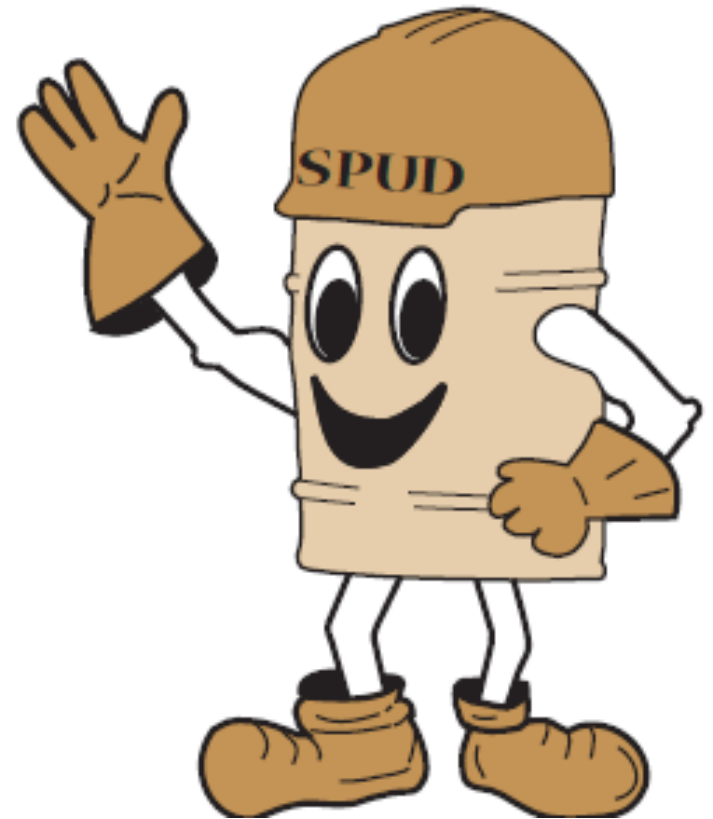


# Marcellus Shale Drilling and Hydraulic Fracturing; Technicalities and Controversies

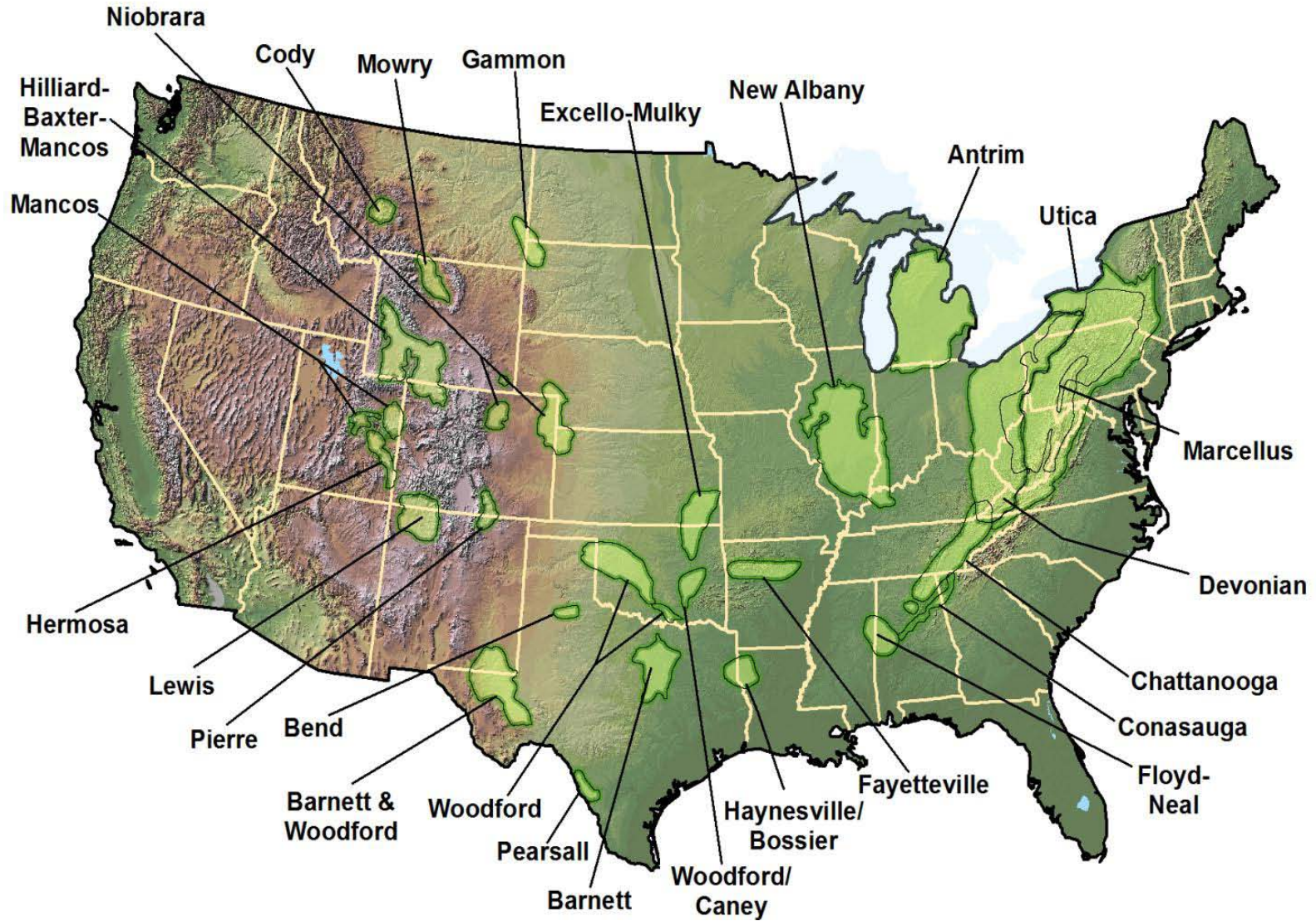
Kyle J Ferrar, MPH  
Center for Healthy Environments and Communities  
University of Pittsburgh  
Graduate School of Public Health  
Environmental and Occupational Health



# Outline

- I. Background
- II. Unconventional Development
- III. Mineral Rights
- IV. Permitting
- V. The Drilling Process
- VI. Hydrofracturing
- VII. Flowback Wastewater
- VIII. Processing, Transportation, and Storage

# UNITED STATES SHALE BASINS



Modern Shale Gas Development in the U.S.: A Primer, (2009) U.S. Dept of Energy

# Conventional Gas Plays

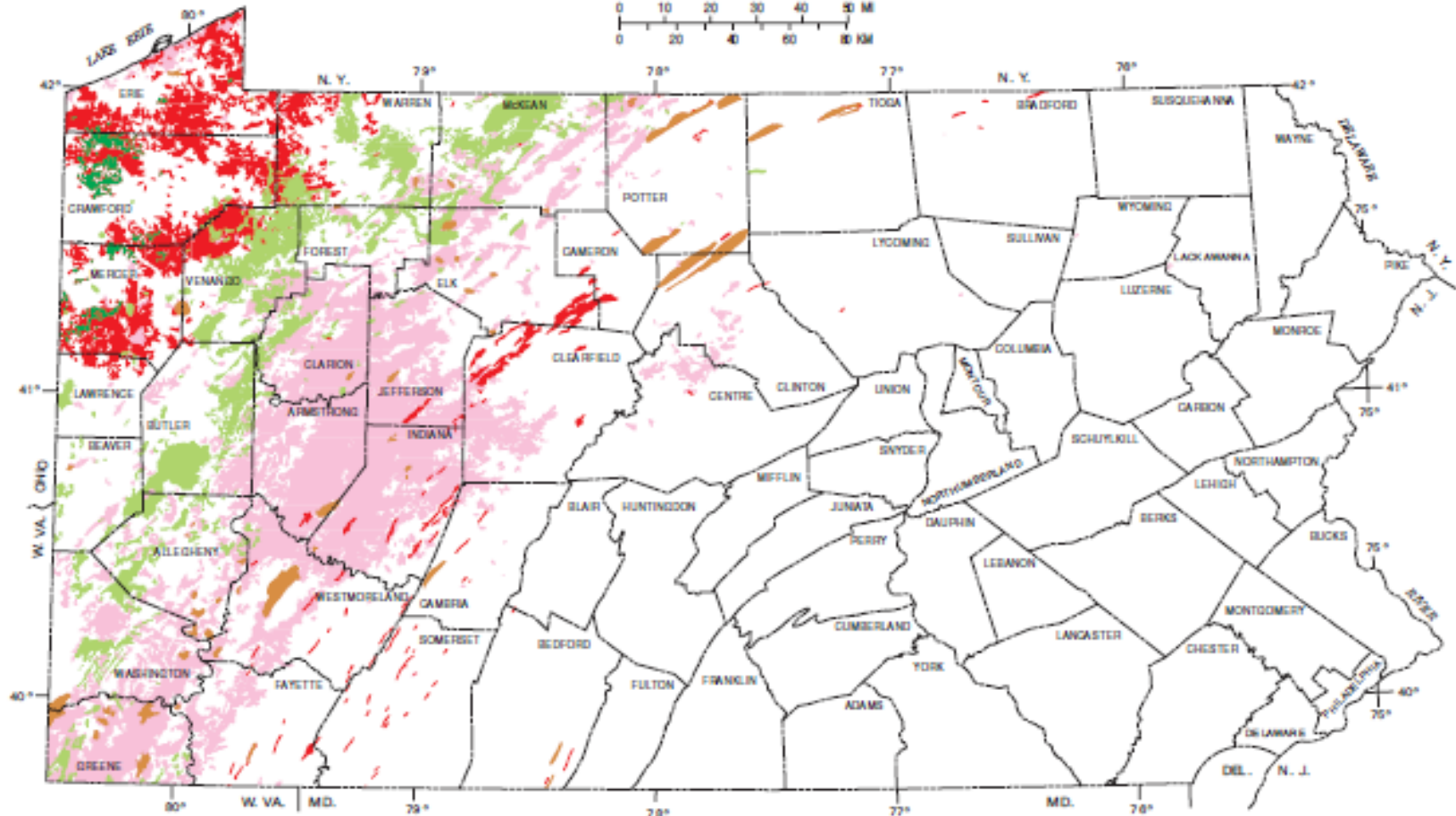
MAP 10



## OIL AND GAS FIELDS OF PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA  
DEPARTMENT OF  
CONSERVATION AND NATURAL RESOURCES  
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY  
[www.dcnr.state.pa.us/topogeo](http://www.dcnr.state.pa.us/topogeo)

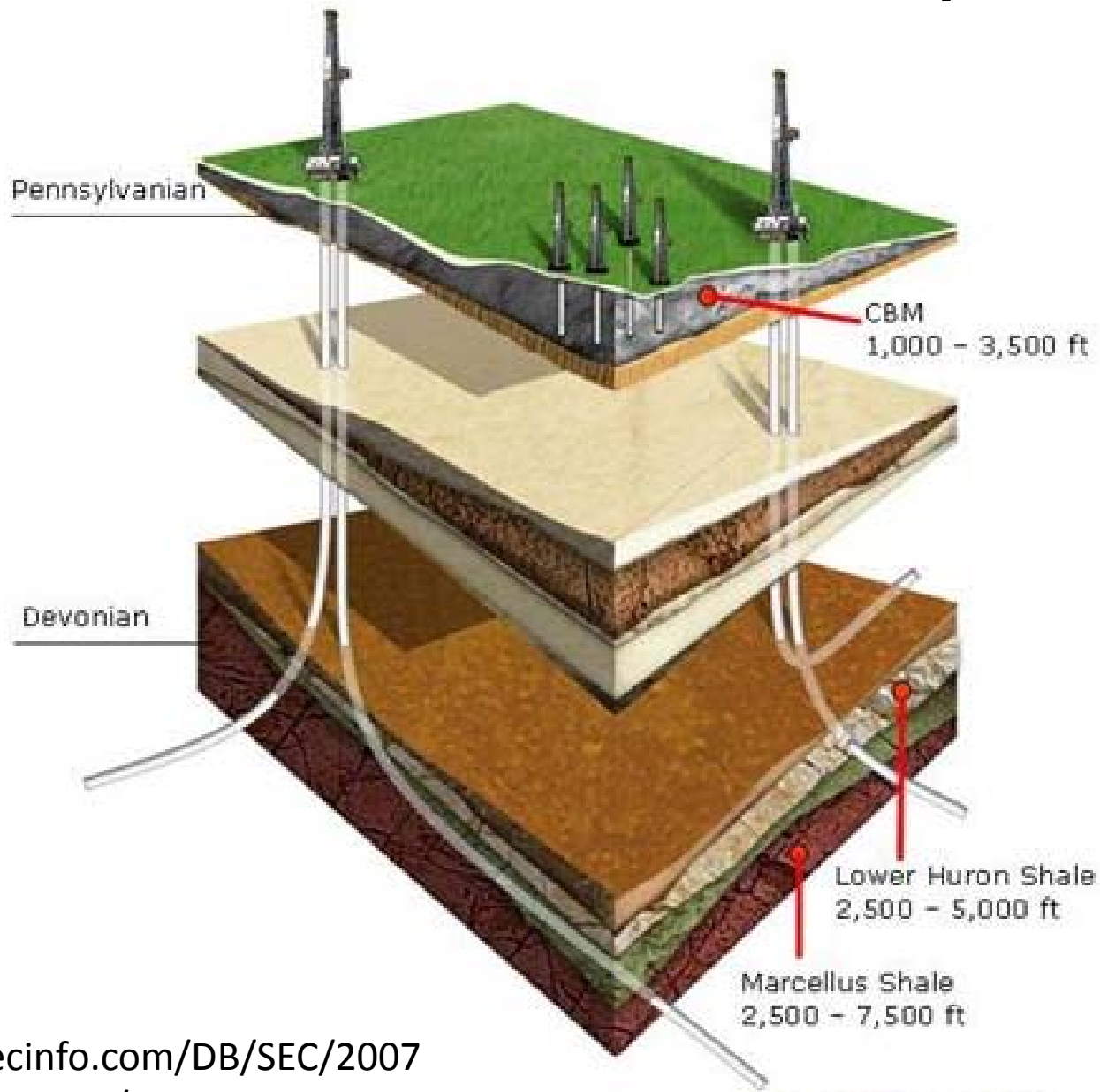
SCALE 1:2,000,000



### EXPLANATION

- Shallow oil field
- Deep oil field
- Shallow gas field
- Deep gas field
- Gas storage area

# Unconventional Development

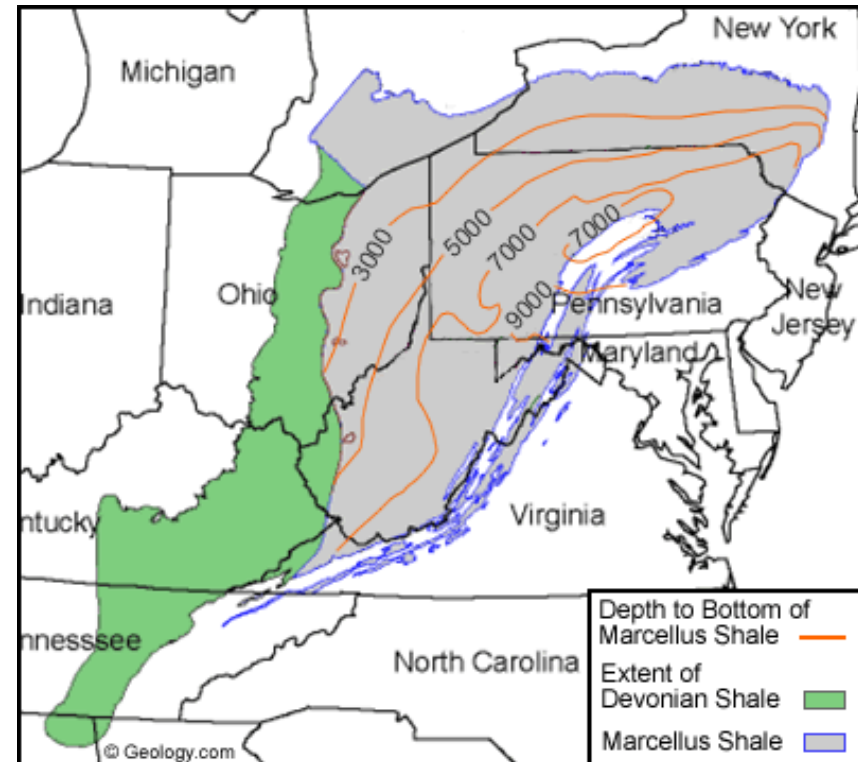
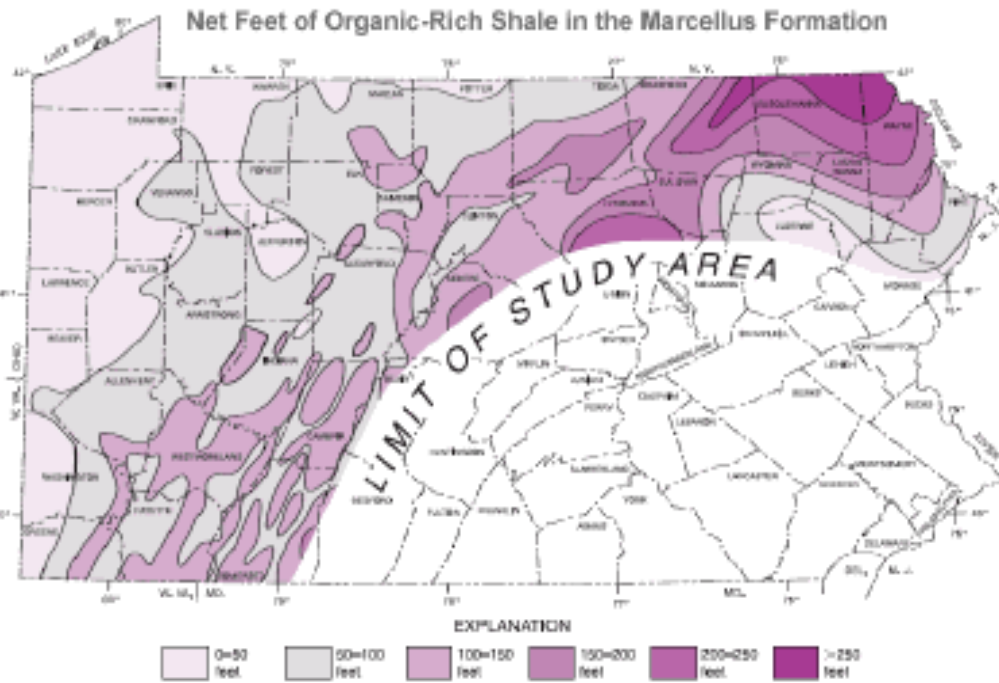




# Where to Drill?

Shale Thickness

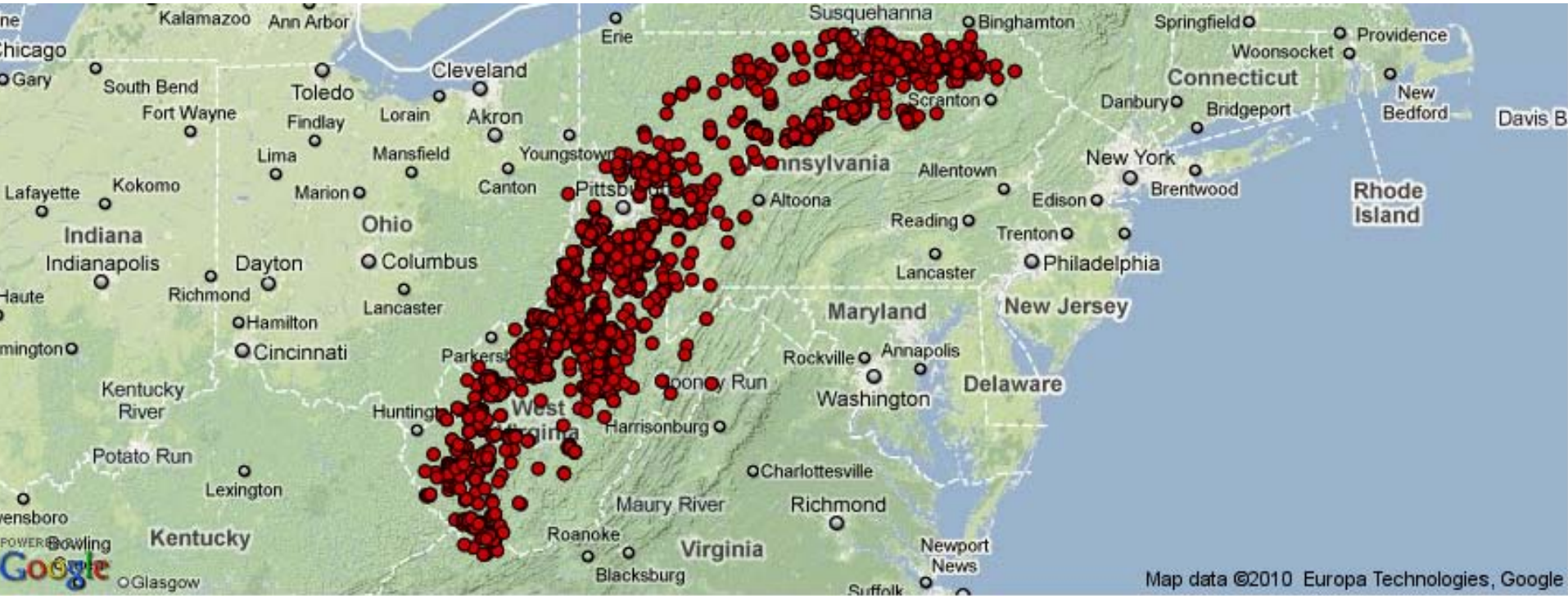
Shale Depth



Harper, John A. (2008). The Marcellus Shale - An Old "New" Gas Reservoir in Pennsylvania. Pennsylvania Geology, Volume 38, Number 1. Pennsylvania Bureau of Topographic and Geologic Survey.

Harper, John A. (2008). The Marcellus Shale - An Old "New" Gas Reservoir in Pennsylvania. Pennsylvania Geology, Volume 38, Number 1. Pennsylvania Bureau of Topographic and Geologic Survey.

# Marcellus Wells





# Who and Where?

## **Gas Producing Counties**

- Armstrong County
- Clearfield County
- Crawford County
- Fayette County
- Indiana County
- Jefferson County
- McKean County
- Mercer County
- Westmoreland County
- Venango County
- Washington County

## **Active Companies in PA**

- Chesapeake Energy
- CNX Gas
- Exxon Mobil
- Range Resources
- XTO Energy



# Mineral Rights

- Mineral
- Landmen
- Signing parties
- Lawyers
- Signing Bonus
- Royalties
- Lease Contracts
- “Waiting on pipeline” clause
- Severance Tax
- Property Law

A geological correlation chart comparing rock strata in Western Pennsylvania and Northwestern New York. The chart is organized into columns for 'System' (Middle Devonian and Lower Dev.) and rows for specific geological units. A 'Hamilton Group' is indicated on the right side, encompassing the Moscow, Ludlowville, and Skaneateles shales. A checkmark is present next to the Tioga bentonite layer in the Marcellus Shale of Northwestern New York.

System	Western Pennsylvania	Northwestern New York		
Middle Devonian	Harrell Shale	Genesee Fm.		
	Tully Limestone	Tully Limestone		
	Mahantango Formation	Moscow Shale	Hamilton Group	
				Ludlowville Shale
				Skaneateles Shale
	Marcellus Shale	Marcellus Shale Tioga bentonite ✓		
Selinsgrove Limestone	Onondaga Limestone			
Lower Dev.	Needmore Shale	Bois Blanc Fm.		

# Geological Reviews

## A “Thumper Truck”

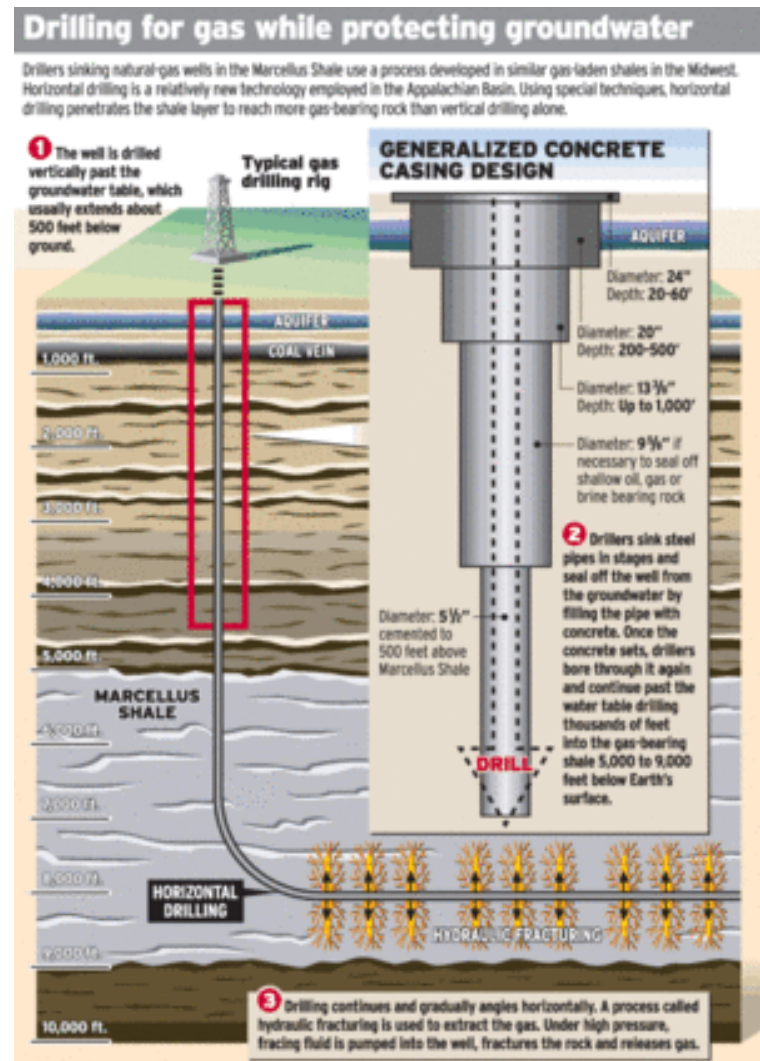


# Rigging Up



# Drilling

- The *Drill String*
  - Diesel Powered
  - Drilling Bit
  - Drilling Pipe
- Air Rotary Drilling Rig
- Hydraulic Rotary Drilling Rig
  - Barite/Bentonite infused drilling muds
- Tripping Pipe
- Horizontal Legs

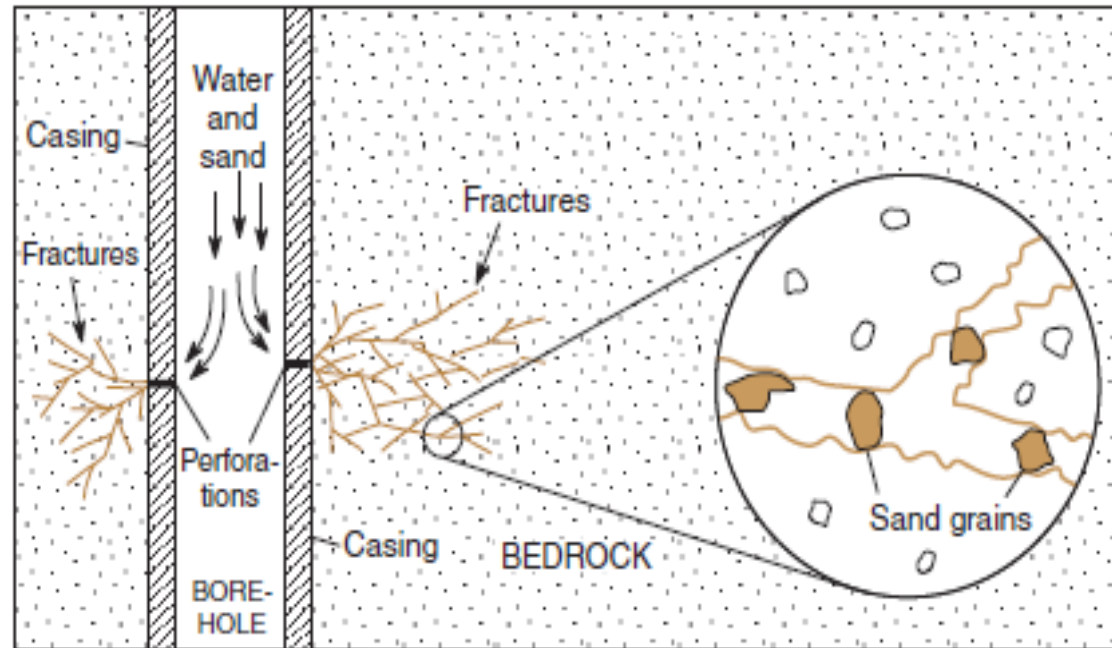


[http://media.timesleader.com/images/300\\*423/0222\\_GasDrilling.gif](http://media.timesleader.com/images/300*423/0222_GasDrilling.gif)



# Stimulating by Hydraulic Fracturing

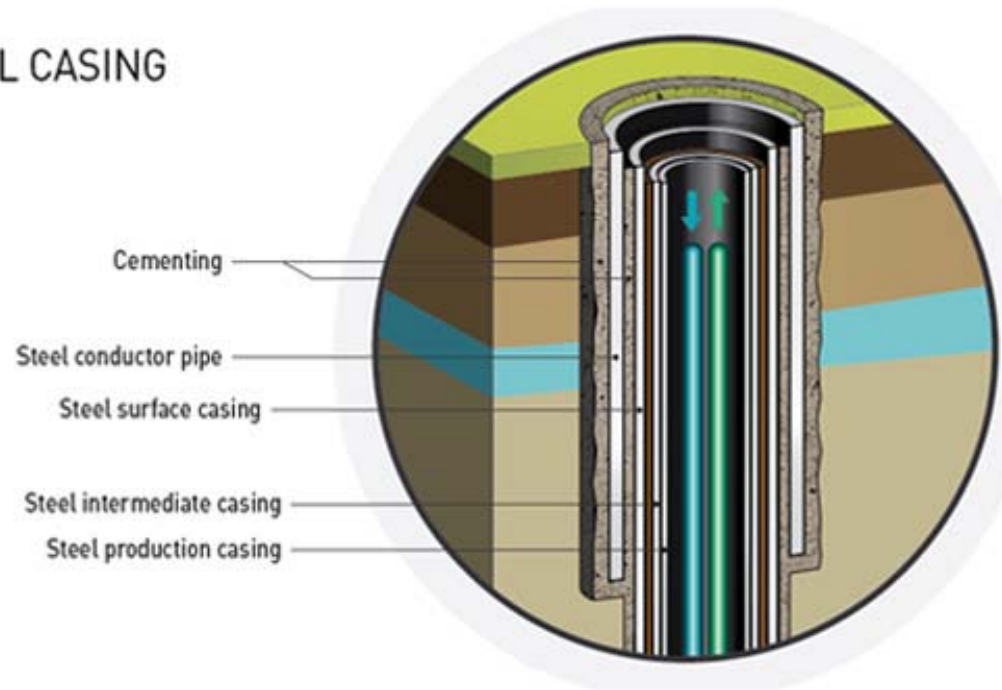
- Perforating
  - “Perf Gun”
  - Multiple Stages
  - 1,000 meter sections
  - Shots
- Wells may be hydrofractured up to 5 times



# Aquifer Contamination

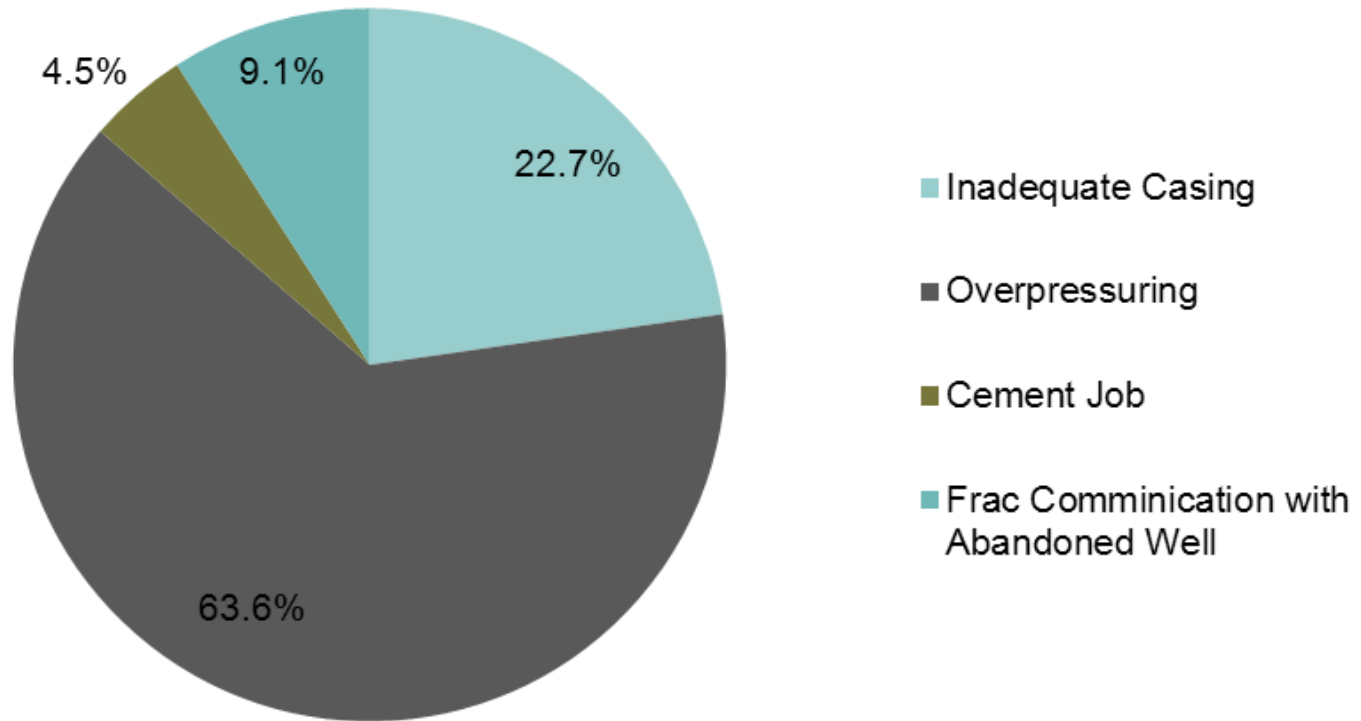
- From the surface
- From the casing
  - Pipeline Production
  - Radiographic imaging
  - Pipe Dope
  - Voids in the cement
  - Seismic Tests
  - Pressure Tests
- Methane and contaminant migration after hydrofracturing.

WELL CASING



# Methane Migration

Based on 22 Stray Gas Cases Associated with New and Operating Wells Since 1992



# “Frac Water”

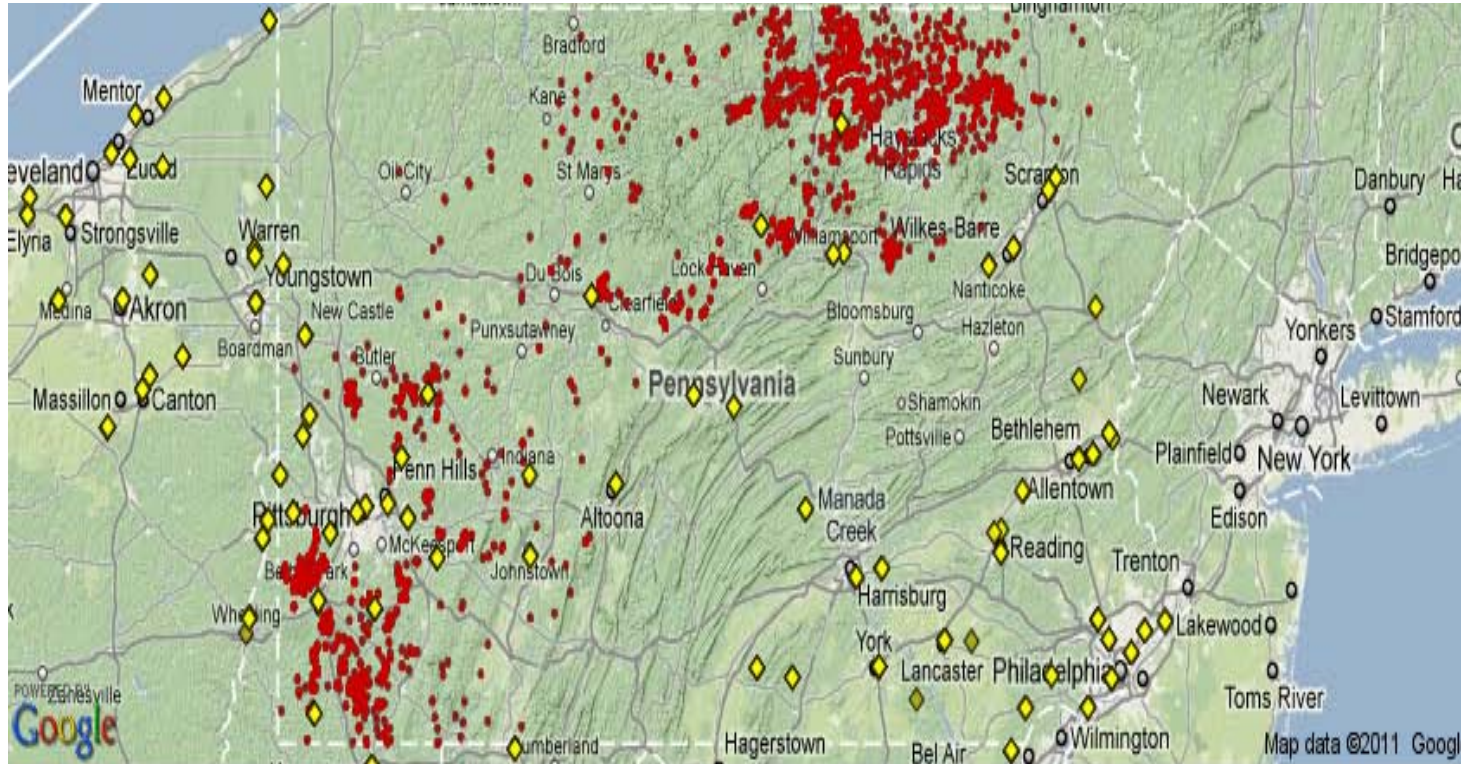
## Impoundment



- Flow-back Water
- Produced Water
- Proprietary chemicals
- Up to 5 million gallons per “frac”
- Water sources
- Water transported via tankers
- Open pits to closed tankers
- Disposal options



# Ambient Air Sampling



Ozone Monitoring Stations

All records

Drilled Marcellus Shale Wells in Penn...

All records



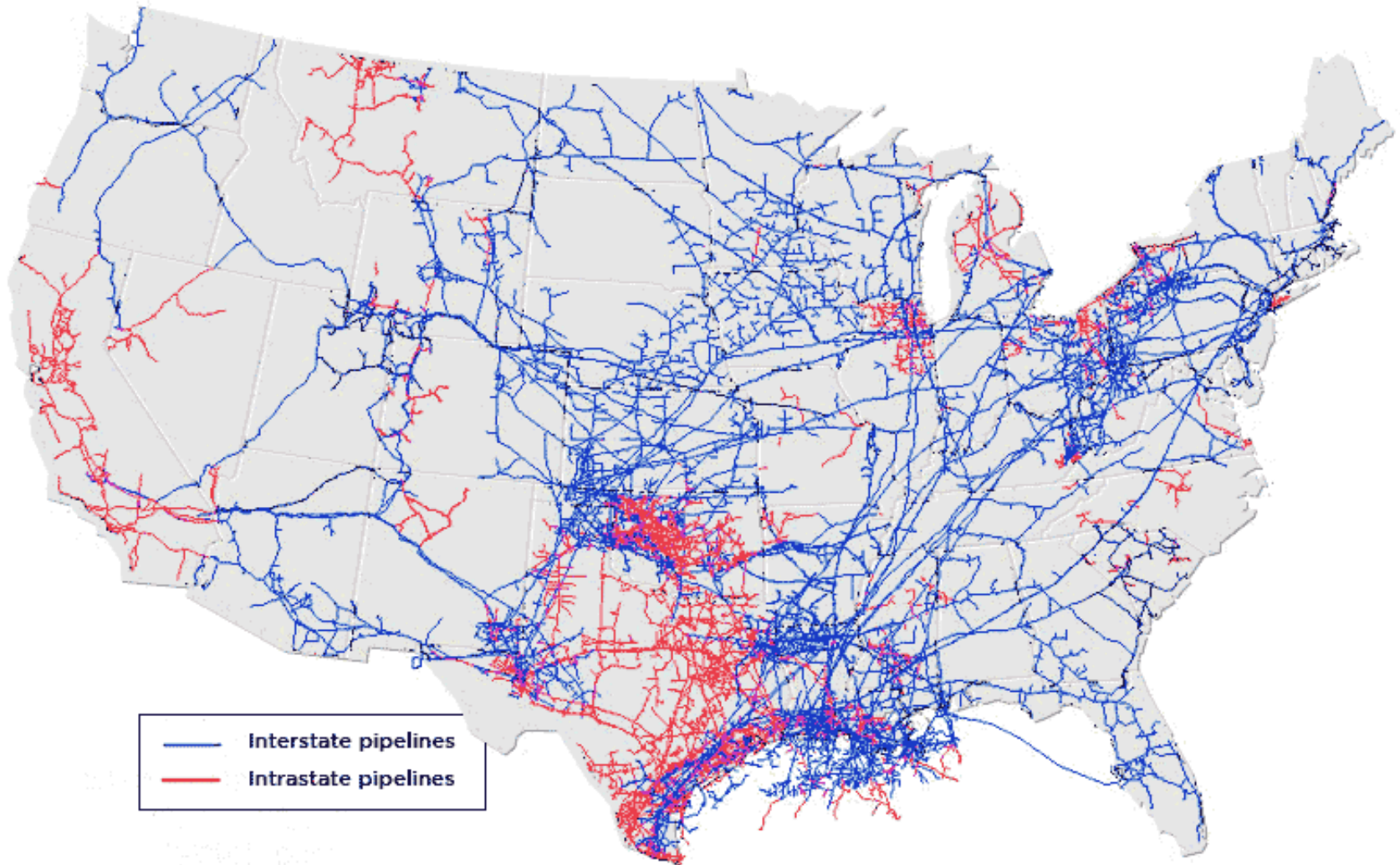
**FracTracker**

Ozone Monitors

<http://data.fractracker.org/cbi/snapshot/page?concept=~01e5c7d91ce88211e08661d167f87ce508>

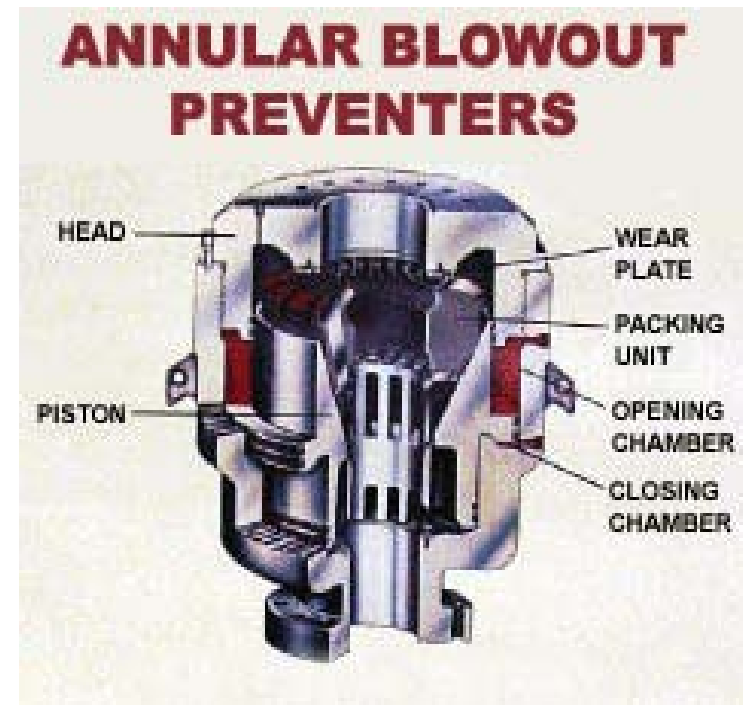
Created by  
Kyle Ferrar  
on Sep 28, 2011

# Natural Gas Pipeline Network



# New Drilling Regulations

- Blow Out Prevention (BOP) devices
- Well Construction, casing and cementing standards.
- Surface Casing
- Casing centralizers
- Casing and cementing plan
- Pressure Testing
- Cement testing
- Zone of critical cement
- Quarterly monitoring program



# Beyond the Marcellus

Generalized Cross Section  
Utica and Marcellus Shale  
Ohio to Pennsylvania

