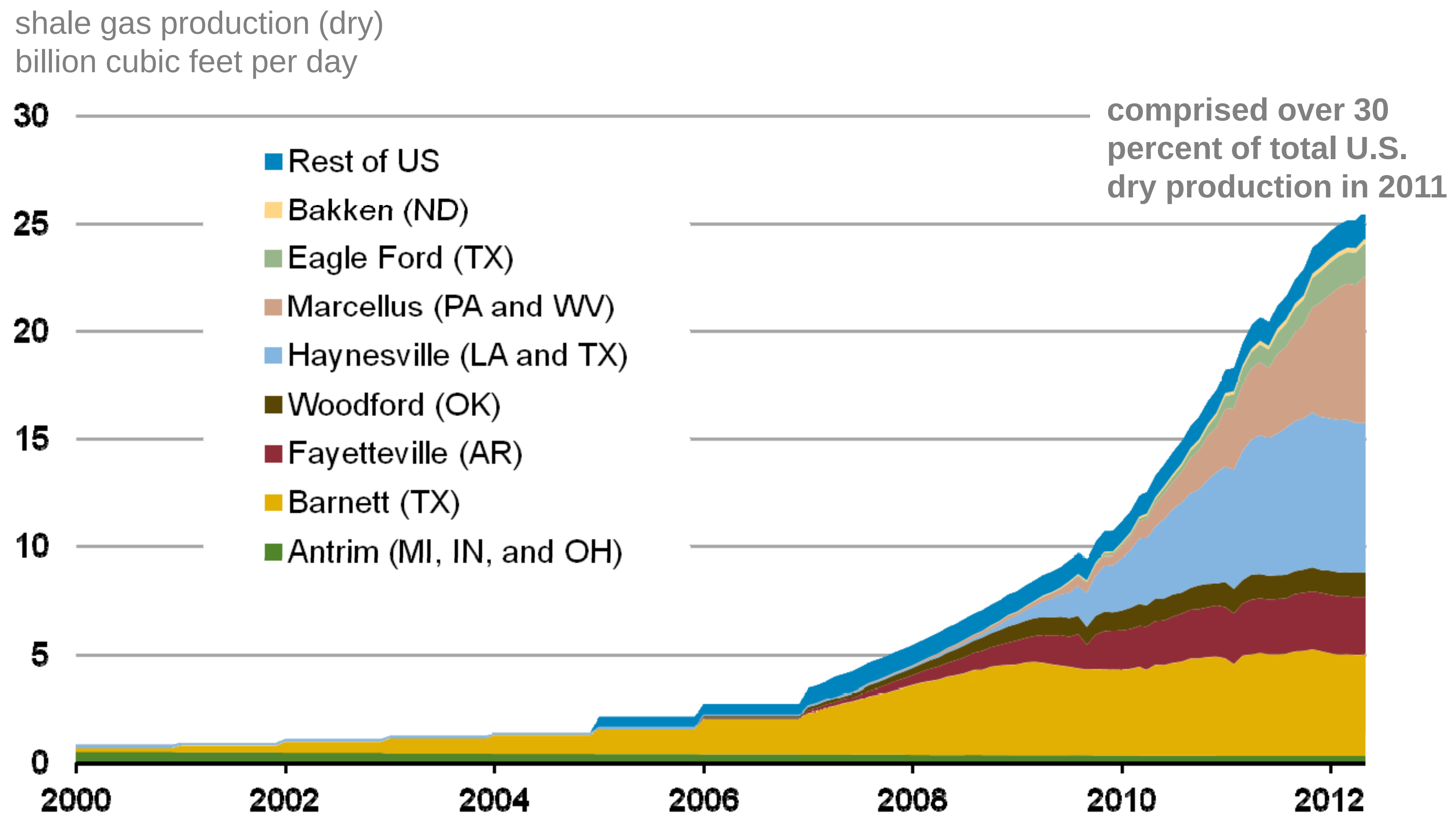


Natural Gas Wells in Pennsylvania

2005-2012



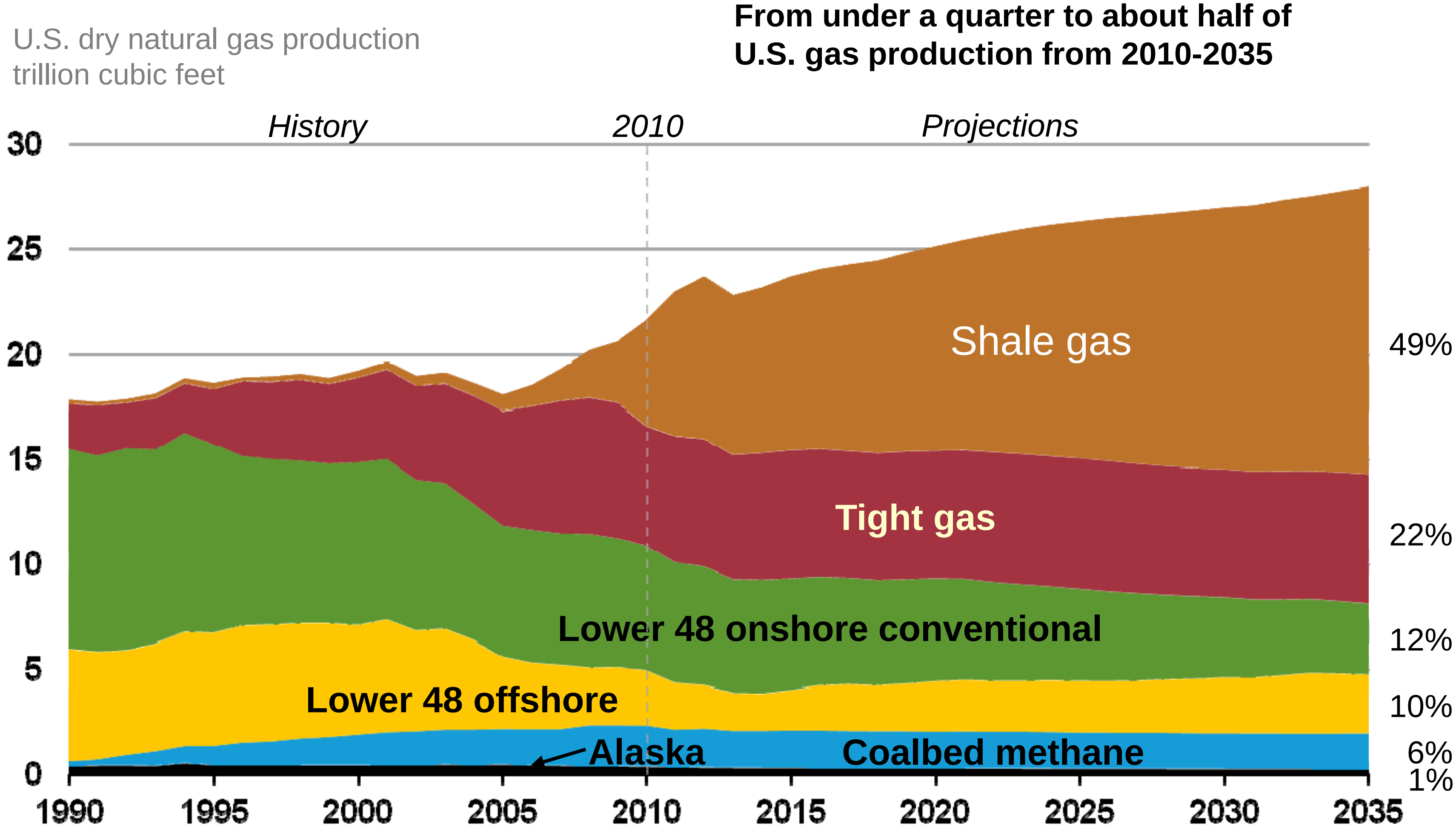
U.S. Shale Gas Production



Sources: Lippman Consulting, Inc. gross withdrawal estimates as of May 2012 and converted to dry production estimates with EIA-calculated average gross-to-dry shrinkage factors by state and/or shale play; EIA, July 2012

Shale Gas Growth

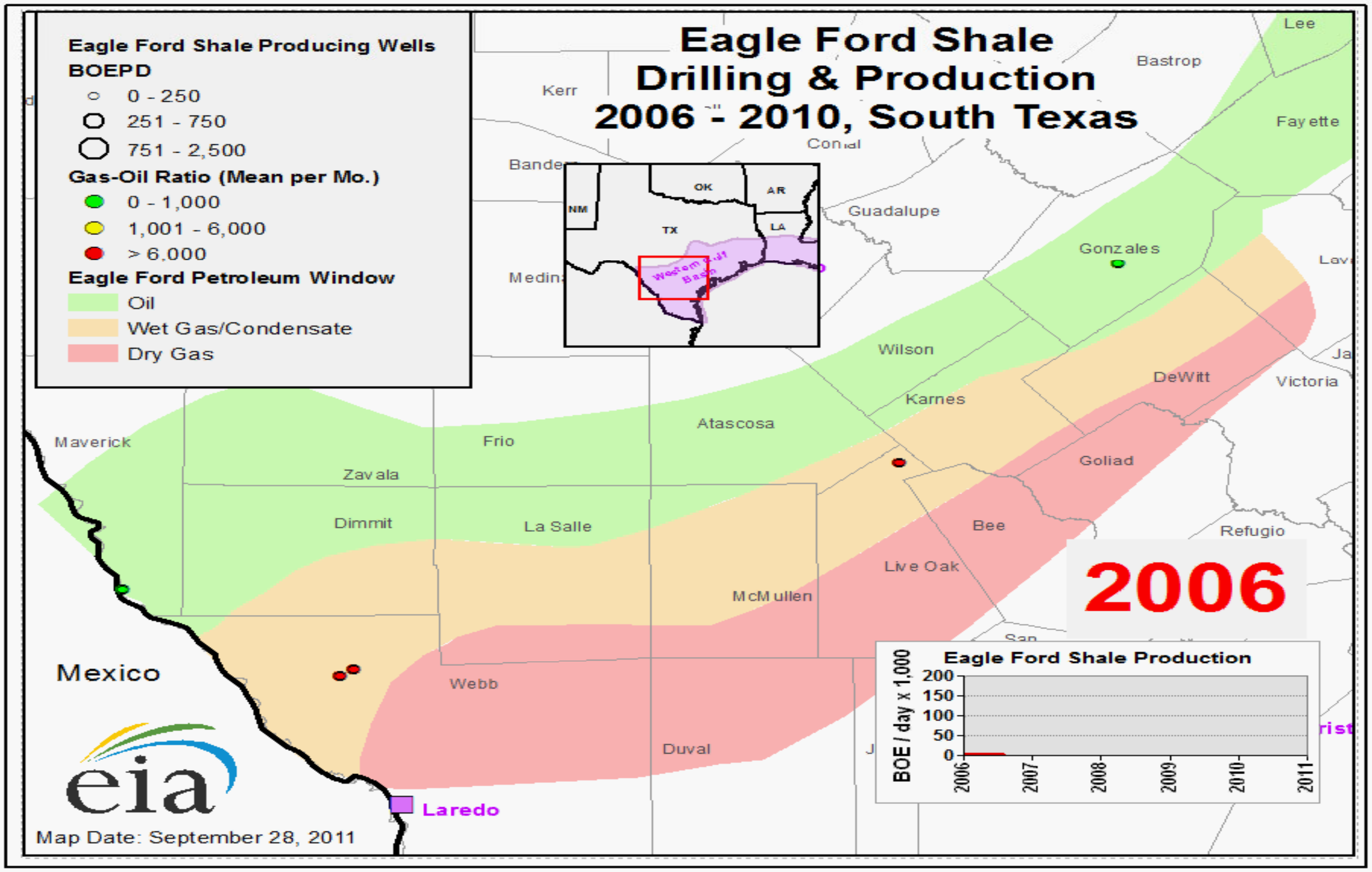
From under a quarter to about half of U.S. gas production from 2010-2035



Source: EIA, Annual Energy Outlook 2012

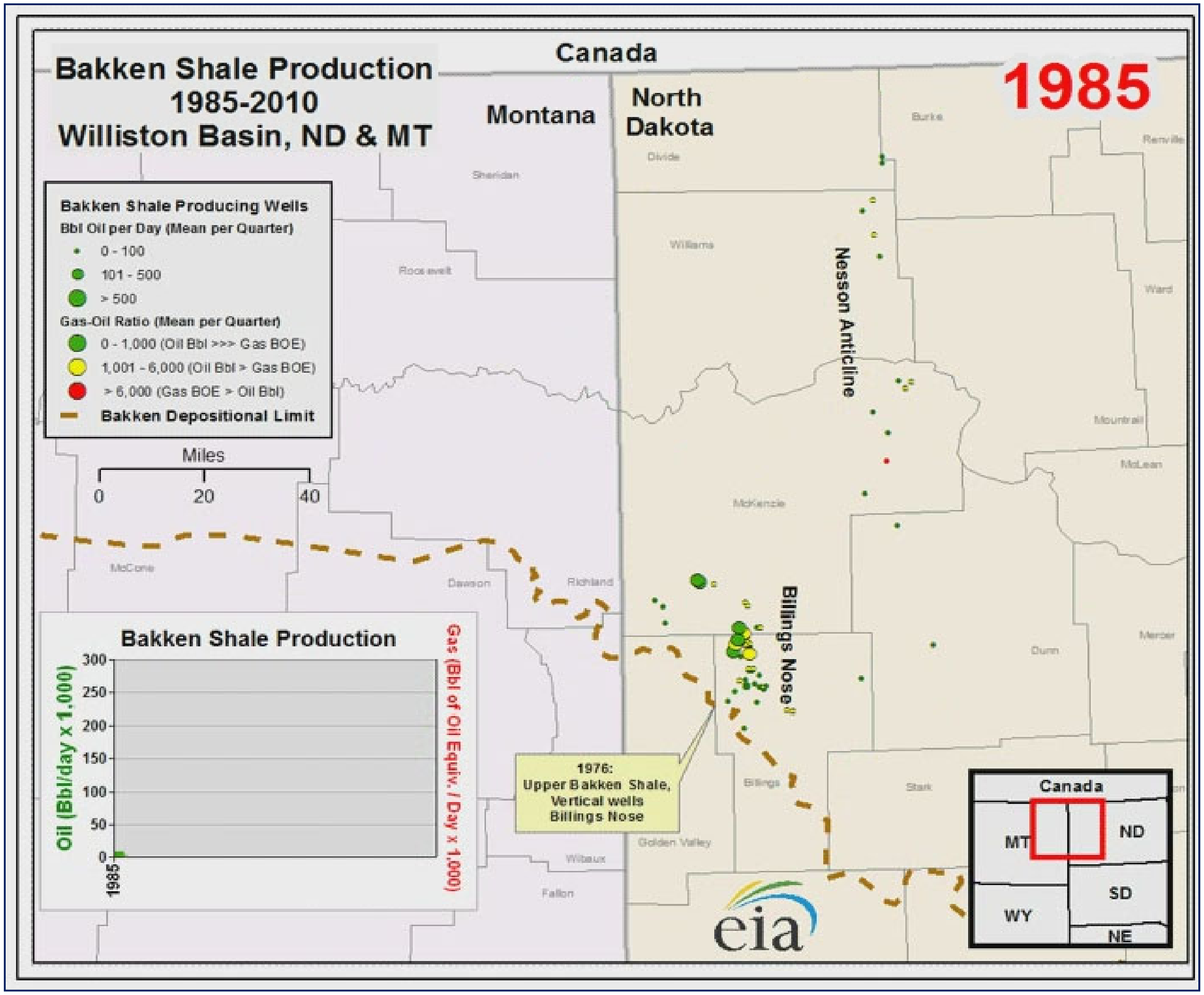
Eagle Ford Shale

Production 2006 - 2010

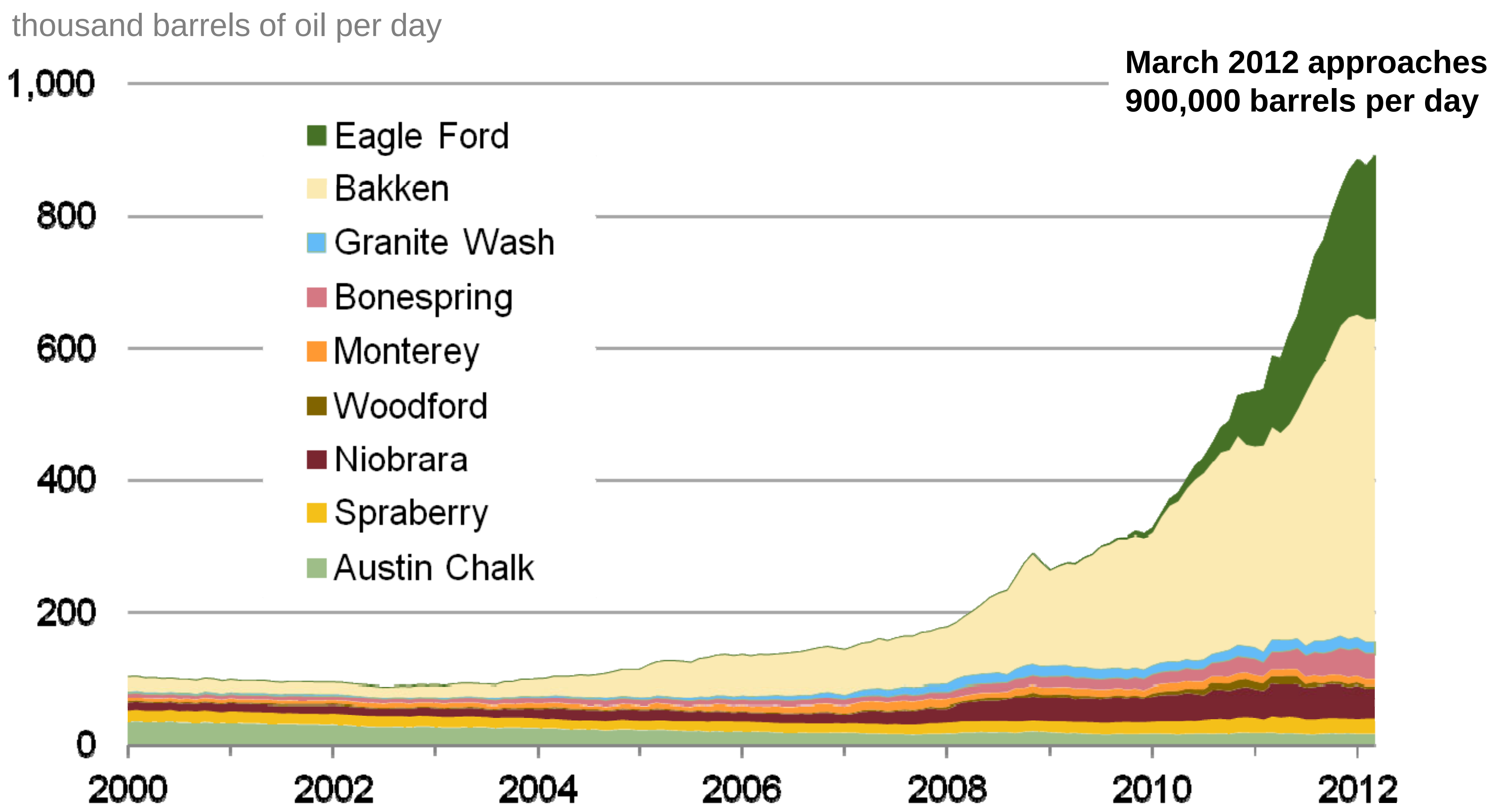


Bakken Shale

Williston Basin, North Dakota & Montana



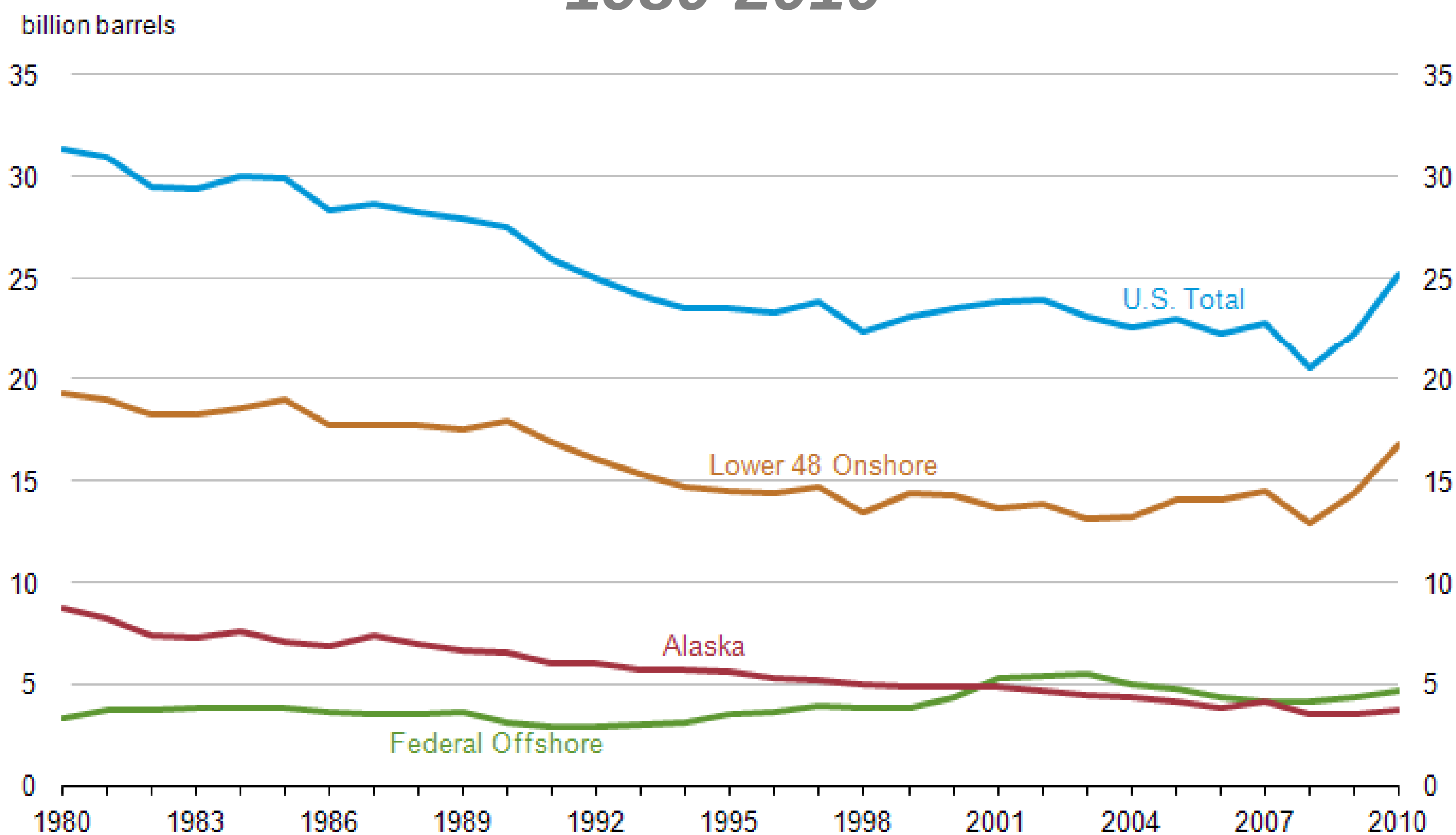
Tight Oil Production for Selected Plays



Source: HPDI, Texas RRC, North Dakota department of mineral resources, and EIA, through March, 2012; EIA, July 2012

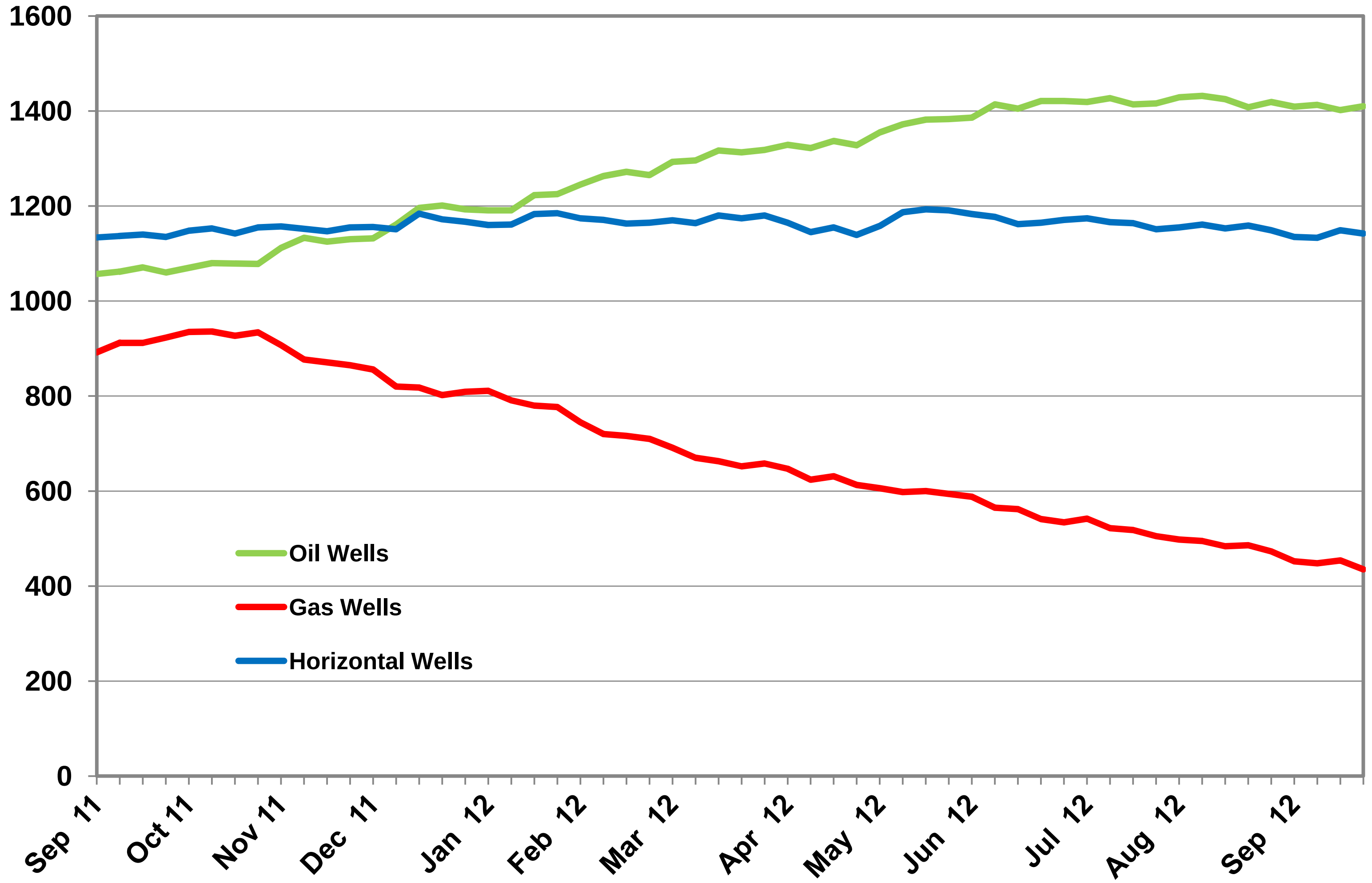
U.S. Oil plus Condensate Proved Reserves

1980-2010



Source: U.S. Energy Information Administration, U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 1980 through 2010 annual reports.

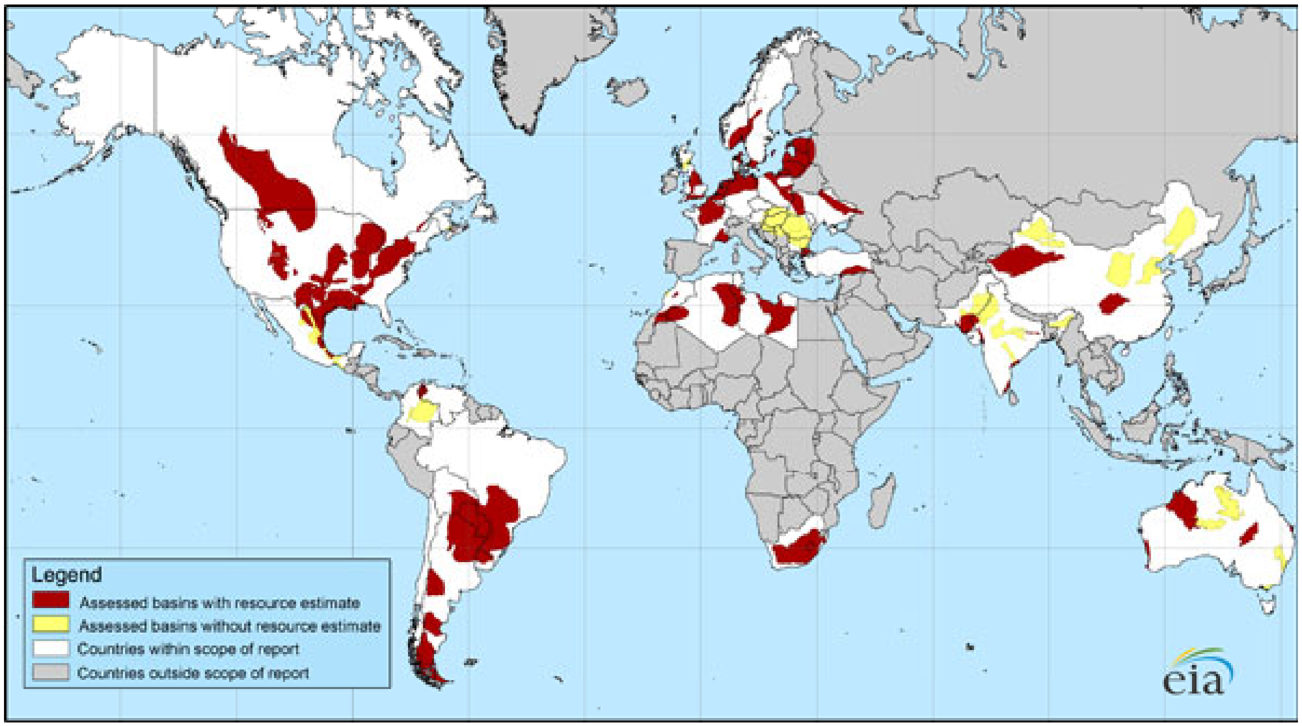
Drill Rig Count



Source: Baker Hughes, September 28, 2012

Shale Gas…..A Global Phenomenon?

Where is the opportunity to capitalize on this resource development?



Source: **U.S. Energy Information Administration based on Advanced Resources International, Inc. data**

International Growth and Constraints

- **Global interest in shale is growing**
  - **Europe, Argentina, India, China, Australia, North Africa, SE Asia**
- **Worldwide adoption of existing shale techniques along with potential challenges moving forward**
- **Development of new industry**
- **More infrastructure needed to support the development**
- **Regulatory support needed**
- **Lack of seismic and logging information**
  - **Less international seismic information available**

Modified from: Rusty Braziel, Bentek Energy

Shale Oil / Gas Expansion

New technology required – N.A. is laboratory

Pace of gas shale development depends on drilling intensity and technology development

Too early to determine impact of new technologies

International resources to be developed

Shale "Gale" Future

- Technology learning curve - continued improvements
  - Increase well productivity
  - Lower cost
  - Improved recovery
  - Manage risks and environmental impact

- Challenges
  - Large variations in shale quality
  - Defects in the well manufacturing process – completion quality
  - Complete develop will require lots of wells
    - 40,000 - 100,000 wells to develop the Marcellus or Bakken

- Focus on what technology to use and when to use it

- As new technology is developed, many uneconomic shales will become economic

Questions?

Silica Sand Mining -- St. Peter Sandstone

Frac Proppants

- In N.A. effected by shift from natural gas to liquid-rich / oil play exploration
- Less demand for finer grades and more demand for larger grades of mesh
  - Less demand for finer grades of 40/70 and 100 mesh sand
  - More demand for larger grades of mesh – 20/40 and 16/30
  - Hickory sand is coarser and applicable
- Development of ceramic proppants
  - High strength (bauxite) for the deeper hotter wells
  - Intermediate strength
  - Lightweight ceramics used mostly in U.S. and Canada
- Identify and develop solutions to inefficient transport infrastructure
- Build critical relationships needed to move proppants from mine to well quickly and economically

Big Seven Shale Plays

Antirum, U.S.	Horn River, Canada
Bakken, U.S. and Canada	Horton Bluff, Canada
Barnett, U.S.	Huron, U.S.
Bend, U.S.	Lewis / Mancos, U.S.
Chattanooga, U.S.	Lower Shaunavon, Canada
Cody, U.S.	Mancos, U.S.
Deep Basin, Canada	Marcellus, U.S.
Devonian, U.S.	McClure, U.S.
Eagle Ford, U.S.	Monterey, U.S.
Excello / Mulky, U.S.	Mowry, U.S.
Fayetteville, U.S.	Montney, Canada
Floyd / Conasauga Neal, U.S.	New Albany, U.S.
Gothic / Hovenweep Cane Creek, U.S.	Niobrara, U.S.
Granite Wash, U.S.	Pierre, U.S.
Haynesville, U.S.	Utica, U.S. and Canada
Hilliard Baxter-Mancos, U.S.	Woodford, U.S.

Source: modified from Halliburton

Independence does not eliminate interdependence

"…quasi oil self-sufficiency will neither insulate the United States from the rest of the global oil market (and world oil prices), nor diminish the critical importance of the Middle East to its foreign policy."

Source: Harvard Kennedy School, Oil: the Next Revolution, June 2012

Technology Deployment

Computer industry

0-6 months

Health Industry

1-3 years

Oil industry

20-25 years

"Success is the ability to go from one failure to another with no loss of enthusiasm"

W. Churchill

Unconventional Hydrocarbon Plays In Asia

- **Unconventional hydrocarbon plays have begun to gain significant attention and investment in Asia, with 46 CBM contracts awarded in Indonesia since 2008**

- **China produced 1.5 Bcm coal seam gas in 2011 and plan to double that in 2012**
  - **30 shale gas wells recently have been drilled in the Greater Sichuan Basin**

- **Disruptive upstream technologies changed the face of oil and gas industry in North America**

- **Could Asia be next?**

- **Frontier opportunities in China, India, Pakistan and Indonesia**
  - **Shale plays, coal seam gas plays and other alternate hydrocarbon plays**

Innovative Technology: E&P Examples

Environmental Footprint

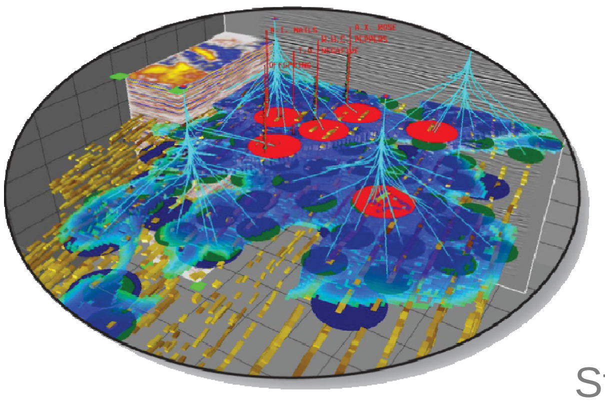
Dynamic Reservoir Optimization

Subsalt

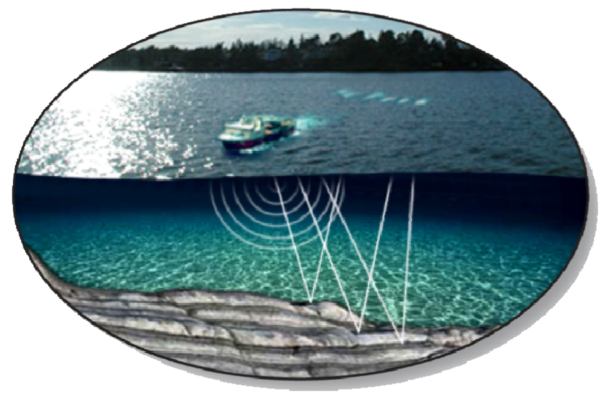
Improved Recovery / Yield

Exploitation

Exploration



Resource
Plays



Stimulation / Fracturing

New Sciences

Bio-energy

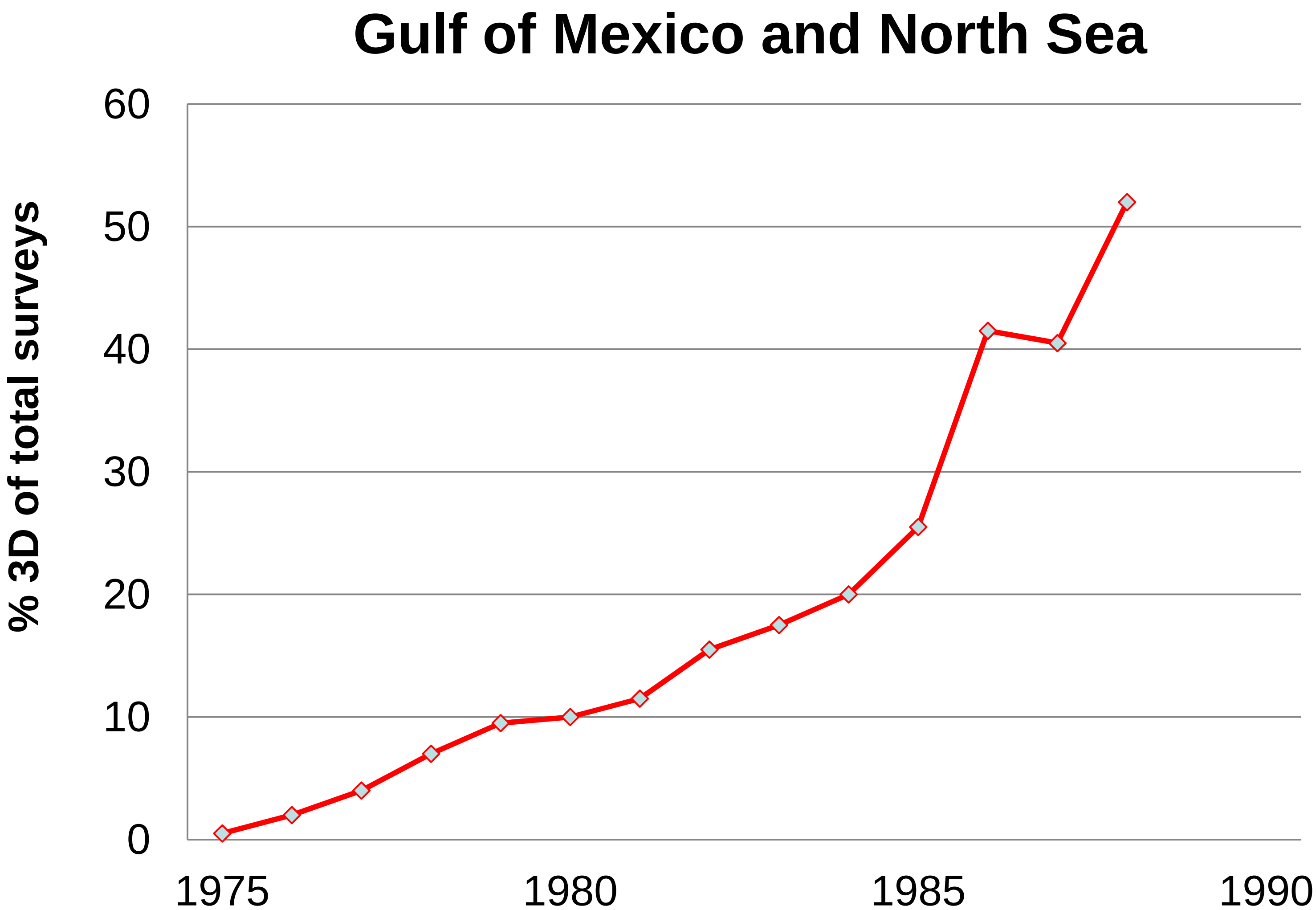
Reduce Cost

High Definition
Imaging

Well intervention

Reservoir Illumination

Case Study: 3D Seismic



From: Hansen T, Kingston J, Kjellesvik S, Lane G, I´Anson K, Naylor R and Walker C: "3-D Seismic Surveys," Oilfield Review 1, no. 3 (October 1989): 54–61.

Future Energy System

Implications of shale gas

Natural gas is no longer viewed as transitional fuel rather a destination fuel

Restructuring of the energy value chain

Two future challenges

- **Environmental sustainability**
- **China impact**
  - Energy policy
  - Internal interests
  - Impact of 5-year plan

Change in Energy System – 2020(?)

US & Canadian Gas Shale Plays

Antirum, U.S.	Horn River, Canada
Bakken, U.S. and Canada	Horton Bluff, Canada
Barnett, U.S.	Huron, U.S.
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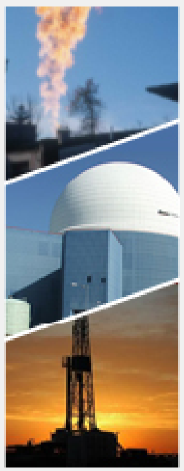
Devonian, U.S.	McClure, U.S.
Eagle Ford, U.S.	Monterey, U.S.
Excello / Mulky, U.S.	Mowry, U.S. Montney, Cdn
Fayetteville, U.S.	New Albany, U.S.
Floyd / Conasauga Neal, U.S.	Niobrara, U.S.
Gothic / Hovenweep Cane Creek, U.S.	Pierre, U.S.
Haynesville, U.S.	Utica, U.S. and Canada
Hilliard Baxter-Mancos, U.S.	Woodford, U.S.

Source: Halliburton

Conferences

July 23-25, 2012 Denver, CO

Proppants Summit



Will the supply of frac sand & proppants keep up with the unprecedented shale boom?

Come together with the entire proppants supply chain and the end-user community to:

- Address the challenges of current proppant and frac sand shortages
- Identify and develop solutions for the supply crunch caused by insufficient transport infrastructure
- Build the critical relationships you need to get proppants from mine to well rapidly and economically
- Understand the business case for expanding the supply base

From the E&P companies whose operations sit idle for lack of sand, to the proppant producer struggling against bureaucracy to expand his operations; from the land-owner looking to open a new mine, to the railroad developers, trucking companies and barge operators who will ship the sand extracted to its final destination.

The meeting's goal is simple: to bring the entire value chain under one roof, and build the logistics relationships and infrastructure deals that will ensure the flow of sand and proppants—thereby ensuring the future of North American energy independence.