The Pennsylvania Marcellus Shale Natural Gas Play Past – Present & Future

The Pennsylvania Emergency Management Agency Annual Conference

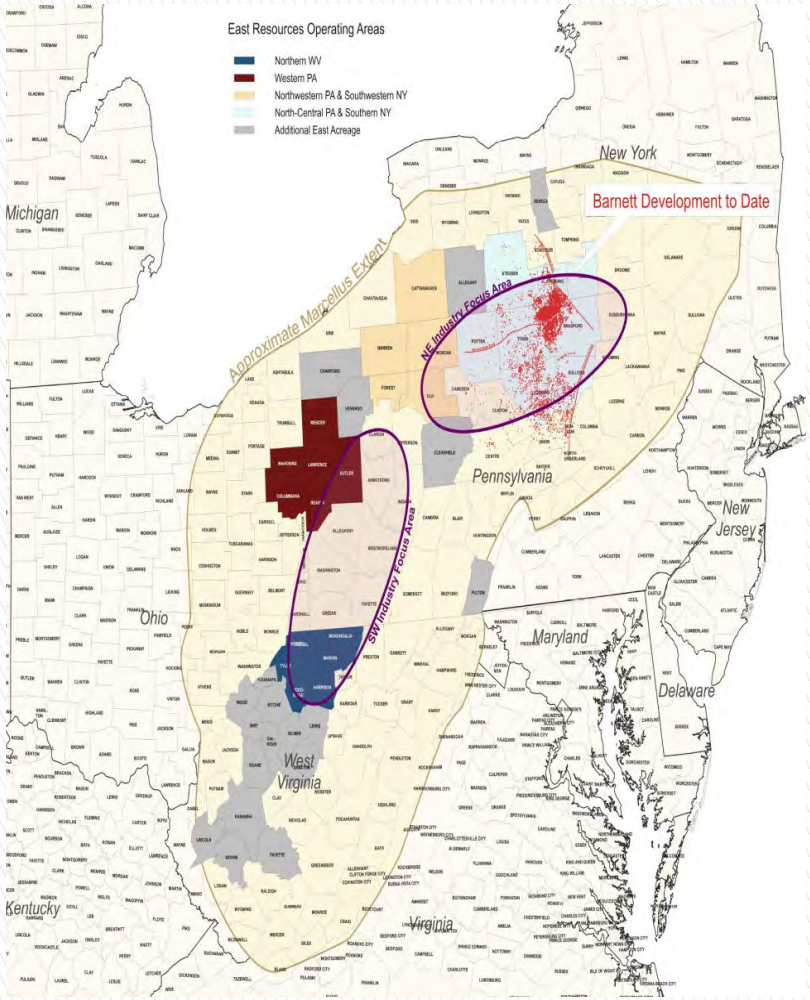
September 15, 2010

Lancaster Host Resort and Conference Center

Scott C. Blauvelt, P.G.
Shell Exploration and Production Company

Marcellus Shale Geology

Overview

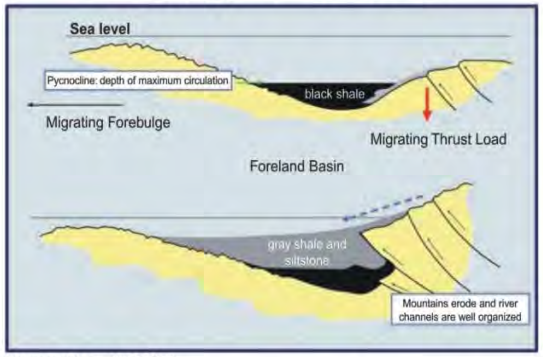


- The Marcellus is a devonian-age black, low-density organic-rich shale
  - Approximately 365 million years old
- Extends from the southern tier of New York, through western portion of Pennsylvania, into the eastern half of Ohio, and south through West Virginia
- Typical drilling depths are between 4,000 and 9,000 feet
- OGIP estimates for the Marcellus up to 1,500 Tcf
  - Thickness varying from 50' to over 300'
  - Total organic content (TOC) from 2.0% - 14.0%
  - Thermal maturity ranges from 0.6% to 3.0% Ro
  - Slightly over-pressured conditions (0.4 - 0.7 psi/foot)

Marcellus Shale Geology

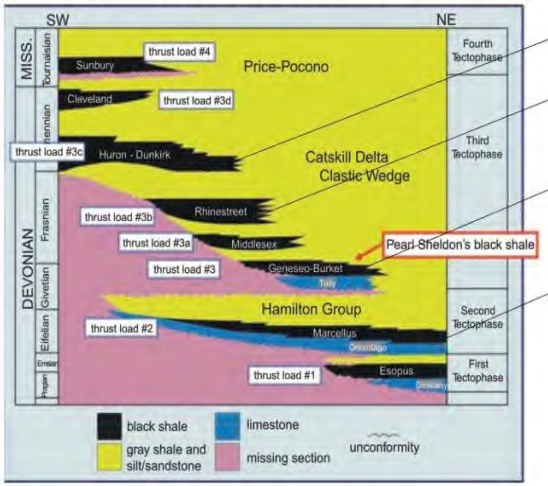
Shale Depositional Model

Sinking Of Appalachian Basin Seabed



Source: Ettsenohn (1994)

Appalachian Basin Devonian Black Shale



Source: Ettsenohn (1994)

Generalized Appalachian Basin Stratigraphic Column

Stratigraphic Column

ERA	SYSTEM/ SERIES	PLAY/ROCK UNIT	TECTONIC EVENTS	AGE
PALEOZOIC ERA	MISSISSIPIAN	BEREA SANDSTONE	ALLEGHENIAN OROGENY	360
	UPPER DEVONIAN	HURON SHALE	COLLISION ENDS, NORTH AMERICAN PLATE REBOUNDS FROM OVERRIDING AFRICAN PLATE, ANOXIC, DEEP BASIN MIGRATES WESTWARD	
		RHINESTREET SHALE		
		GENESEO SHALE		
	MIDDLE DEVONIAN	MARCELLUS SHALE	COLLIDING AFRICAN PLATE OVERIRDES & DEPRESSES NORTH AMERICAN PLATE, CREATING A DEEP, ANOXIC, SEDIMENT DEPRIVED BASIN	380
	LOWER DEVONIAN	ONONDAGA LIMESTONE	ACADIAN OROGENY	
		ORISKANY SANDSTONE		400

MILLIONS OF YEARS AGO

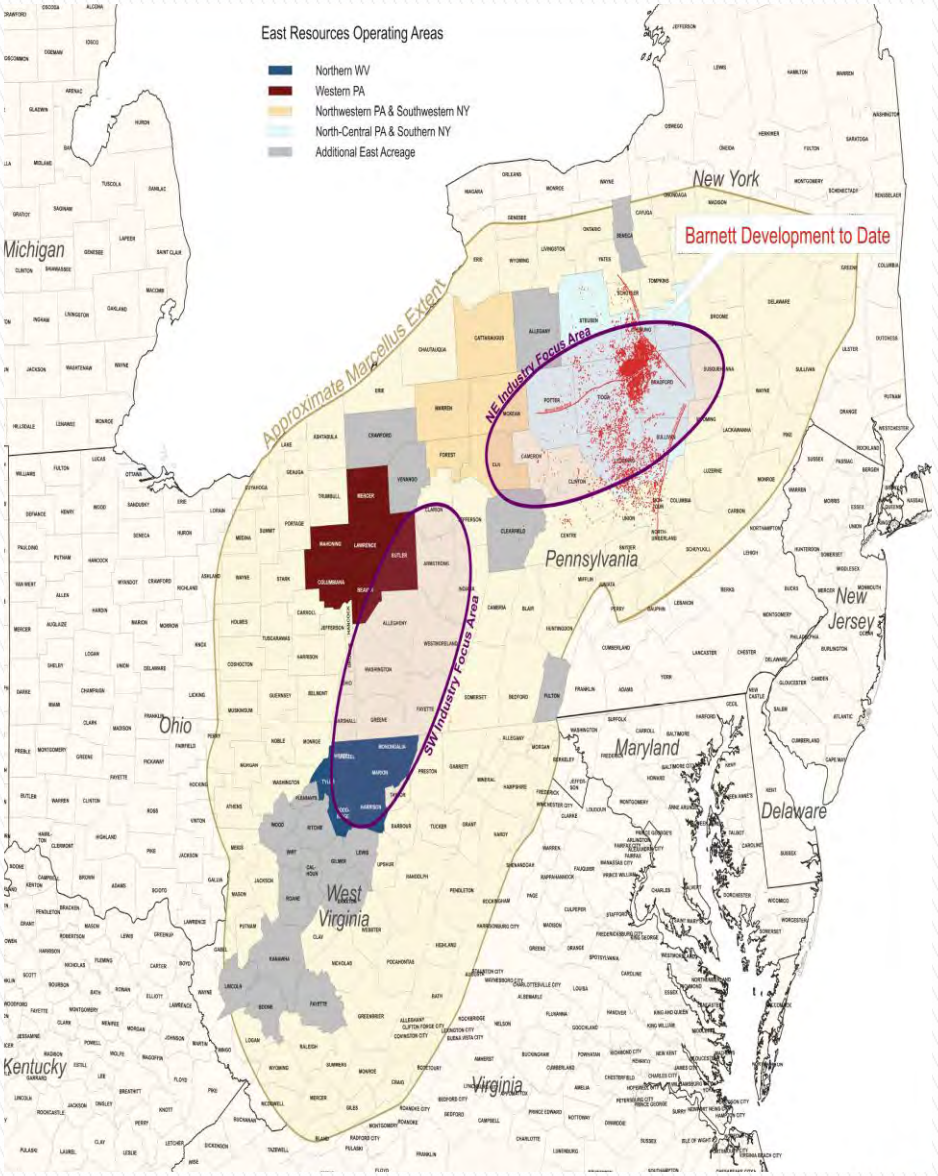
Information modified from USGS, New York State Oil & Gas Resources Reports and Pennsylvania Geological Survey

Appalachian Basin Black Shales Depositional Model

Marcellus Shale Geology

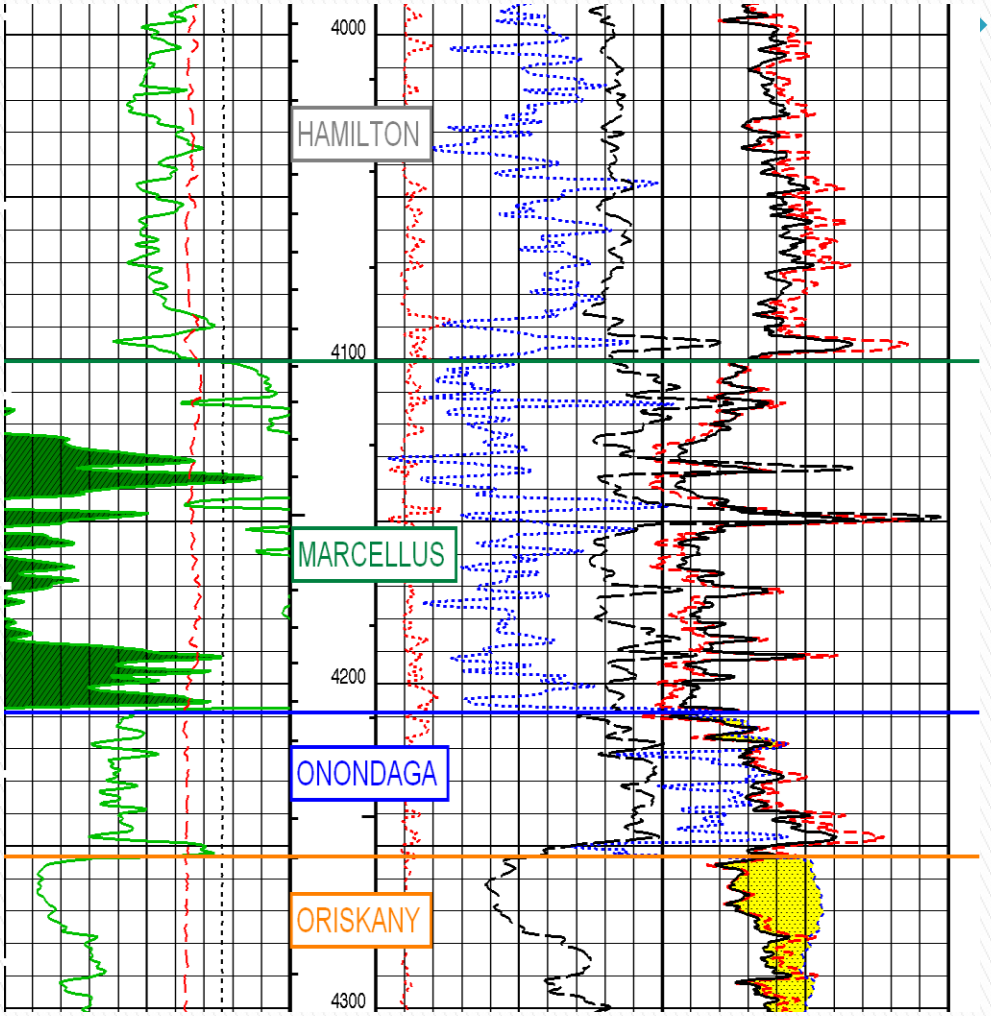
Marcellus Isopach and Ro Map

- Gas BTU content is higher in Western PA (~1,350 BTU) due to lower thermal maturity
- Gas in other areas is dry (~1,000 BTU)

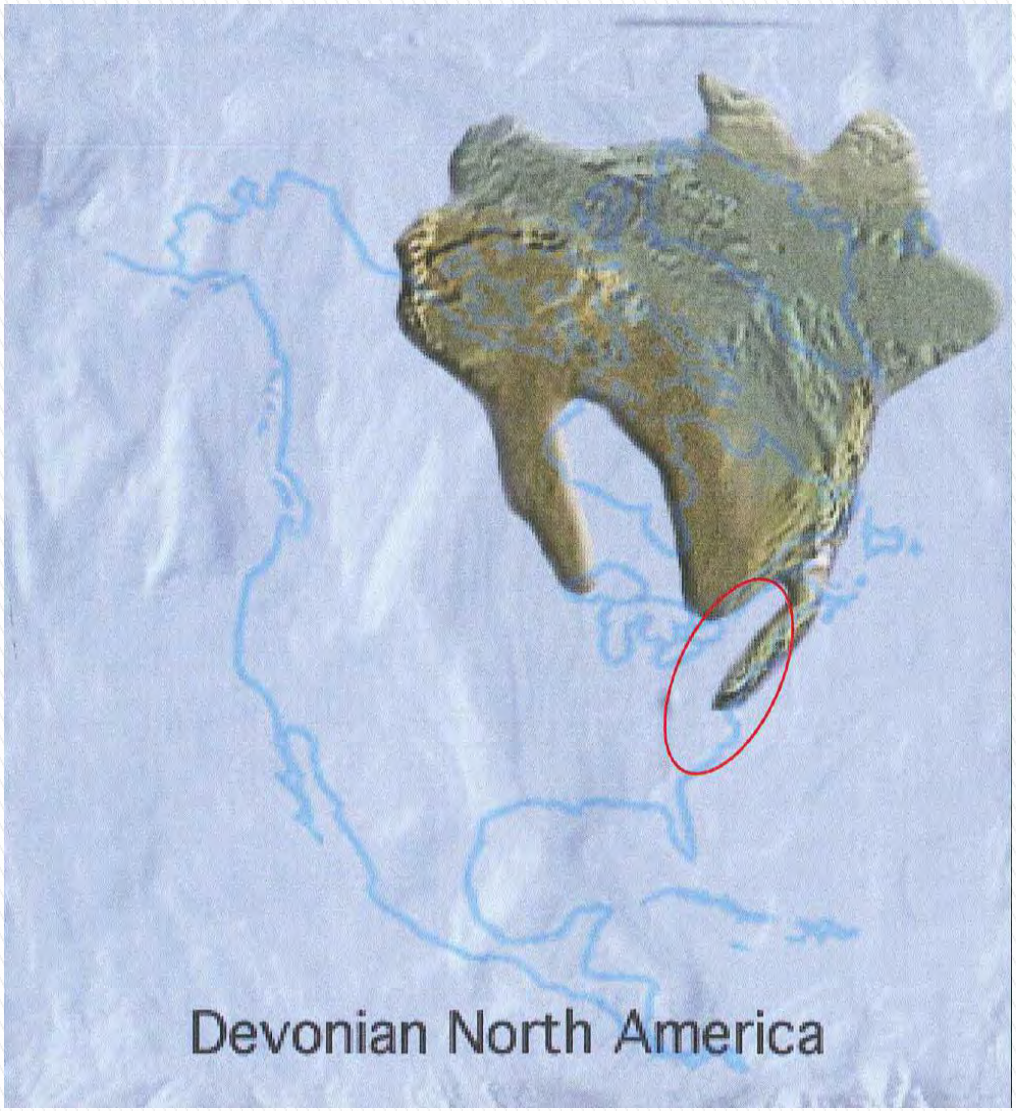


Marcellus Shale Geology

Marcellus Type Log



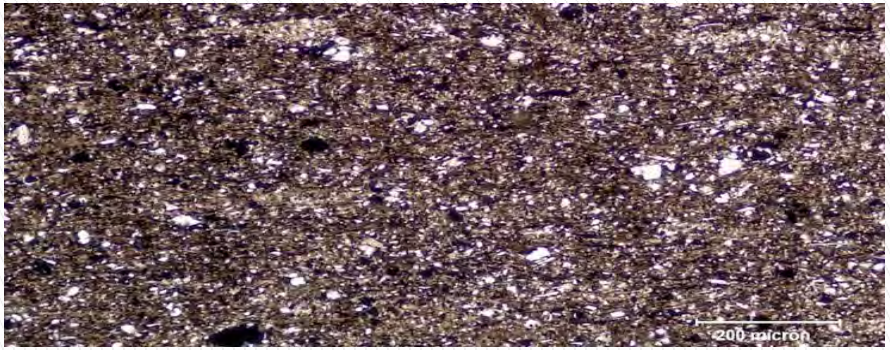
- The Marcellus formation is a Middle Devonian-age black shale
  - Rapid subsidence subsequent to the Acadian orogeny created a deep, stagnant environment that accommodated large concentrations of very fine-grained clastics and organics
  - Overlain by the grey shales of the Hamilton formation as energy was re-introduced into the basin
  - Onondaga limestone and Tully limestone act as lower and upper frac barriers, respectively



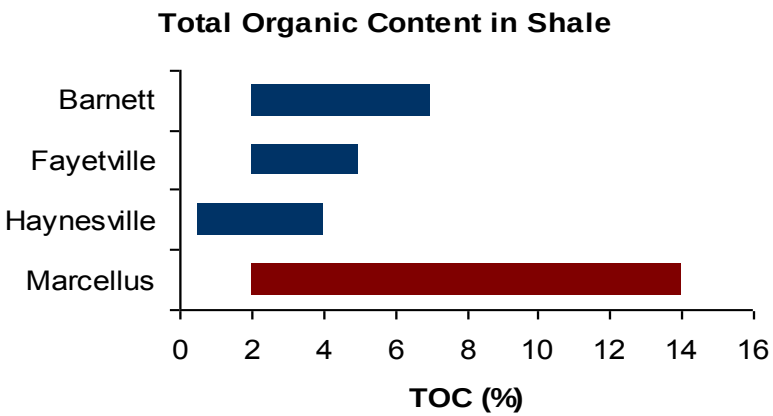
Much of the Appalachian Basin was a shallow inland ocean during the Devonian times

Marcellus Shale Geology

Shale Composition



Siliceous/argillaceous mudstone at medium magnification exhibits a speckled, heterogeneous matrix supporting abundant micromicas and quartz and feldspar silt. Lighter matrix patches likely represent a mixture of kerogen and microcrystalline silica. Clays and pyrite make up the darker areas. Flattened, light-colored shapes consist of microcrystalline silica with agglutinated or adherent silt and micas flakes. (Plane-polarized light. Scale bar = 200 microns)



- Shale characteristics can be relatively homogeneous over large areas due to depositional continuity
- The shale matrix is generally composed of illite, chlorite, silica, kerogen, feldspars, micas, calcite and pyrite
  - Noteworthy traits of the Marcellus' composition are relatively high silica content, which dramatically increases fracability, and the absence of swelling clays which can be extremely detrimental to a well's producibikity
  - Permeabilities are estimated to be between 100 nd and 1,000 nd with TOCs ranging from 2% to 14%
- Vitrinite reflectance values range from 0.6 to 3.0, generally indicating high thermal maturity
- The Marcellus produces gas from primary porosity, secondary porosity and through desorption
  - As much as 20% to 40% of Marcellus reserves may be associated with desorbed gas

- Marcellus footprint:
  Immense at 95,000 square miles
- Drilling to take place over decades
- Market factors:
  price, economy competition for drill rigs, demand for gas, influence activity

United States Shale Gas Plays

Shale Gas Plays

Basins

Stacked Appalachian Plays

Marcellus

Utica

Devonian (OH shale)

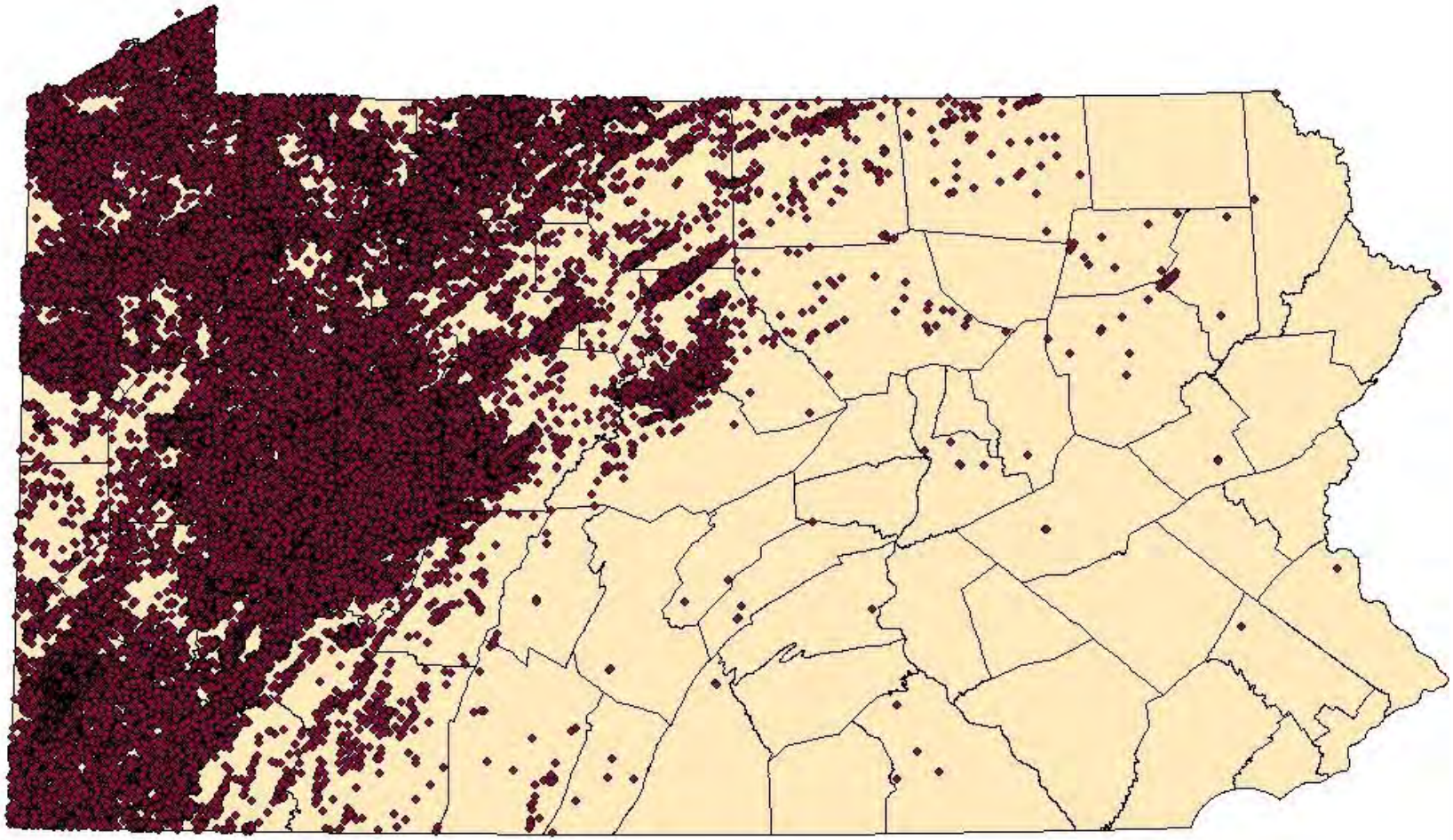
November 2008

Miles

0 150 300 600

N

PENNSYLVANIA DOCUMENTED OIL & GAS WELLS



WELLS REPRESENTED ABOVE: 135,322

Why Natural Gas?

- Secure
- Abundant
- Domestic
- Clean (One Carbon Atom)
- No tax payer subsides

Why Frac?

- Method used to create fractures that extend from a well bore into rock formations which are held open by a proppant such as grains of sand to prevent the fractures from closing, thus allowing gas to flow back into well bore
- The “easy” gas has been extracted, fracturing is required to extract natural gas from unconventional shale formations
- After fracing, “tight” shale formations like the Marcellus, natural gas can economically be produced
- **Hydraulic Fracturing is NOT new to our industry, the technology is 80 years old**

Pennsylvania Department of Environmental Protection

Rachel Carson State Office Building
P.O. Box 8555
Harrisburg, PA 17105-8555
June 1, 2009

Bureau of Watershed Management 717-772-4048

Michael Paque, Executive Director
Ground Water Protection Council
13308 North MacArthur Boulevard
Oklahoma City, OK 73142

Dear Mr. Paque:

I am the program manager for Pennsylvania's Ground Water Protection Program in the Pennsylvania Department of Environmental Protection (DEP). I have been concerned about press reports stating extensive groundwater pollution and contamination of underground sources of drinking water in Pennsylvania, as a result of hydraulic fracturing to stimulate gas production

After review of DEP's complaint database and interviews with regional staff that investigate groundwater contamination related to oil and gas activities, no groundwater pollution or disruption of underground sources of drinking water has been attributed to hydraulic fracturing of deep gas formations.

Sincerely,

Joseph J. Lee, Jr., P.G., chief
Source Protection Section
Division of Water Use Planning

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Source Rock, Reservoir Rock

- A petroleum source rock is a fine-grained organic rock (shale) in which oil or gas is generated
- A petroleum reservoir is comprised of subsurface rocks (sandstone or carbonate rock) with sufficient porosity and permeability to hold and ultimately produce commercial amounts of oil or gas

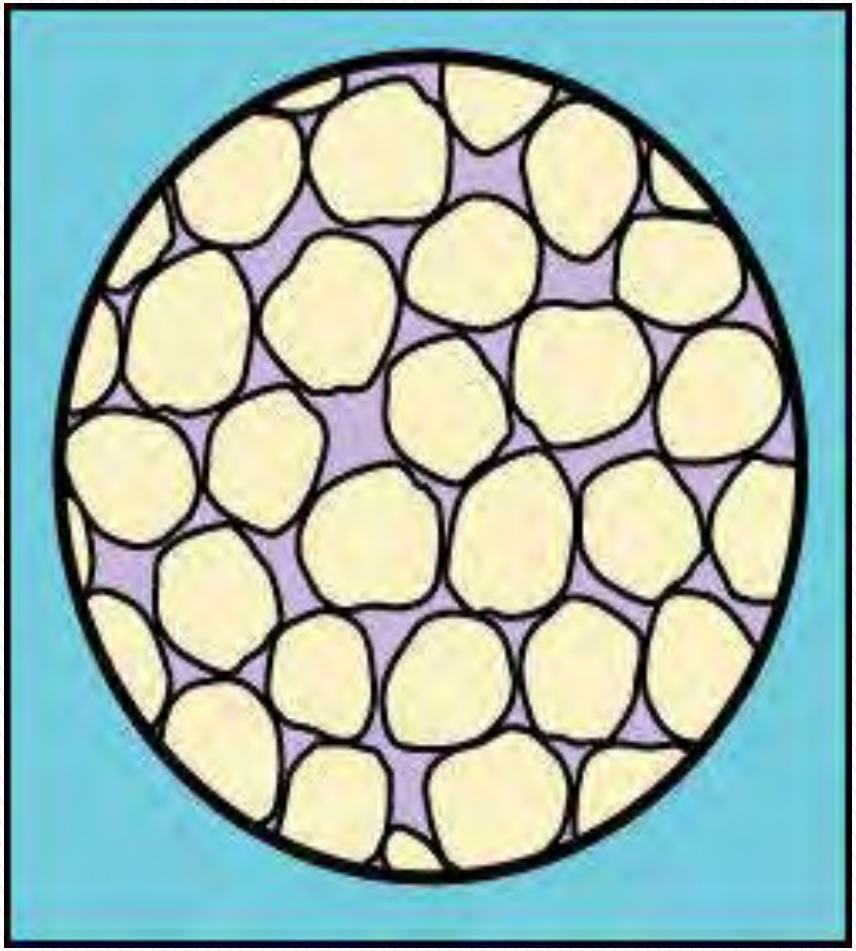
Conventional/Unconventional Reservoir?

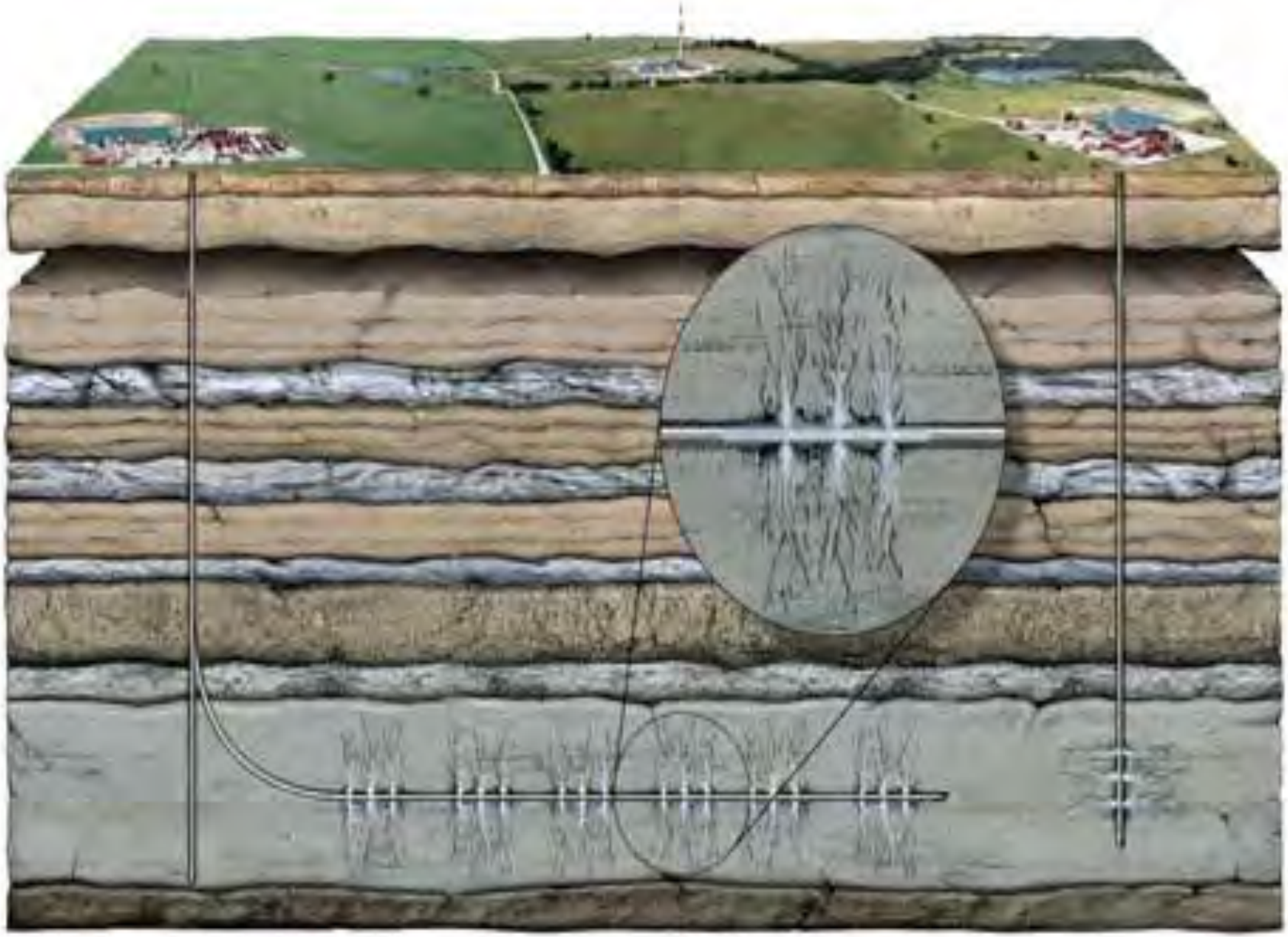
- Conventional reservoirs typically consist of porous and permeable sandstones or carbonate rocks that yield oil and or natural gas by draining interconnected pore spaces

- Unconventional reservoirs include not only “tight” (i.e. low porosity) sandstones, but also self-sourcing reservoirs rich in organic matter such as gas shales and coalbed methane formations. These reservoirs lack the porosity and permeability of conventional reservoirs, and must be fraced to enhance the interconnectedness of pore spaces.

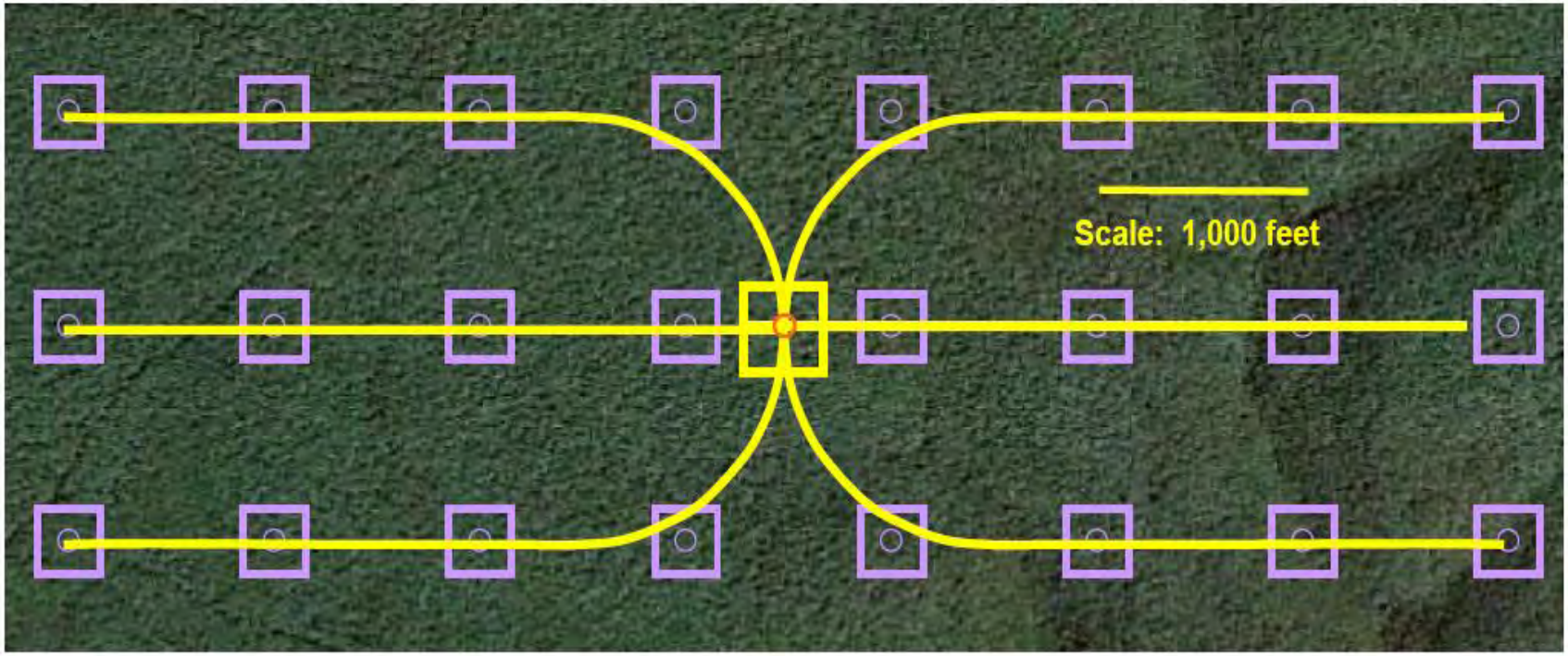
- The Marcellus Shale is an unconventional reservoir

Conventional Reservoir Rock, Unconventional Shale Rock





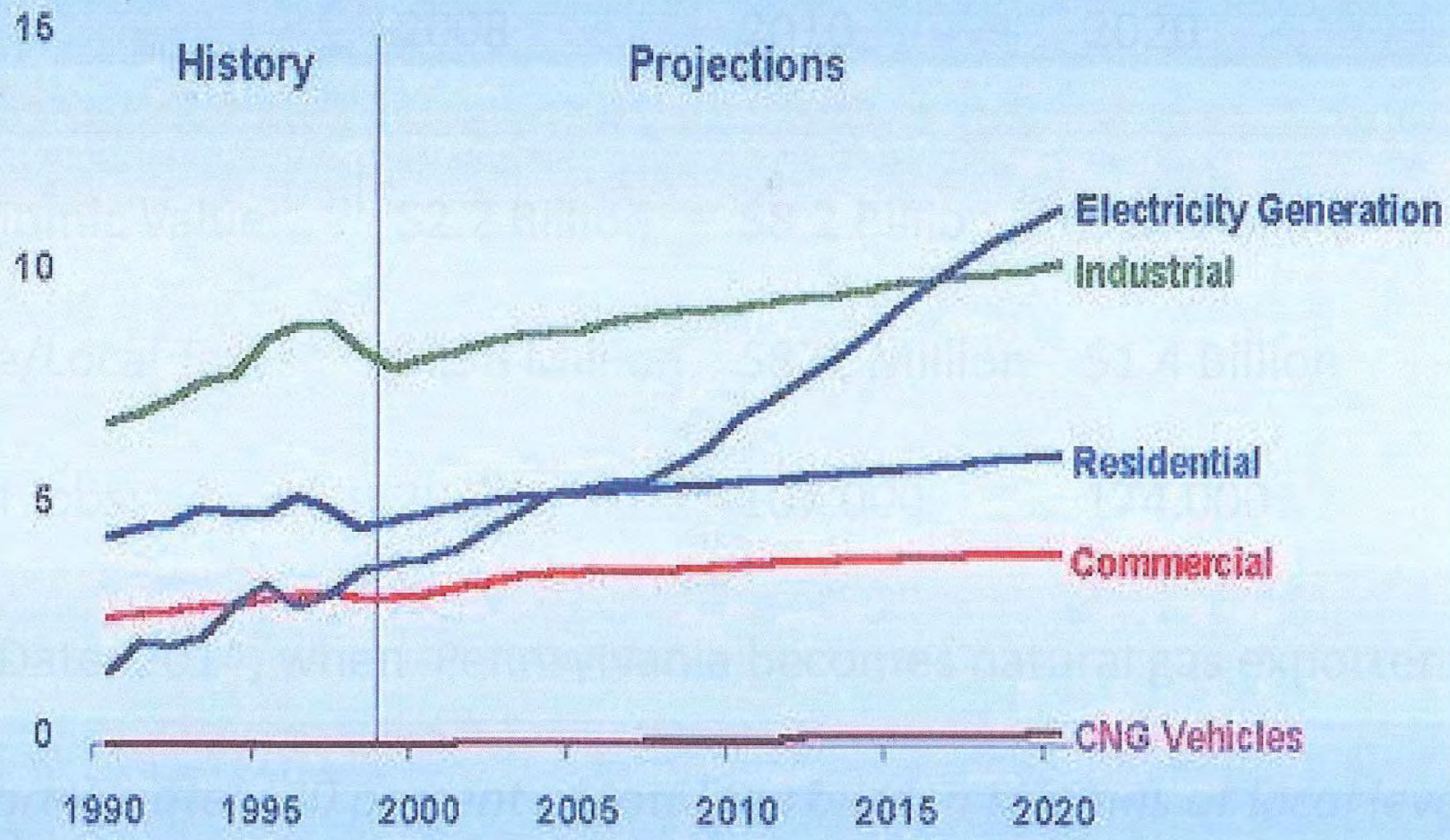
Horizontal Drilling provides greater access with a smaller footprint



Total surface disturbance during drilling, including access road, drilling pas and required pipeline infrastructure:

- Horizontal wells develop 500 acres per pad with 2% total surface disturbance
- Vertical wells on 1,000 foot spacing develop 23 acres per well with 19% total surface disturbance

U.S. Natural Gas Consumption by Sector, 1990-2020 (trillion cubic feet)



Marcellus Shale Potential

- Fully developed, the Marcellus Shale has the potential to be the second largest natural gas field in the world, behind only the South Pars/Asalouyeh field shared between the nations of Iran and Qatar

- Converted to British Thermal Units (BTUs), the natural gas found in the Marcellus could be equivalent to the energy content to 87 billion barrels of oil, enough to meet the demand of the entire world for nearly three years

- Future Marcellus natural gas drilling and production suggests that Pennsylvania could be producing more than 13 billion cubic feet of natural gas per day by 2020, which would make the Commonwealth the second largest producer of natural gas in the United States

- More than 3,500 wells could be drilled in 2020, which is about the same level of drilling currently taking place in the Barnett shale play in Texas, which is the largest natural gas producing field in the U.S.

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2009 Activity

- During 2009, natural gas output averaged 327 million cubic feet per day of natural gas equivalents, which includes dry natural gas and petroleum liquids. Output at year-end 2009 was over 500 million cubic feet per day

- $4.5 billion of spending by Marcellus producers during 2009 generated $3.8 billion in value added, $389 million in state and local tax revenue, and more than 44,000 jobs

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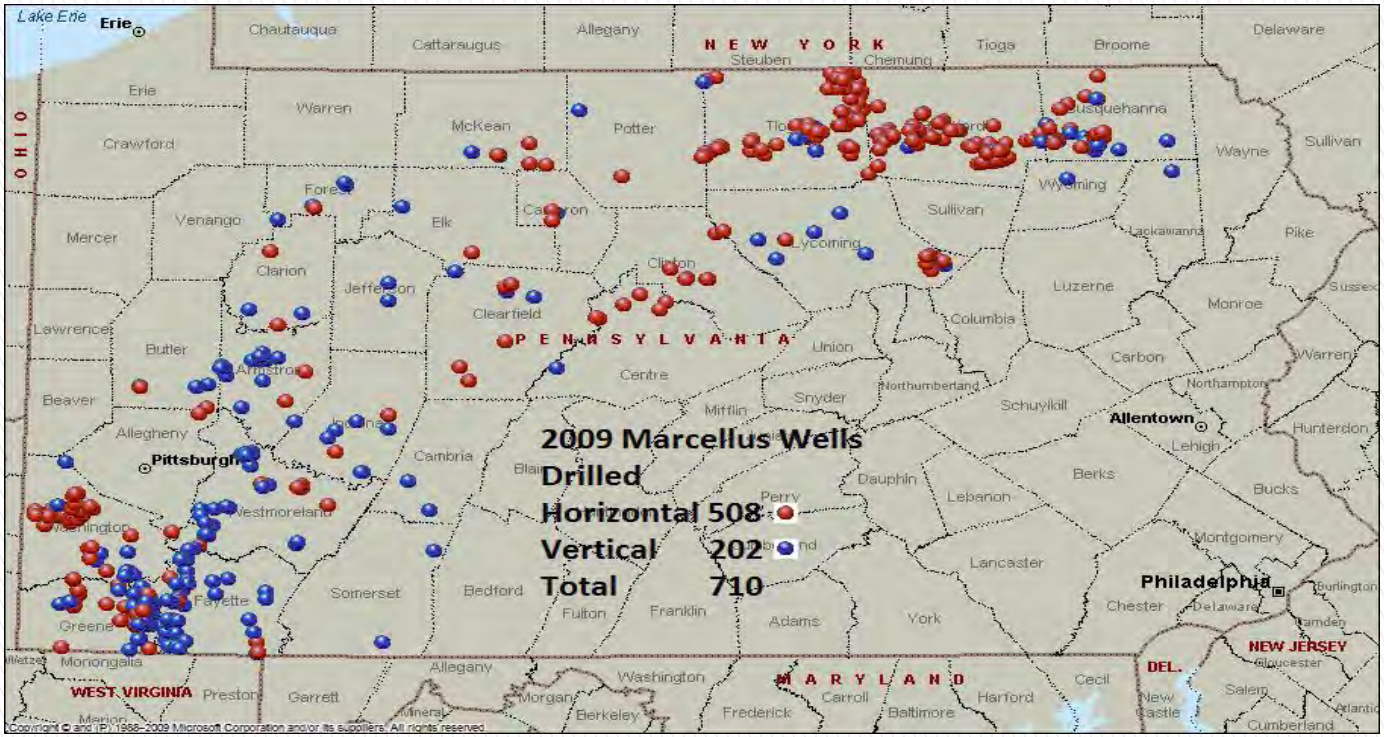
Marcellus wells drilled in Pennsylvania

- 710 wells drilled during 2009 in Pennsylvania that could be verified as Marcellus Shale wells
- There was a noticeable increase in drilling activity in the northeastern counties of Susquehanna, Bradford and Tioga with 282 wells drilled during 2009 from approximately 63 wells drilled during 2008



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2010/2011 Activity

- Companies plan to increase their investment spending to $8.8 billion for 2010 and to over $11 billion in 2011
- The Pennsylvania Marcellus industry is poised for a substantial take-off in development
- The Allegheny Conference (2009) recently found that Pennsylvania's pre-Marcellus oil and gas industry in total generated $7.1 billion in economic impacts
- Oil and gas producers drilled a total of 4,189 wells in Pennsylvania during 2007
- Every non-Marcellus well drilled generates $1.7 million in economic impacts
- Each Marcellus well generates $6.2 million in economic impacts
- The planned level of spending by Marcellus producers, suggests that over 1,700 wells could be drilled during 2010
- Spending plans suggest over 2,200 wells could be drilled during 2011

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Marcellus Industry Activity and Economic Impacts out to 2020

- Drilling activity increases from 2,500 wells drilled during 2012 to over 3,500 wells drilled during 2020
- Pennsylvania could be producing over 7 billion cubic feet of gas per day by 2015, which is more than Wyoming's production during 2008
- By 2015, the Pennsylvania Marcellus could be producing 7 billion cubic feet per day, substantially exceeding all gas output from offshore federal waters
- Production could reach 13 bcf per day by 2020, which would make Pennsylvania the second largest producer of natural gas behind Texas

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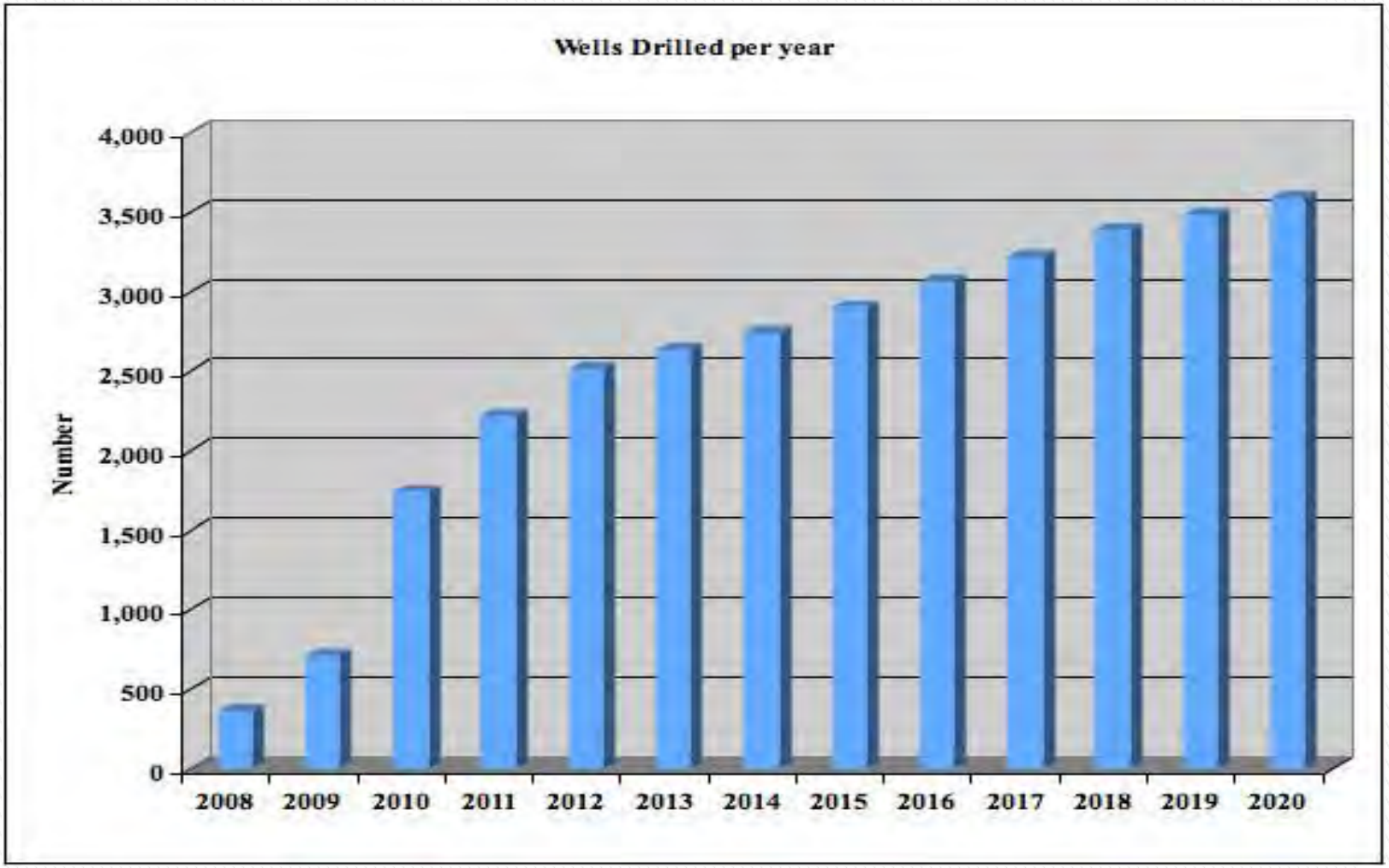
Forecast for Marcellus Natural Gas Drilling, 2009 – 2020



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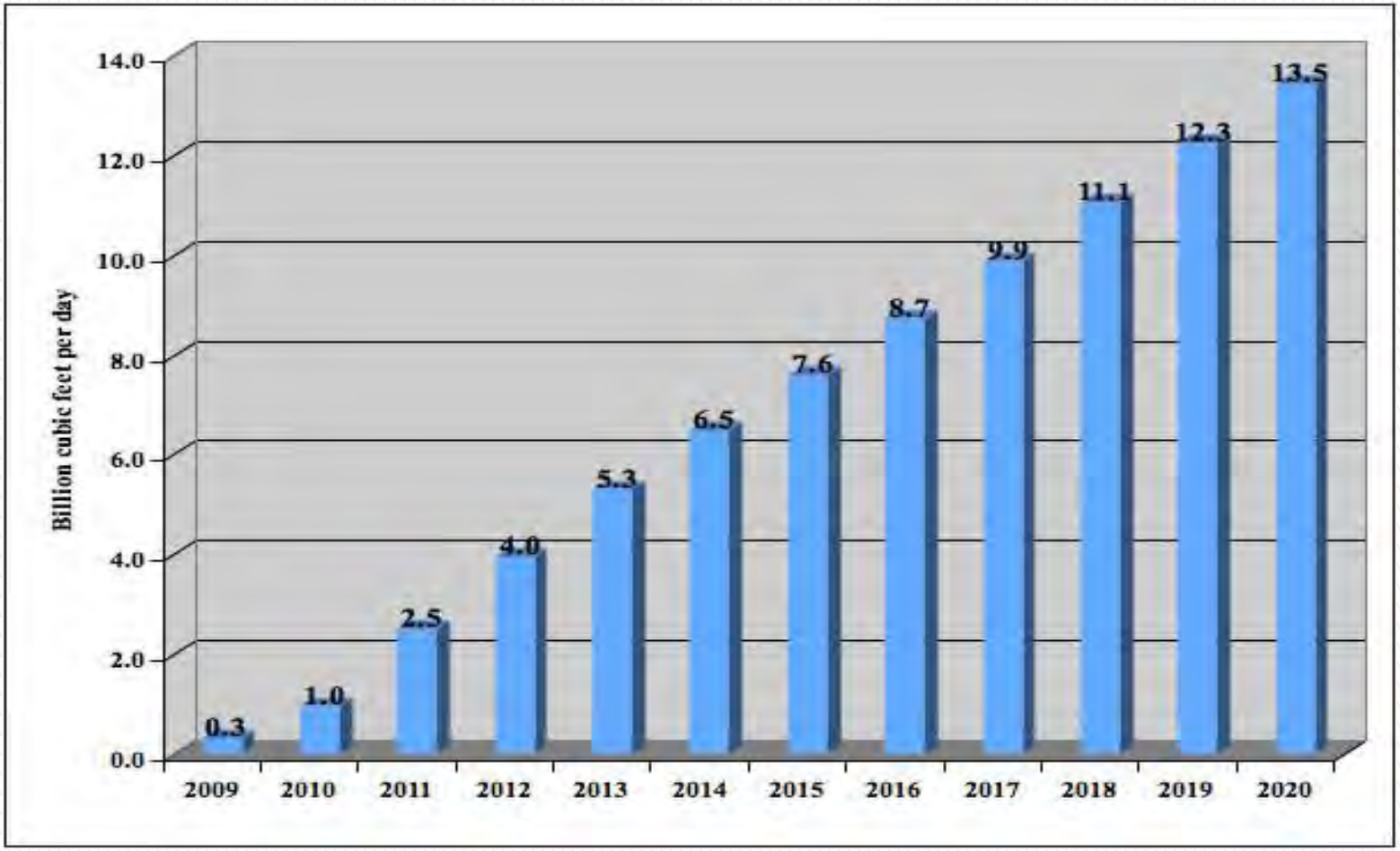
Forecast for Marcellus Natural Gas Production, 2010–2020



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Summary of Estimated, Planned and Forecasted Economic Impacts

Millions of 2010 dollars			
Year	Value Added	State & Local Taxes	Jobs
2008	2,556	265	30,137
2009	3,877	389	44,098
Planned			
2010	8,039	785	88,588
2011	10,129	987	111,413
Forecast			
2015	14,415	1,417	160,205
2020	18,853	1,872	211,909

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Thank You