Marcellus Shale Geology and Oil and Gas Drilling and Production

Taury Smith

New York State Geological Survey

Reservoir Characterization Group at the New York State Museum

NEW YORK STATE GEOLOGICAL SURVEY Est. 1836 NEW YORK STATE MUSEUM

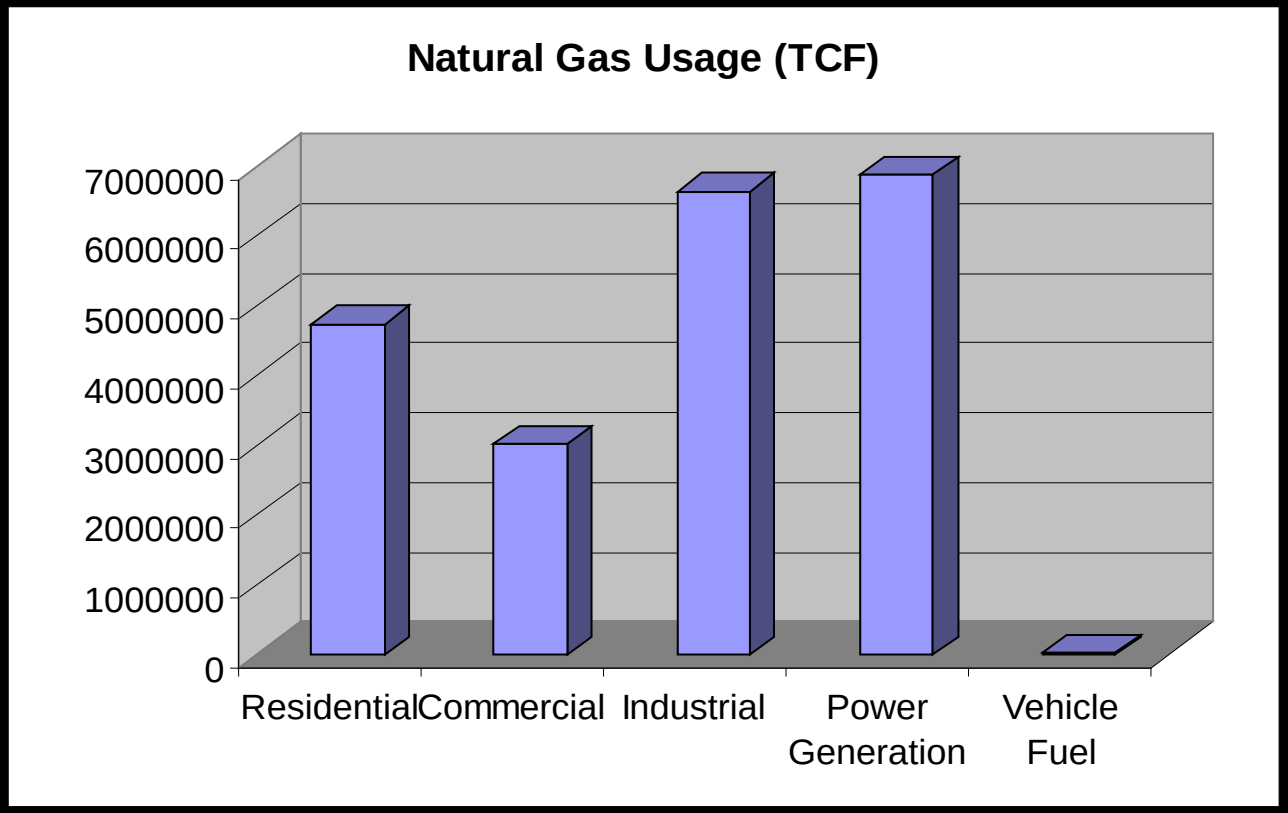
EXHIBIT 4: COMBUSTION EMISSIONS
(POUNDS/BILLION BTU OF ENERGY INPUT)

Air Pollutant	Combusted Source		
	Natural Gas	Oil	Coal
Carbon dioxide (CO_2)	117,000	164,000	208,000
Carbon monoxide (CO)	40	33	208
Nitrogen oxides (NO_x)	92	448	457
Sulfur dioxide (SO_2)	0.6	1,122	2,591
Particulates (PM)	7.0	84	2,744
Formaldehyde	0.750	0.220	0.221
Mercury (Hg)	0.000	0.007	0.016

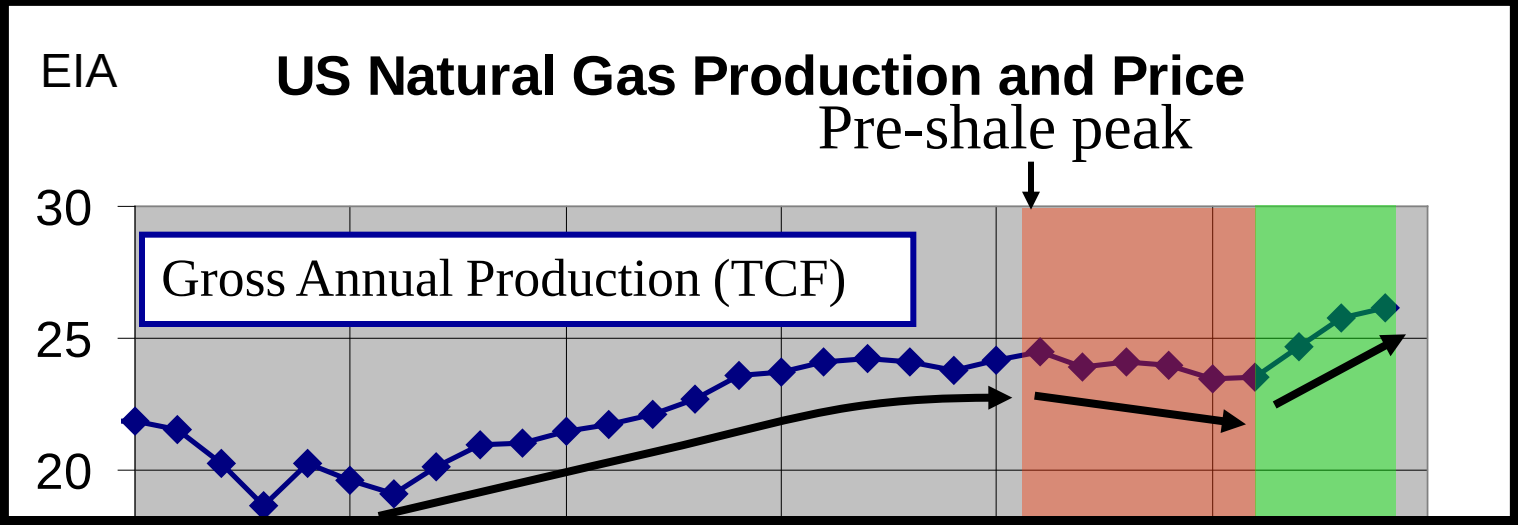
Sources: EIA, 1998

Natural gas (mainly methane) is a fossil fuel but it makes significantly less CO_2 per BTU than oil and coal. It also makes much less or no mercury SO_2, NO_x and other pollutants

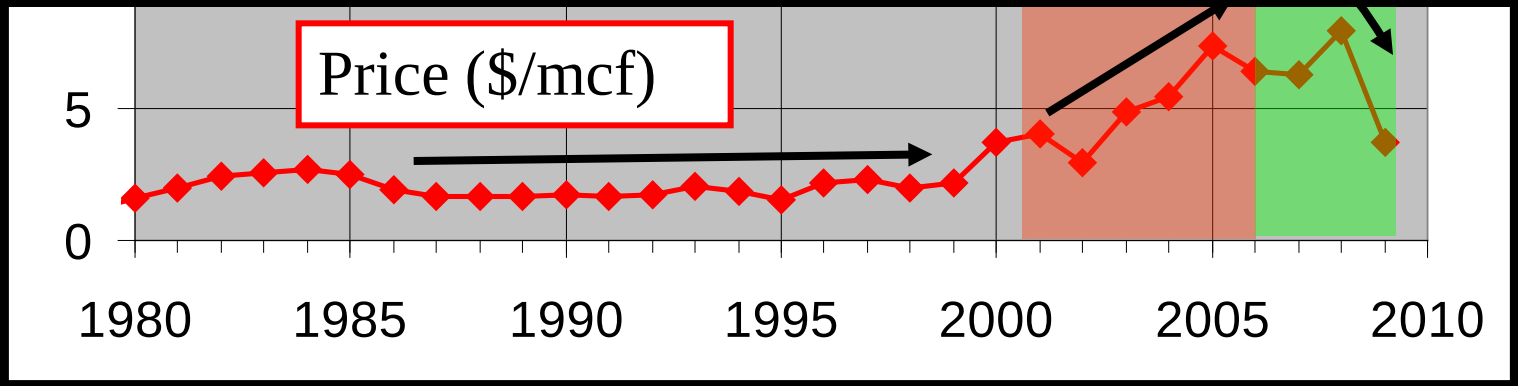
Uses of Natural Gas



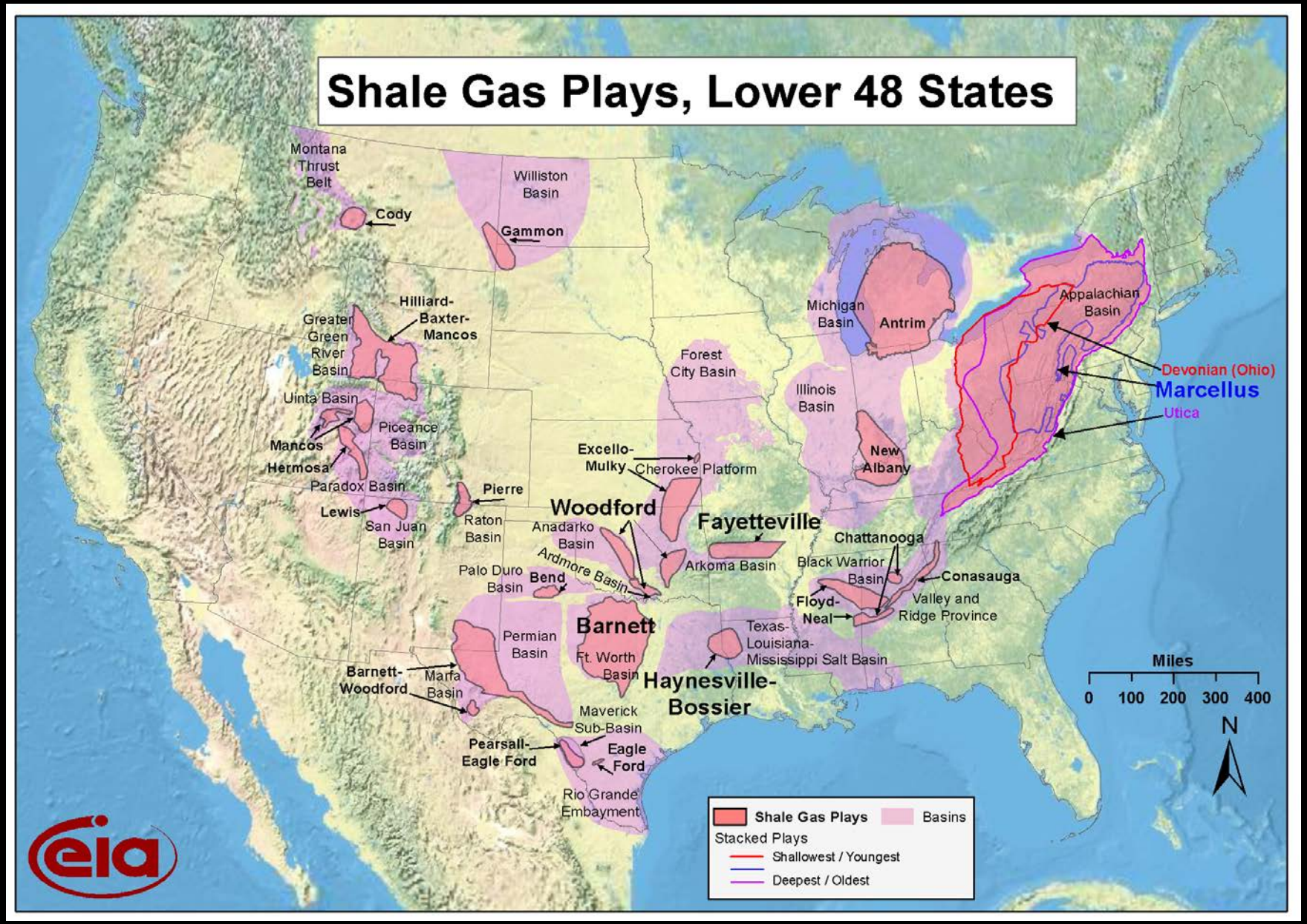
Natural gas is used for heat, cooking, power generation, industrial processes and can be used to power cars and trucks – all of these could and would probably grow if we were certain that there was a cheap, reliable source of natural gas



The price decline associated with the rise of shale gas is currently saving New Yorkers roughly $4 billion/year and the US about $100 billion/year



It looked like natural gas production had peaked in 2001 and was declining leading to higher prices – unlocking of shale gas changed that and has led to increased production since 2007 and a decrease in price



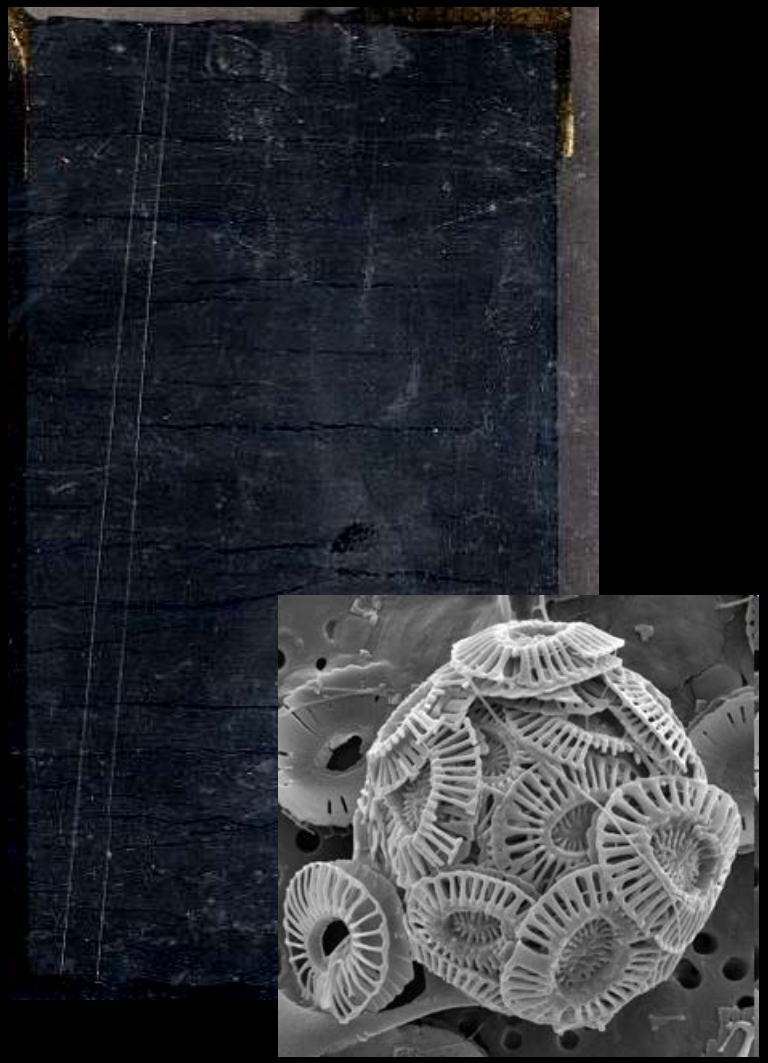
There are numerous marine black shales in the US with potential to produce gas – potential for hundreds or thousands of TCF

US Shale Gas

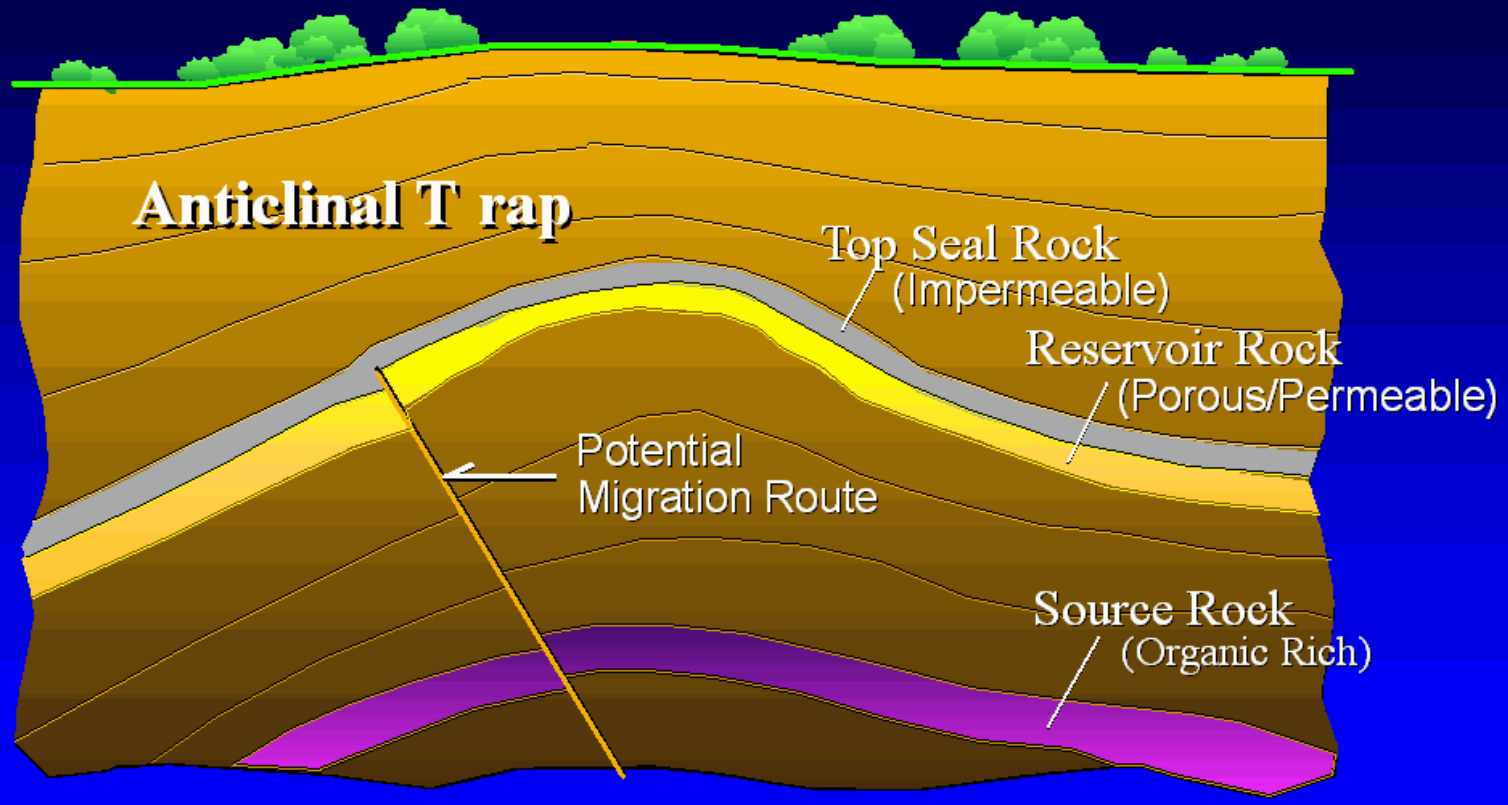
- From less than 1% of US production in 2000, shale gas now accounts for 30% of US natural gas production
- Marcellus first produced in 2006, today the Marcellus produces 4BCF/D or 6% of US total
- Some projections have Marcellus producing 25% of US total in 2020
- GHG emissions in US declining, at least in part because old coal plants are being replaced by new gas plants

Organic-Rich Black Shale

- Organic-rich marine black shales are the source of most of the oil and gas produced in the United States and are now considered potential reservoirs themselves
- The organic matter in marine black shales is mainly algae, plankton, diatoms and spores that are preserved during deposition
- When organic-rich shales are buried and heated some of the organic matter turns into oil and some turns into gas

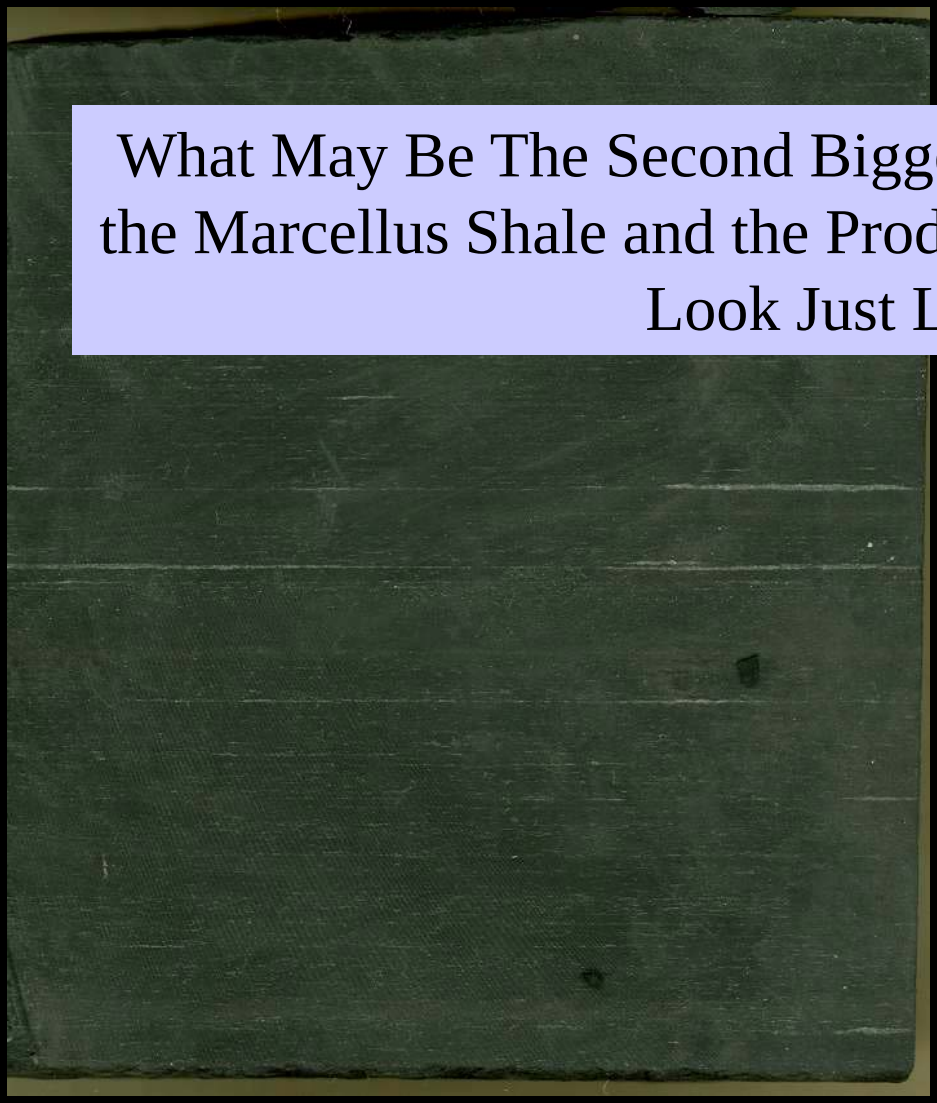


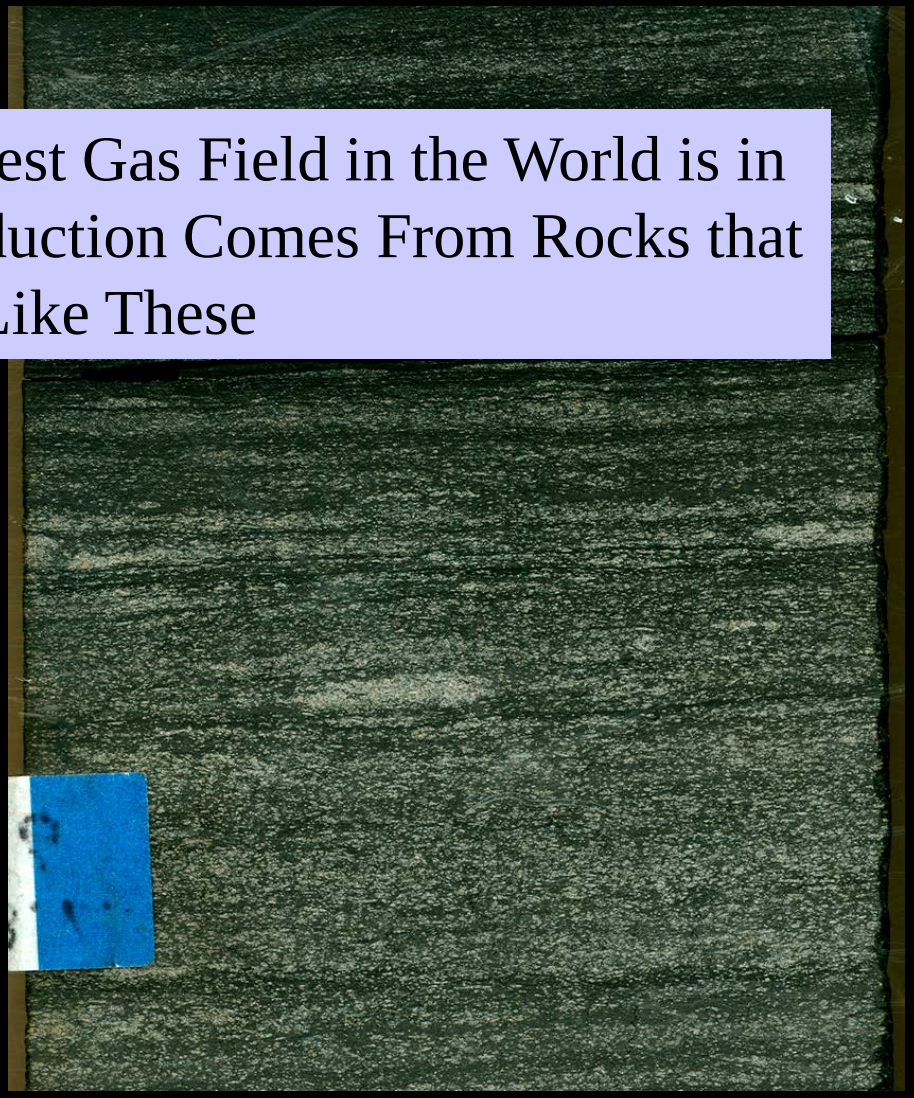
Petroleum System Elements



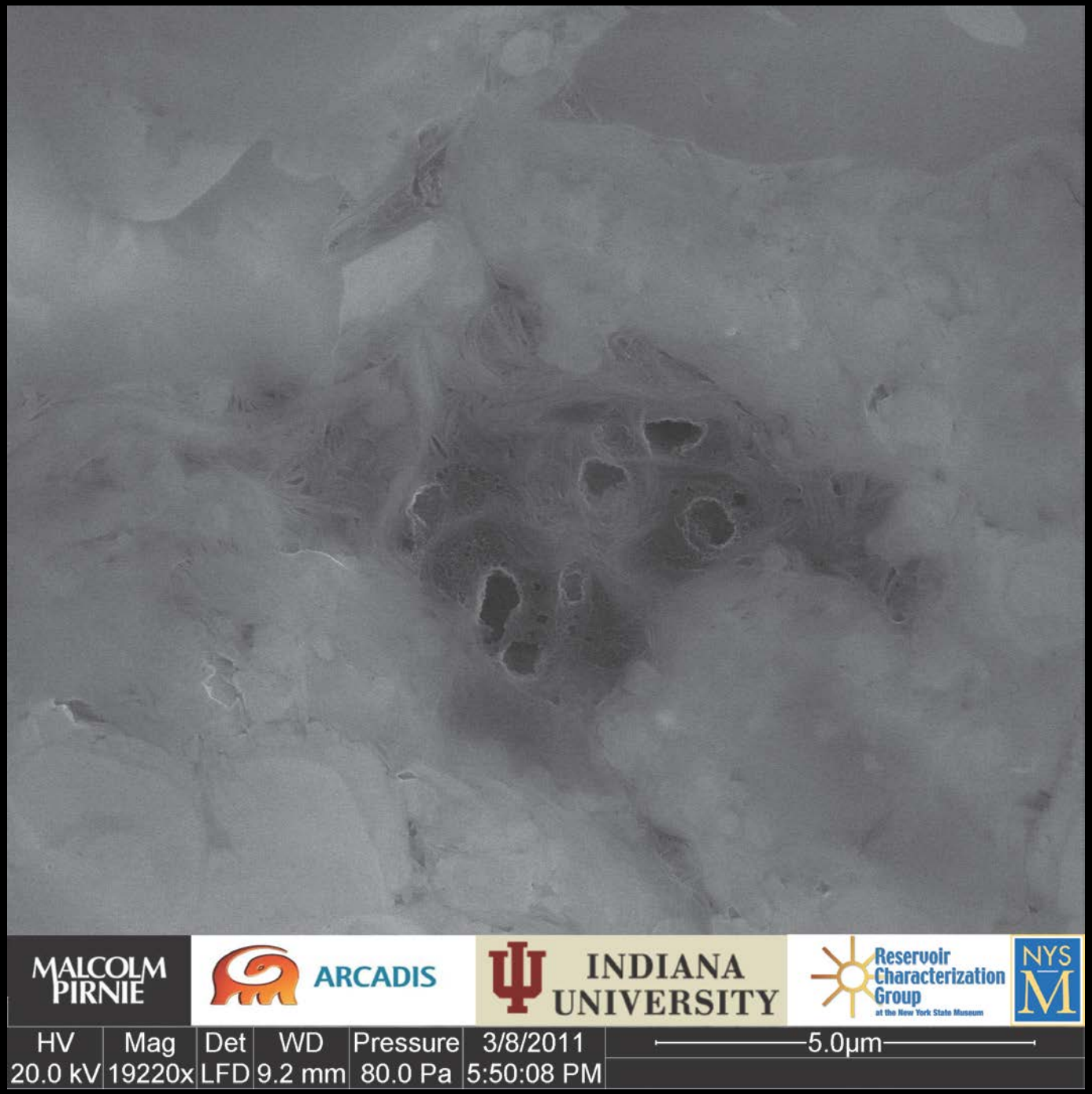
Conventional Petroleum System shows oil and gas migrating from source rock to reservoir - shales typically source rocks and seals on more porous reservoirs – in this case the source is the reservoir

What May Be The Second Biggest Gas Field in the World is in the Marcellus Shale and the Production Comes From Rocks that Look Just Like These



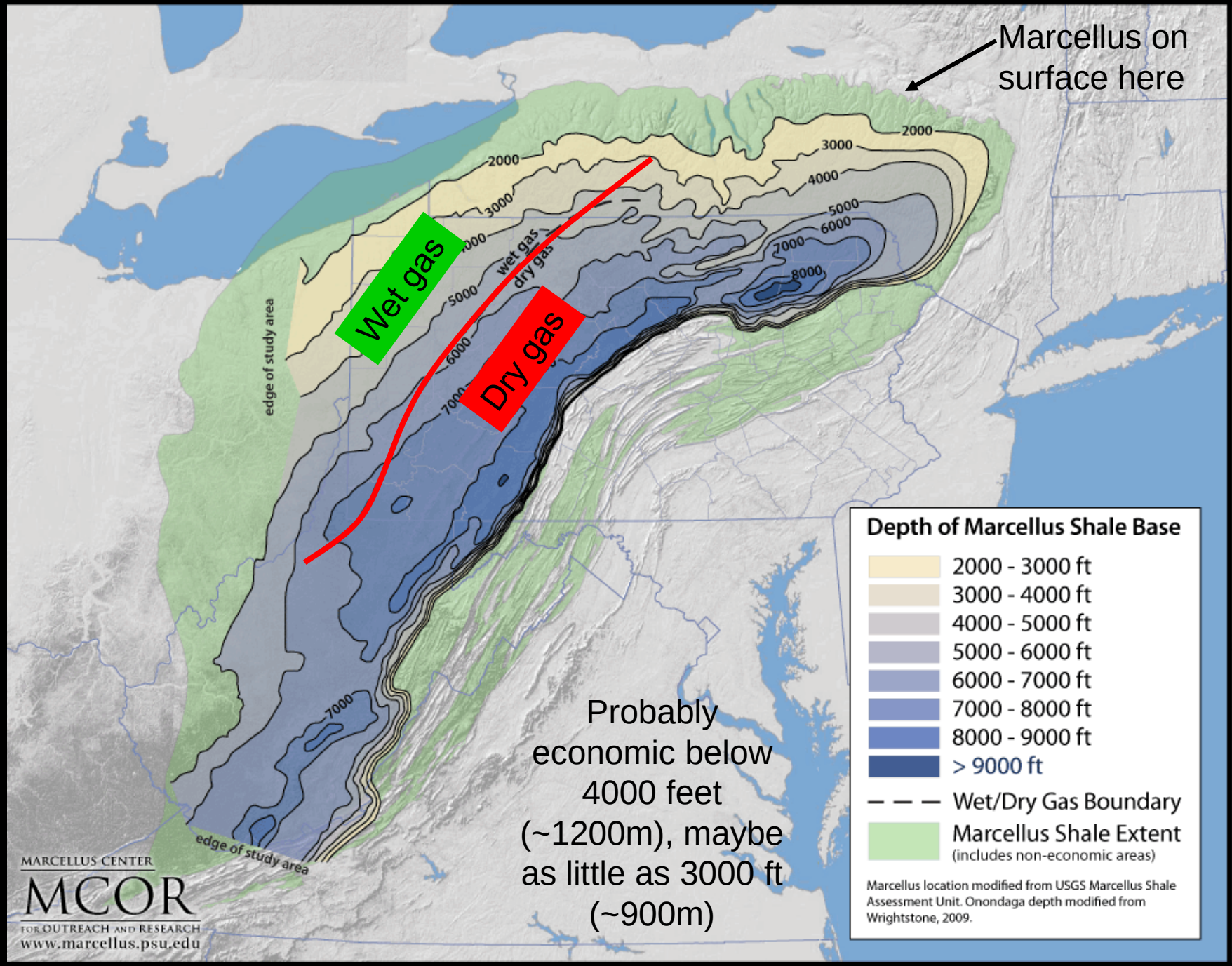


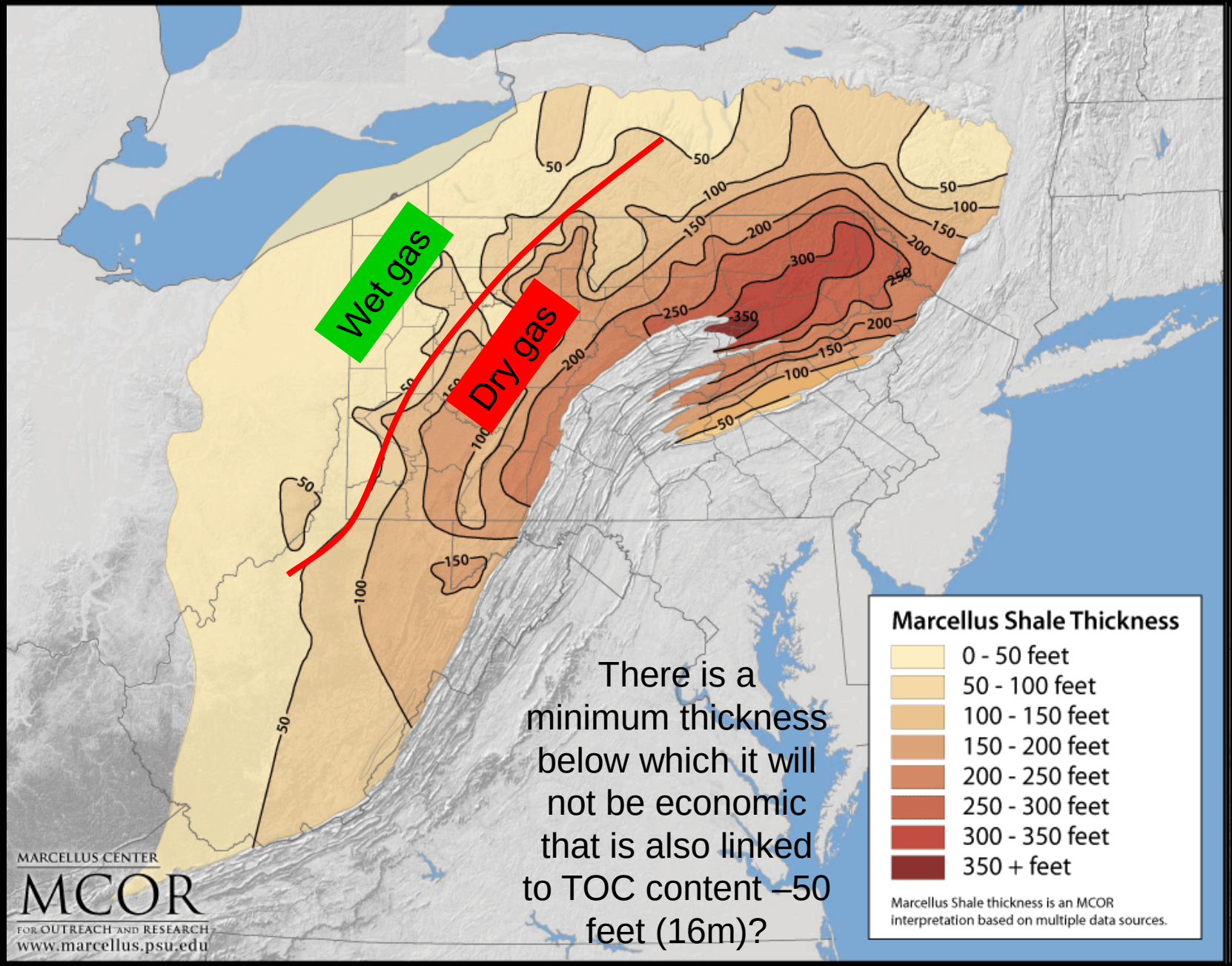
Core samples from Marcellus – light colored material are fossils that are partly silicified



As the organic matter expels oil and gas, pores form and much of the gas that is produced comes from these tiny pores

They aren't well connected and need fractures to flow


Marcellus on surface here
Wet gas
Dry gas
wet gas
dry gas
edge of study area
edge of study area
2000
3000
4000
5000
6000
7000
8000
Probably economic below 4000 feet (~1200m), maybe as little as 3000 ft (~900m)
Depth of Marcellus Shale Base
2000 - 3000 ft
3000 - 4000 ft
4000 - 5000 ft
5000 - 6000 ft
6000 - 7000 ft
7000 - 8000 ft
8000 - 9000 ft
> 9000 ft
Wet/Dry Gas Boundary
Marcellus Shale Extent
(includes non-economic areas)
Marcellus location modified from USGS Marcellus Shale Assessment Unit. Onondaga depth modified from Wrightstone, 2009.
MARCELLUS CENTER
MCOR
FOR OUTREACH AND RESEARCH
www.marcellus.psu.edu


Wet gas
Dry gas
50
100
150
200
250
300
350
Marcellus Shale Thickness
0 - 50 feet
50 - 100 feet
100 - 150 feet
150 - 200 feet
200 - 250 feet
250 - 300 feet
300 - 350 feet
350 + feet
Marcellus Shale thickness is an MCOR interpretation based on multiple data sources.
There is a minimum thickness below which it will not be economic that is also linked to TOC content –50 feet (16m)?
MARCELLUS CENTER
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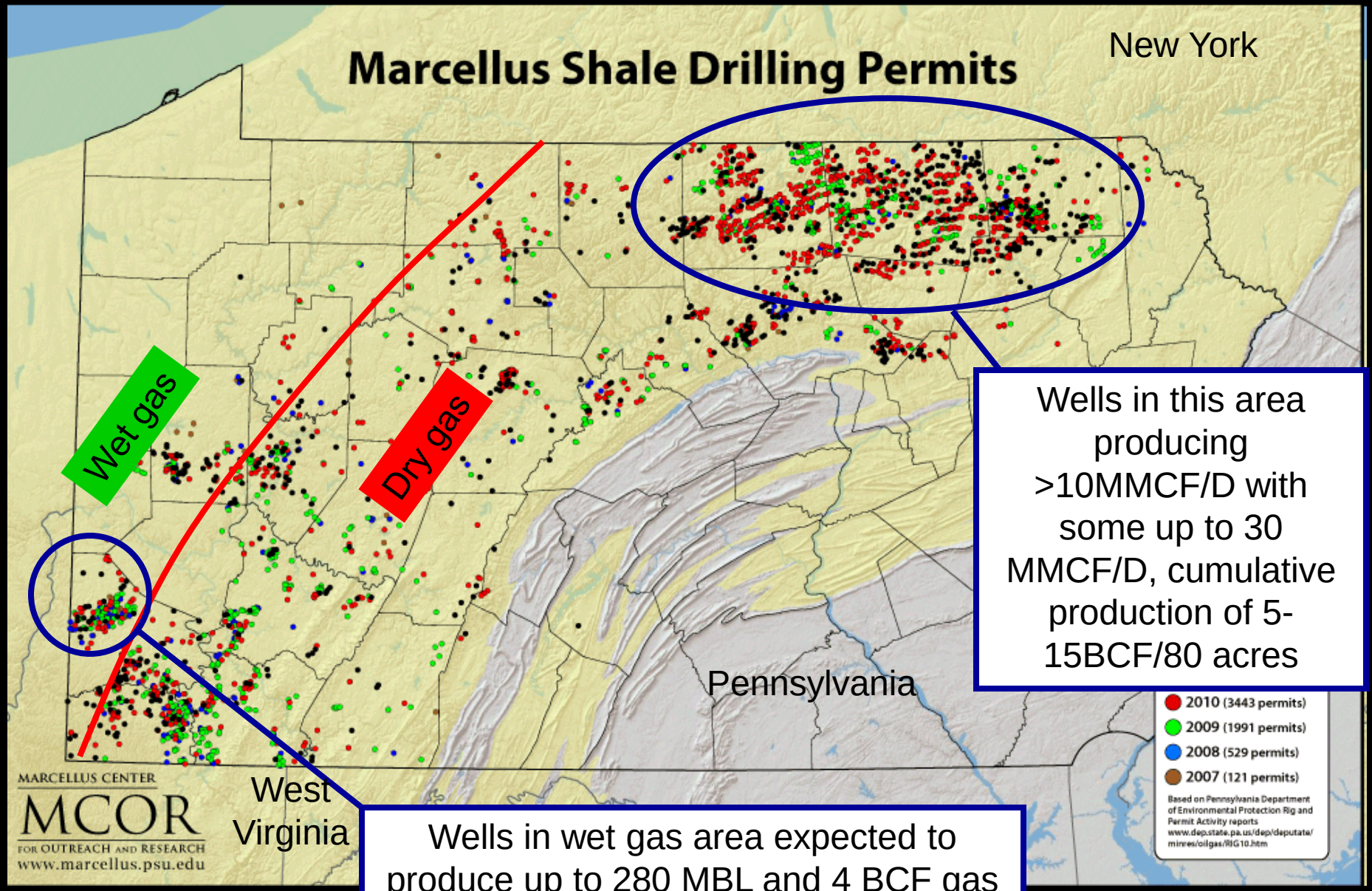
Marcellus Shale Drilling Permits
New York
Wet gas
Dry gas
Pennsylvania
West Virginia
Wells in this area producing >10MMCF/D with some up to 30 MMCF/D, cumulative production of 5-15BCF/80 acres
Wells in wet gas area expected to produce up to 280 MBL and 4 BCF gas - this area is now very popular due to liquids production
2010 (3443 permits)
2009 (1991 permits)
2008 (529 permits)
2007 (121 permits)
Based on Pennsylvania Department of Environmental Protection Rig and Permit Activity reports
www.dep.state.pa.us/dep/deputate/minres/oilgas/RIG10.htm
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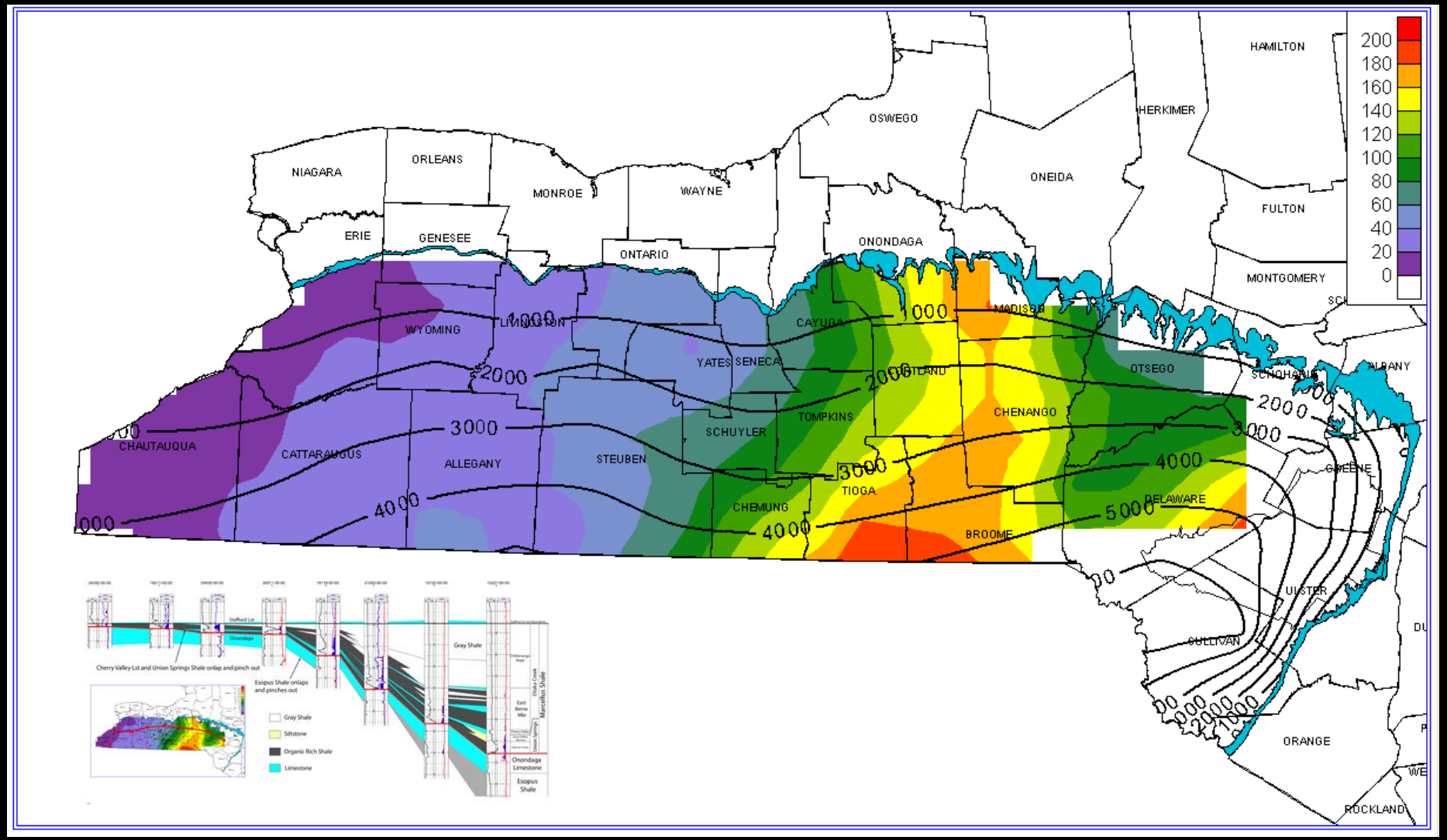
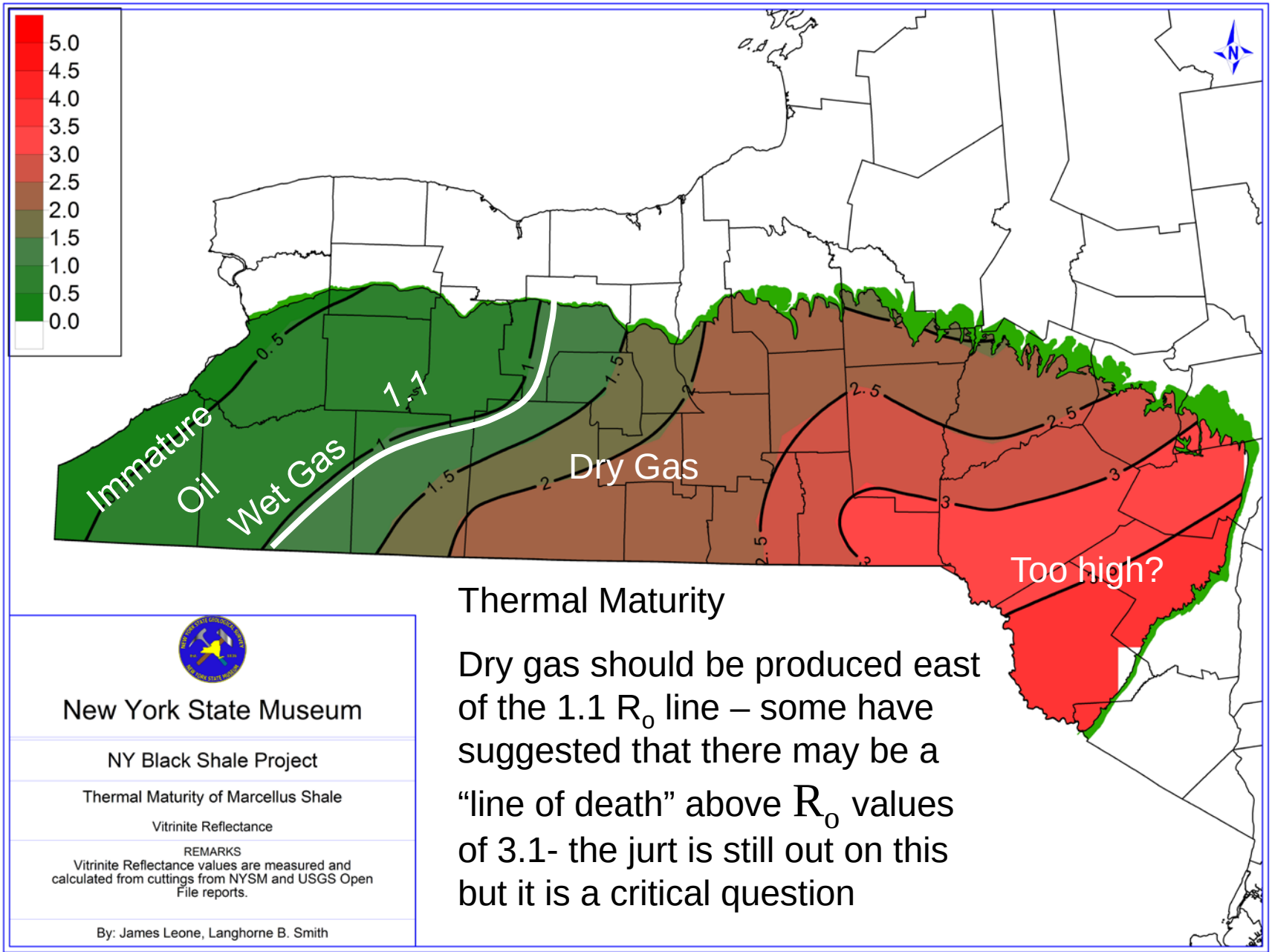


Thicker sections deeper than 4000 feet most likely to be developed first – how shallow can this play work? How far east can it work?



New York State Museum

NY Black Shale Project

Thermal Maturity of Marcellus Shale

Vitrinite Reflectance

REMARKS
Vitrinite Reflectance values are measured and calculated from cuttings from NYSM and USGS Open File reports.

By: James Leone, Langhorne B. Smith

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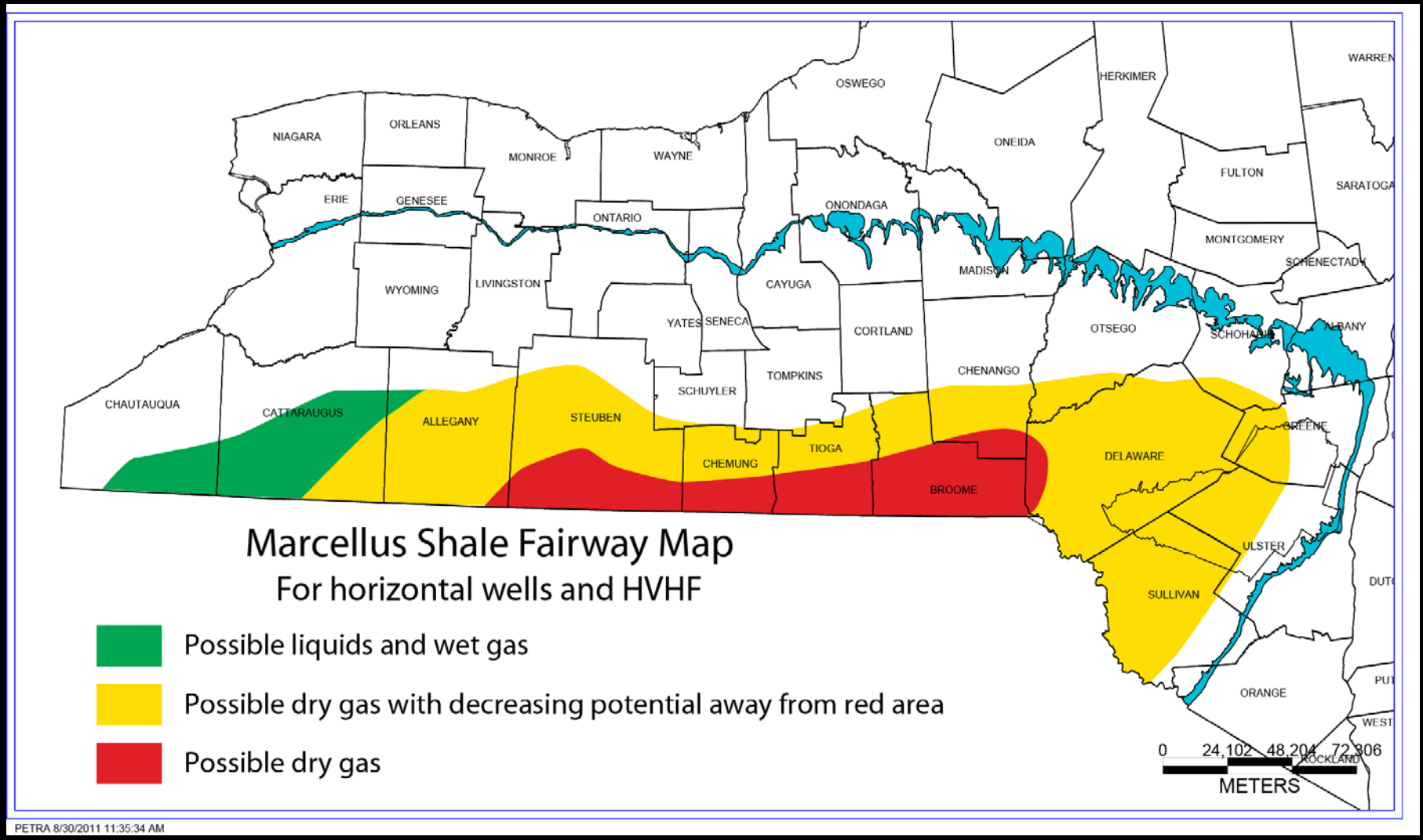
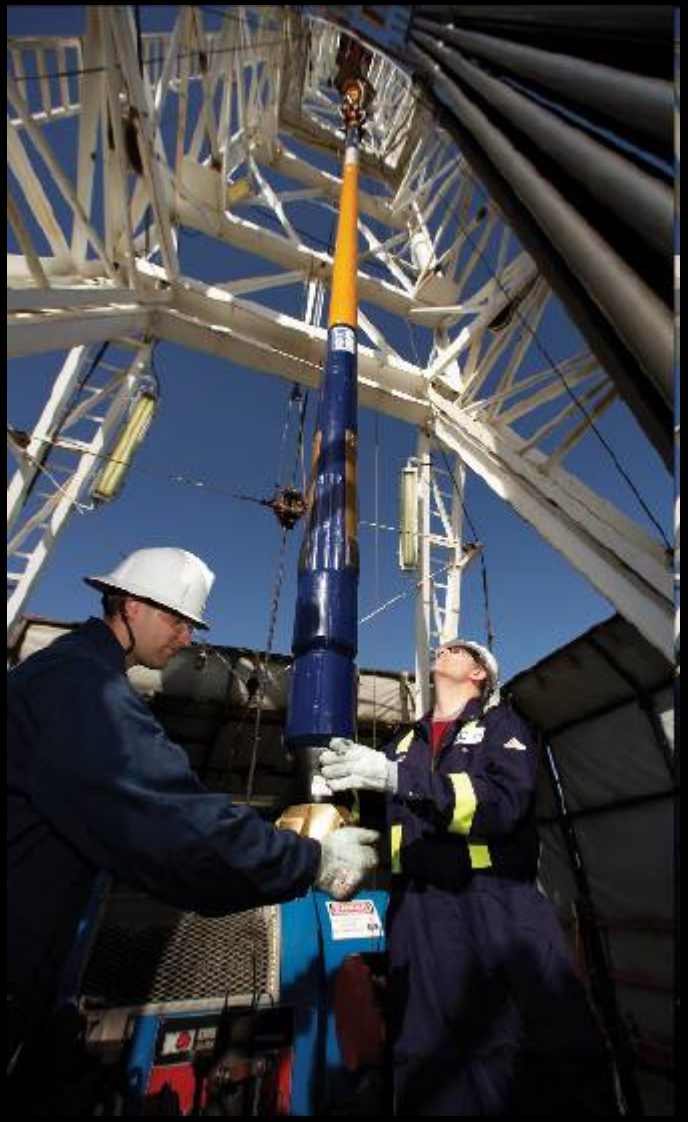
Thermal Maturity

Dry gas should be produced east of the 1.1 R_o line – some have suggested that there may be a "line of death" above R_o values of 3.1- the jurt is still out on this but it is a critical question

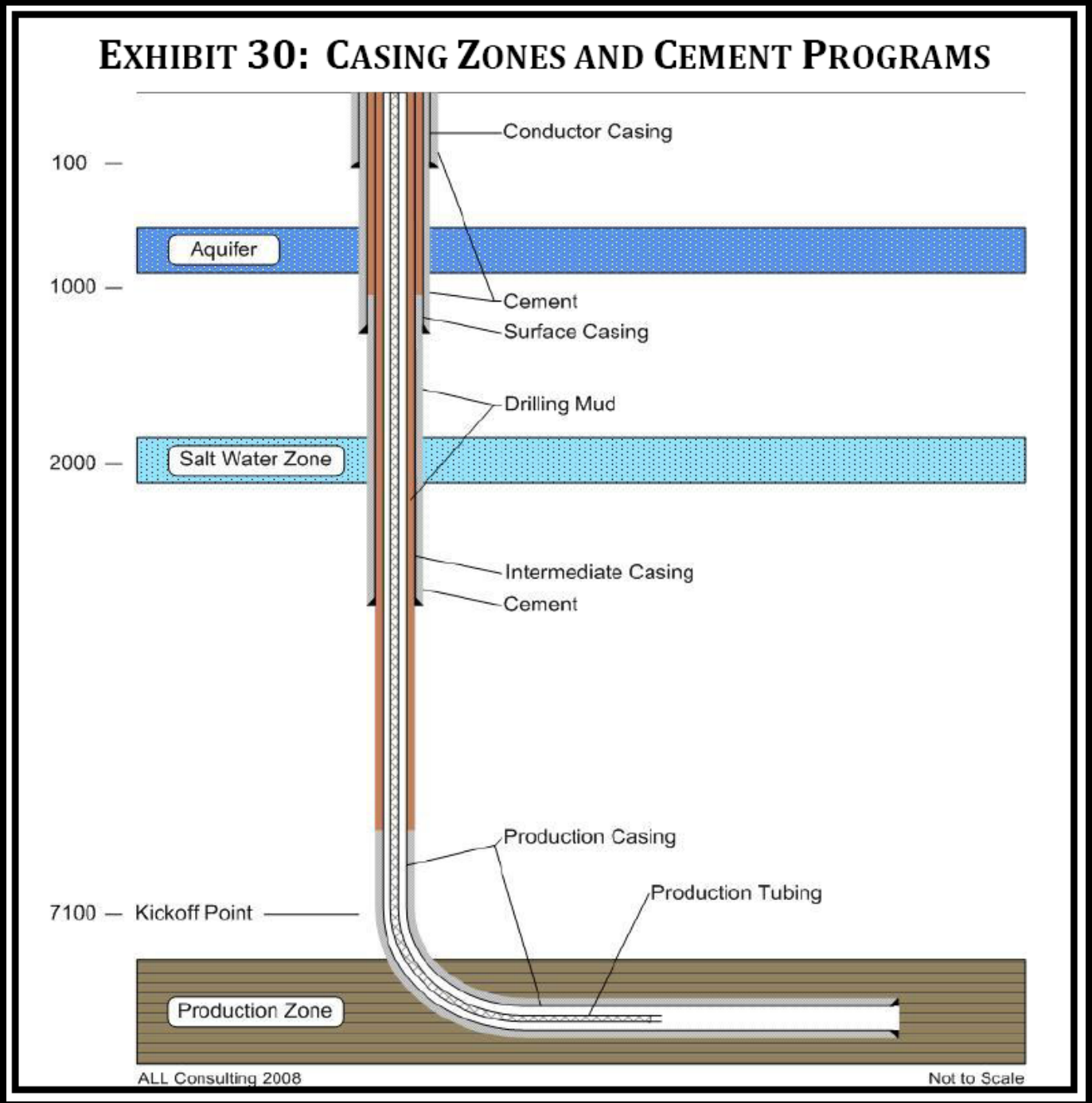


After considering the depth, thickness, TOC content and thermal maturity this map shows the areas of probable and possible economic Marcellus production – if only the red area is developed, this could still mean >60 TCF of gas in NY alone.

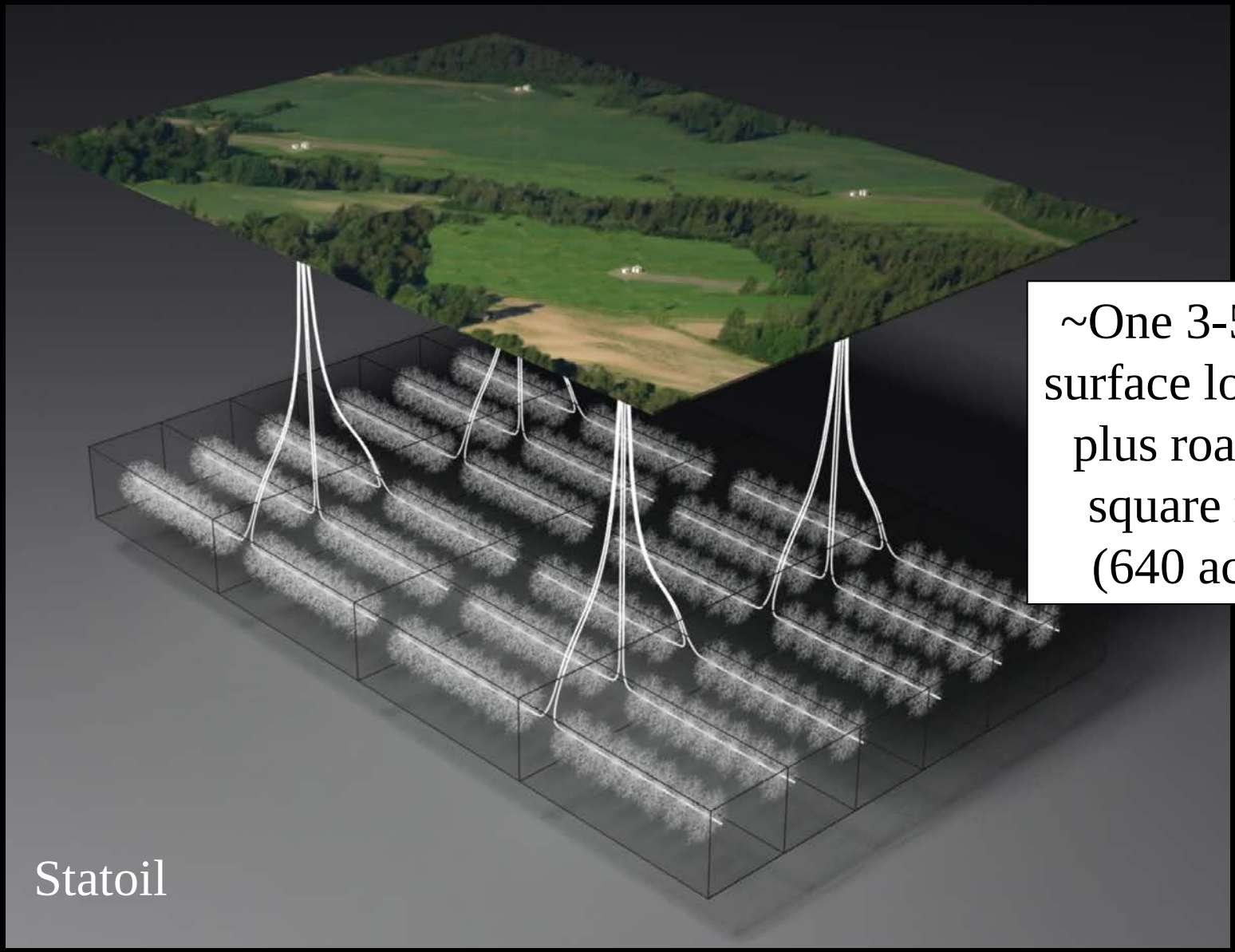
Drilling Rig- This is only present for the drilling of the well(s) and is then moved on to the next well



Steering motor and bit for drilling directional and horizontal wells



At several points during the drilling of the well, steel pipe called casing will be run into the hole and cemented in place – they squeeze cement in between the pipe and bedrock to prevent fluids from migrating outside the pipe – this is a key step that is essential to a good frac job and production well



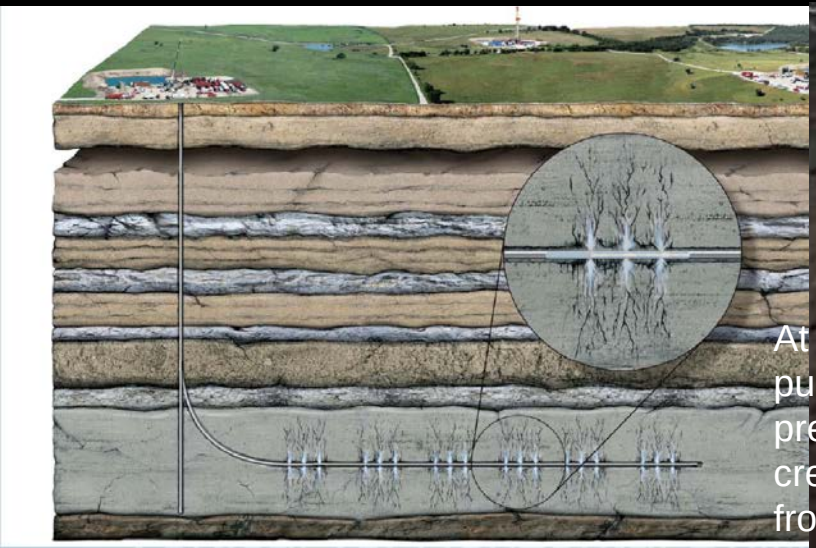
~One 3-5 acre surface location plus road per square mile (640 acres)

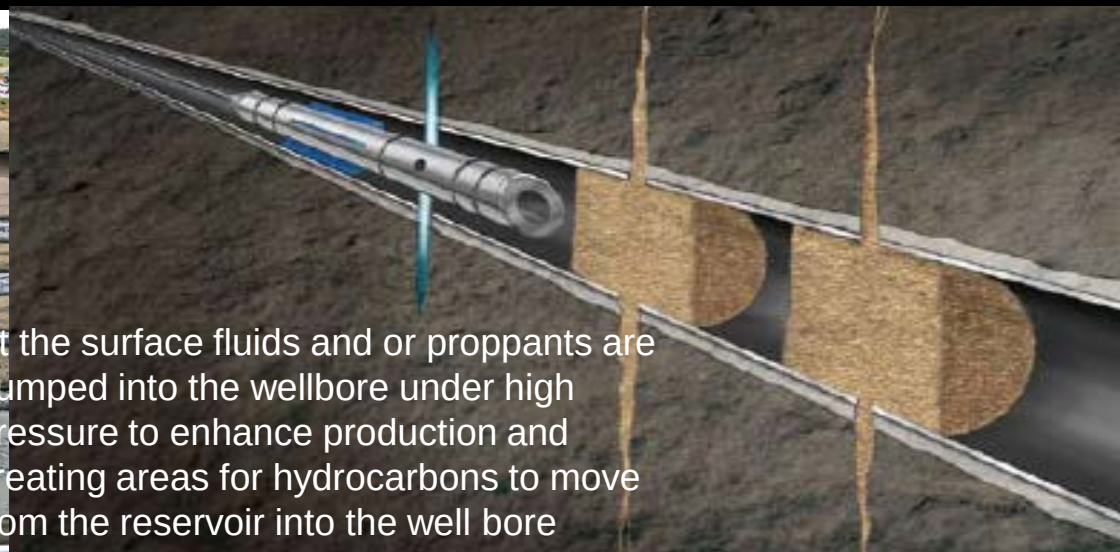
6-8 horizontal wells can be drilled from each surface location and about 1 square mile (or more) can be drained from each surface location – in this case the total land surface disrupted should be around 1% of the total

Hydraulic Fracturing of Rocks

- Perforations are made in the steel casing
- Water, sand and some additives are pumped into the perforations in isolated stages at high enough pressure to fracture the rock (not an explosion)
- This process was first done in the early 1900s and hundreds of thousands of oil and gas wells (and many water wells) have been “fraced” over the years

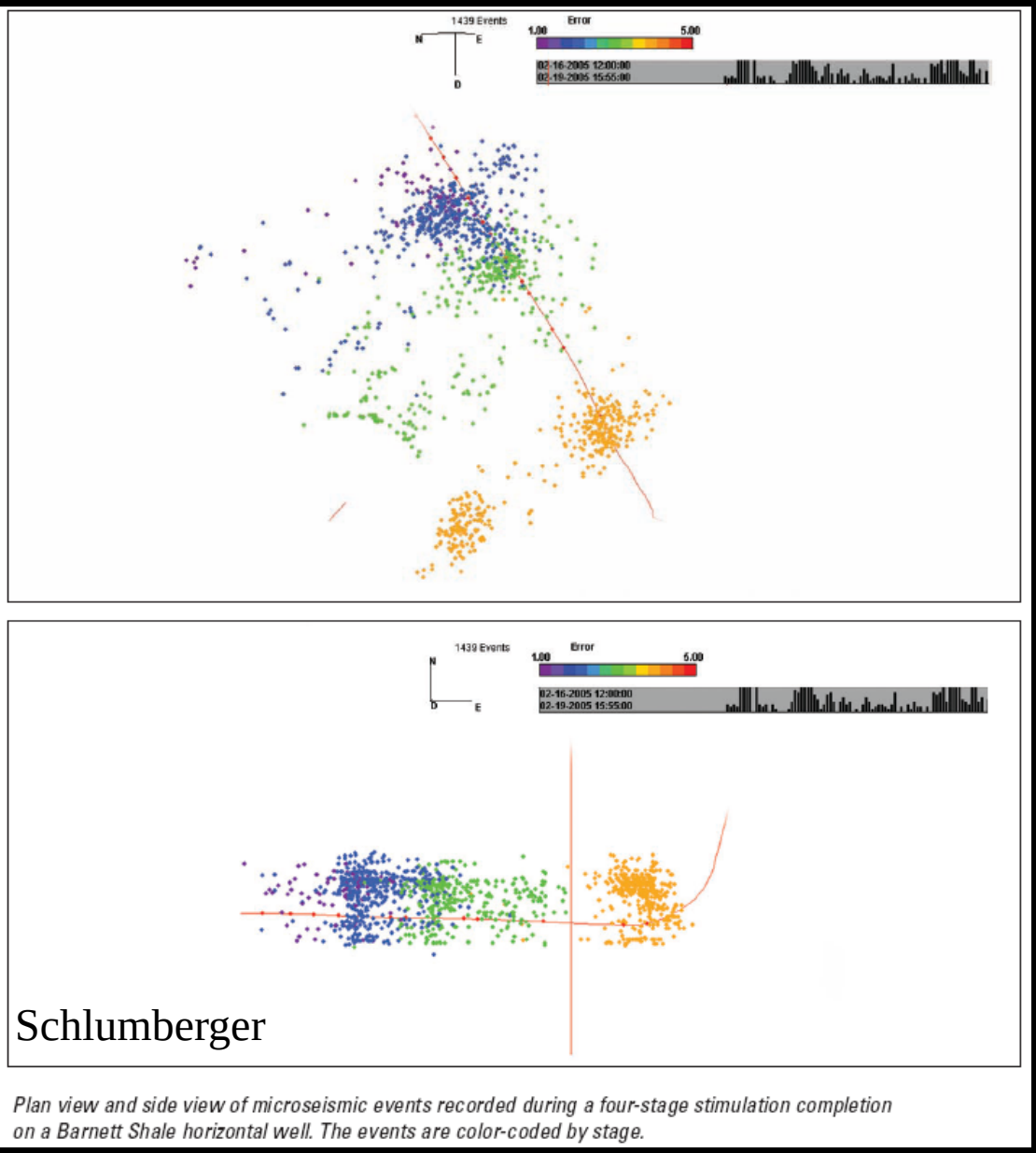
Wylie, Eberhard, and Mullen, 2007





At the surface fluids and or proppants are pumped into the wellbore under high pressure to enhance production and creating areas for hydrocarbons to move from the reservoir into the well bore

Frac job on a Marcellus Shale Well – 2-10 million gallons of water (with ~0.1-0.5% additives) and sand are pumped at high pressure into each well in multiple stages to induce fractures and prop them open – Average frac job is now about 5 million gallons in 12-20 stages



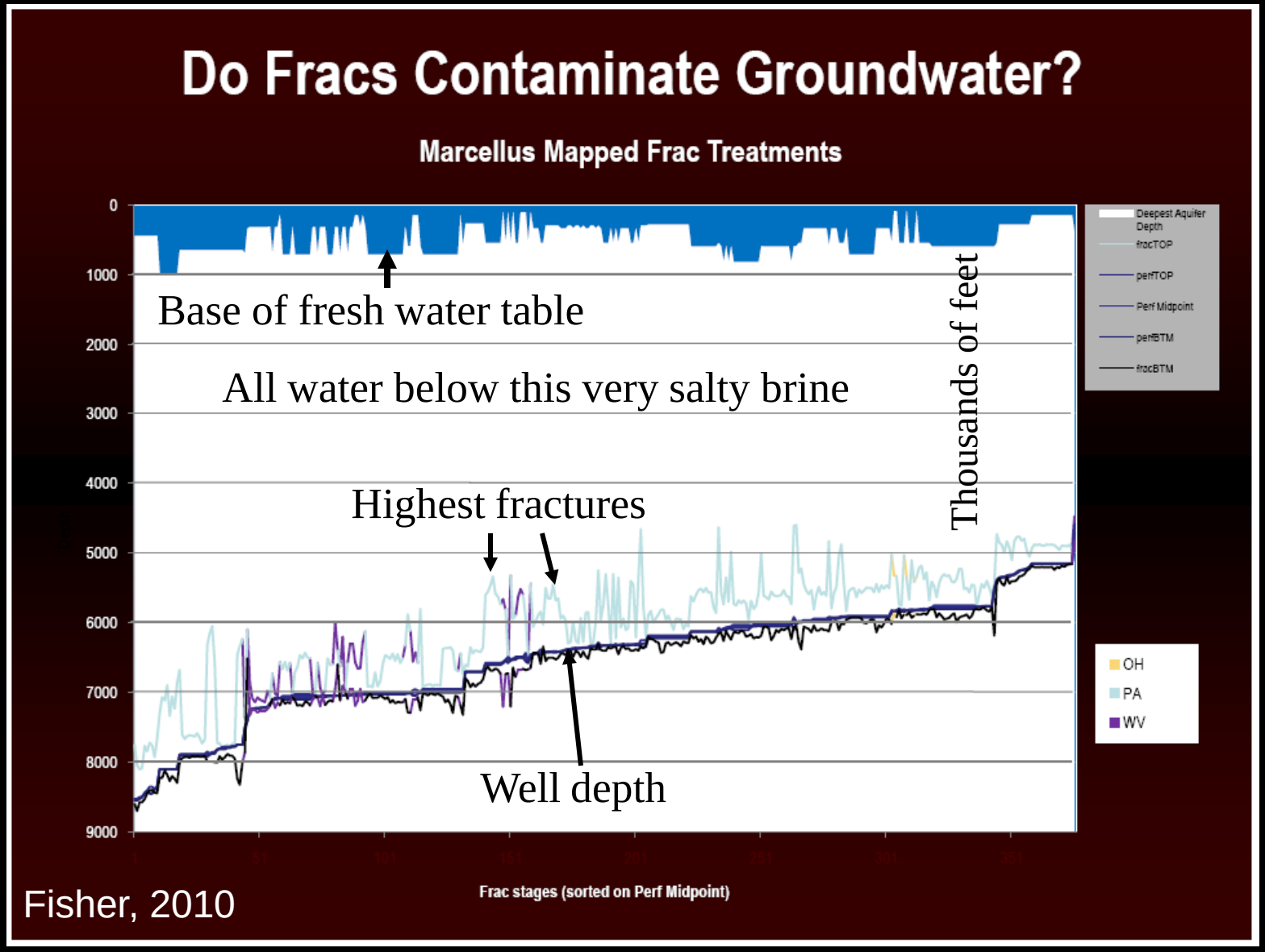
Plan view and side view of microseismic events recorded during a four-stage stimulation completion on a Barnett Shale horizontal well. The events are color-coded by stage.

Microseismic detectors can be used to see how far the fractures extend from the wellbore

This is a map and cross section view of microseismic data around a horizontal well that shows fracture development in a four stage frac job (each color represents a stage)

Wells commonly drilled perpendicular to principle compressive stress

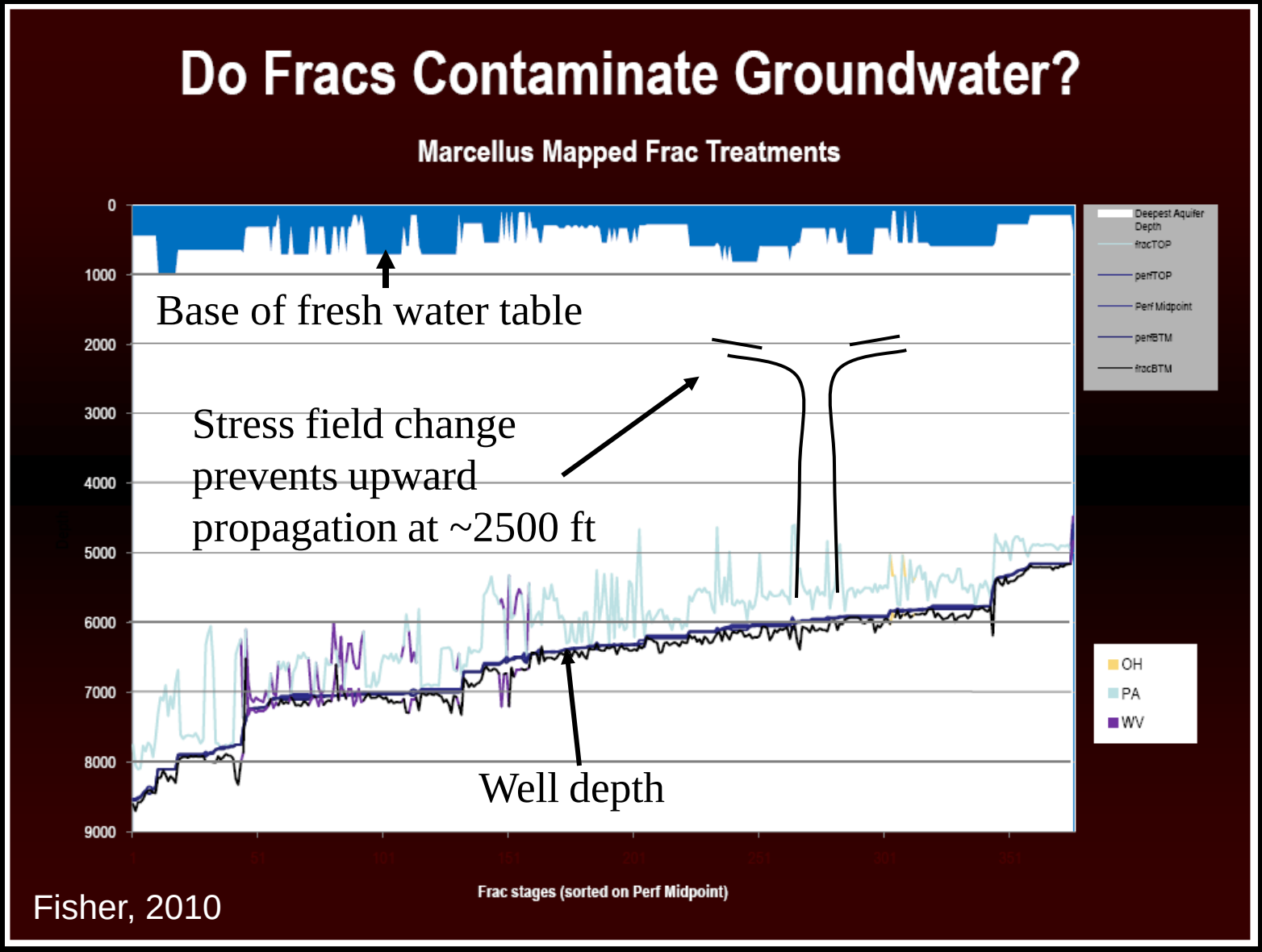
Do Fracs Contaminate Groundwater?



Fisher, 2010

Using special microseismic data, we can see exactly where the fractures form – this figure shows a summary of the depth of the well, highest fracture and base of the fresh water for numerous wells in PA and WV

Do Fracs Contaminate Groundwater?



Fisher, 2010

At about 2500 feet the stress field changes and above that only horizontal fractures will form – so economics and simple physics make it extremely unlikely that fractures will extend upward into fresh water from below

“Fracking”

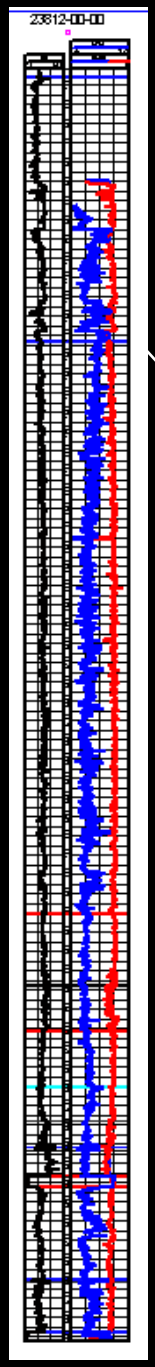
- It has become clear that the way different groups define “fracking” has become part of the problem
- Fracking in the oil and gas business and to regulators means the actual hydraulic fracturing of the well
- Fracking in some of the media and in some opposing groups has come to include all aspects of drilling, casing the well, hydraulic fracturing, and other parts of the operation
- So when companies or regulators say “fracking doesn’t contaminate groundwater” they mean the actual process of hydraulic fracturing – groundwater contamination is possible due to surface spills or methane migration but these are not “fracking”

State and Federal Agencies Say Fracking Does Not Appear to Contaminate Groundwater

- “I’m not aware of any proven case where the fracking process itself has affected water” said Lisa Jackson, Obama’s head of the EPA
- The NYSDEC and regulatory agencies in other states all say they are not aware of any cases where hydraulic fracturing has contaminated groundwater
- Continued focus on “fracking” as the problem distracts from real issues

Methane Migration

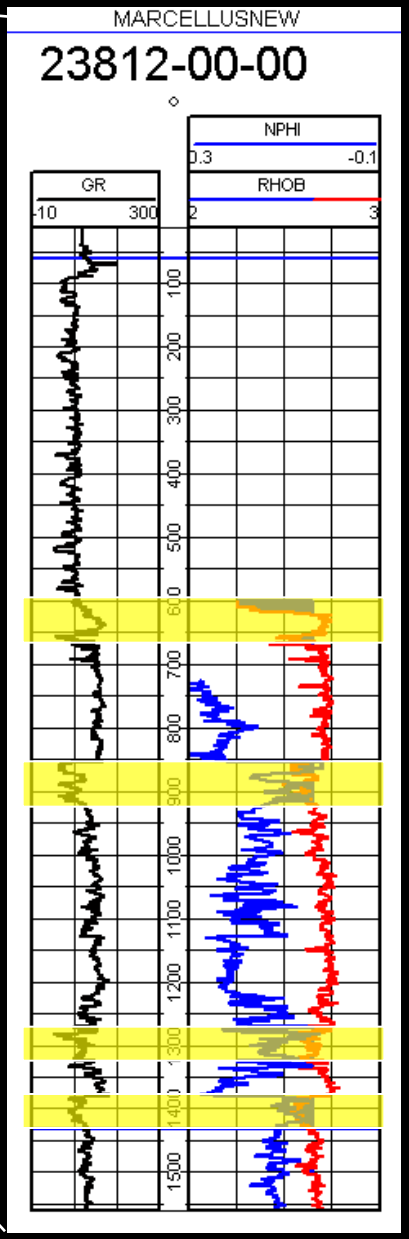
- In some areas where Marcellus drilling is occurring, there is naturally occurring methane in the fresh water aquifer or in the sandstones immediately below the aquifer – the gas migrated upward and into these formations over millions of years
- In some cases drilling and poor cementing of casing have caused an increase in methane concentrations in nearby water wells that is sourced from these shallow horizons (not from fracking of the Marcellus)
- This is a real issue
- But this is also an issue that has gone on for decades that has been studied extensively by the PA DEP



This is where the shallow gas can occur that causes problems

>5000 feet (1 mile)

Marcellus is down here



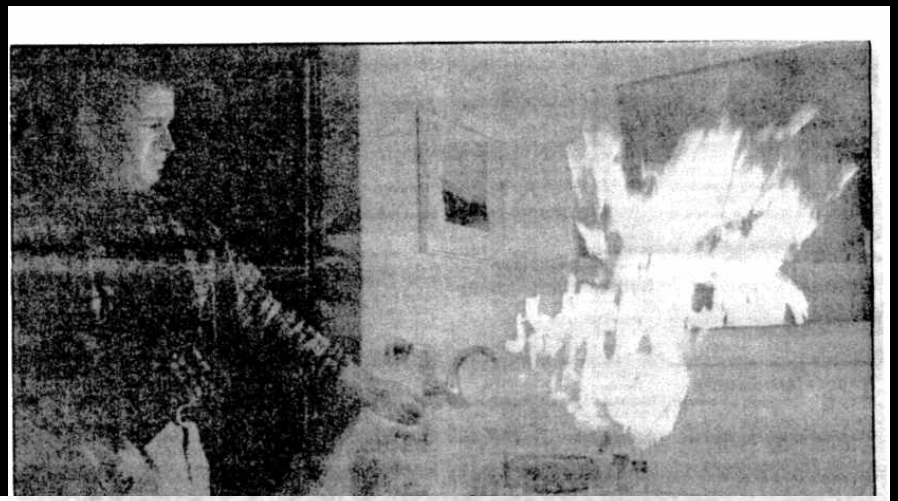
GAS?

GAS?

GAS?

GAS?

Natural gas is found in water wells in NY drilled into shallow gas-bearing strata far from areas of production



Jason Jacobs of Saratoga Lake stands clear of the flume after lighting the natural gas that streams from his bathtub faucet. A new study indicates

DAVID J. ROGOWSKI *Gazette Photographer*

Jason Jacobs of Saratoga Lake stands clear of the flume after lighting the natural gas that streams from his bathtub faucet. A new study indicates that the gas found in some water wells around the region could be a sign of commercially valuable deposits.

/Natural Gas
x Energy

GASEOUS GOLD

Energy deposits in region suggest possibility of large reserves

By MEREDITH KRUSE
Gazette Reporter

JUL 1 S

If a party at their Saratoga Lake home ever gets dull, Jason Jacobs and Lora Colucci have an easy way to liven it up: turn on the water in the bathtub, hold a lighter to the spigot, and watch as three-foot-long flames belch forth.

"When people see it, they either scream and go, 'Oh my God!' or they laugh this evil laugh," Colucci said. "It's like a nightmare and a circus all in one."

Entertainment value aside, the couple has always viewed the flammable natural gas in their well water as a nuisance that prompted them to switch to bottled water for cooking and drinking. But preliminary results of a new study suggests the underground gas pockets that migrate into wells in parts of the region might be valuable enough to interest the petroleum industry.

Based on geologic evidence and reports from homeowners, researcher John C. Kucewitz Jr. said there's reason to believe large deposits — potentially billions of cubic feet — of natural gas exist in Albany, Montgomery, Saratoga, Schenectady and Schoharie counties.

Kucewitz is a senior earth scientist with Wilbur Smith Associates in Latham. Working with researchers from the State University of New York College at Oneonta, he just completed a $10,000 study of the area for the state Energy Research and Development Authority, which supports research into new energy sources across the state. He presented the results Wednesday at a meeting of the Independent Oil and Gas Association of New York in Clymer, Chautauqua County — the heart of the state's small natural gas industry.

Whether [the gas] is commercial or not is something we won't know until a good deal more study is performed," he cautioned. But he said results are encouraging enough to warrant the industry taking a closer look.

Of the dozen or so stories that Kucewitz collected, he said one of the most interesting came from Jane Livingston of Princetown, who heated her home for more than 25 years with gas that her late husband discovered while digging a well in their yard and piped in to their furnace.

Escape valve opened

Although the pressure was relatively low, he calculated that at today's prices, Livingston's well might have produced $144,000 worth of gas a year. But the potential gold mine dissipated when a neighbor up the road drilled a well and allowed the gas to escape.

New York's 5,789 active commercial wells produced 18.3 billion cubic feet of natural gas last year, most of it from western counties like Chau-

See MORE, Page B11

Altamont Enterpris

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ESTABLISHED 1884 — ALTAMONT, NEW YORK, FEBRUARY 9, 1979

NATURAL GAS from the well at Dick Ferraioli's home on Hawes Road burns along as Dick and sons Dan and Tim look on.

A Source Of Energy That Can Be Found Underground — Locally

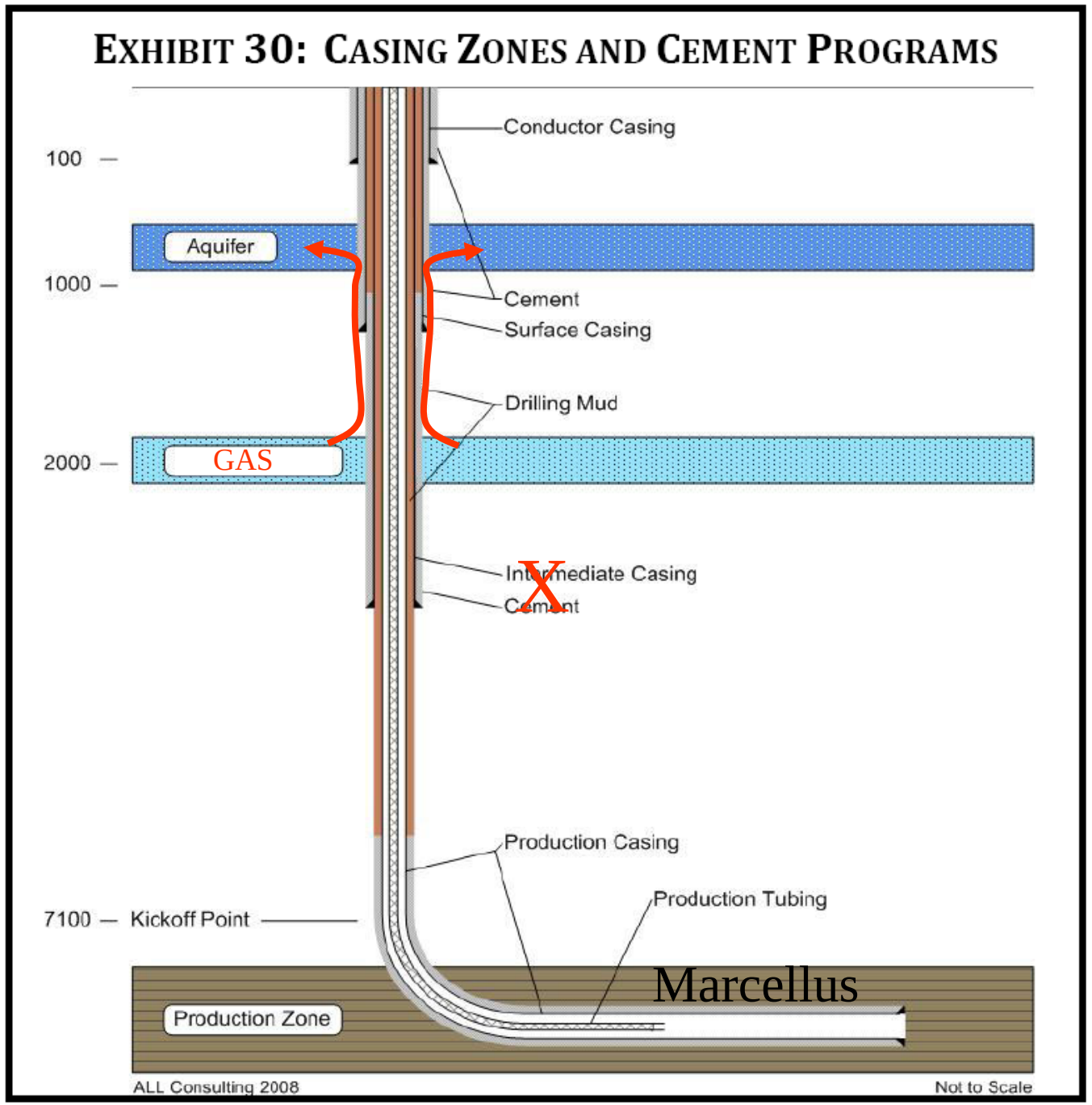
By CAROL DeBLIN AND ARTHUR B. GREGG

Who would ever believe that a long-closed chapter in the history of the Helderberg area would ever again be reopened? But such is the case. The fuel shortages that suddenly dismayed the country have brought searchings and drillings beneath the earth's surface for anything that will keep us warm. Recently there came to hand a report put out in 1930 by the State Education Department of fuel surveys and discoveries made in this state starting back in the 1800s — some right here in our own backyard. This led us to a little investigation. —A. B. G.

ever, we did find that gas detectors are made similar to the smoke detectors so many of us are installing in our homes today. It works in the same way — sounding an alarm if an accumulation of gas is building up. It sounds like a very worthwhile investment for anyone who knows that their well has a gas content.

Over Gifford's Corners way there used to be a small diner where they were able to use their own natural gas, found when they were drilling for water.

"This seems to be what happens. Few people in this area actually set out to search for gas. Those



In Dimock, PA three wells intersected a shallow gas zone (not the Marcellus)

They did not set intermediate casing over that zone which would have been required in NY

Gas migrated up behind the casing and got into the groundwater

Unrelated to fracking

Methane Migration – NE PA

- It is not related to fracking
- The gas comes from the aquifer itself or from shallow formations just below the aquifer, not the much deeper Marcellus
- Methane is a natural substance that can be naturally occurring in water wells – its presence does not necessarily indicate a problem with drilling
- If there is a significant increase in methane concentrations during and just after drilling, it could be a problem with drilling or casing
- Improved drilling and cementing practices and close regulation can minimize this problem

Methane contamination of drinking water possibly accompanying ~~gas~~ well drilling ~~and hydraulic fracturing~~

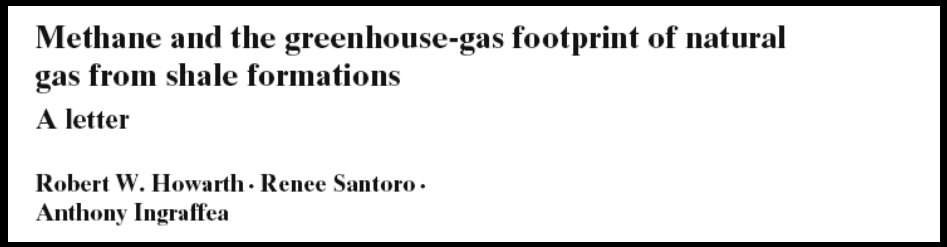
Stephen G. Osborn[a], Avner Vengosh[b], Nathaniel R. Warner[b], and Robert B. Jackson[a,b,c1]

[a]Center on Global Change, Nicholas School of the Environment, [b]Division of Earth and Ocean Sciences, Nicholas School of the Environment, and [c]Biology Department, Duke University, Durham, NC 27708

Edited* by William H. Schlesinger, Cary Institute of Ecosystem Studies, Millbrook, NY, and approved April 14, 2011 (received for review January 13, 2011)

- This group from Duke came on to the scene and with little background information or understanding of the geology pronounced that methane levels were 17 times greater in areas where gas drilling was occurring than in areas where gas drilling was not occurring and then implied that this was due to fracking
- It is a very poorly done study with many flaws
- If they had talked to the local regulators for ten minutes they would never have written this paper

Greenhouse Gas Emissions



Methane and the greenhouse-gas footprint of natural gas from shale formations

A letter

Robert W. Howarth · Renee Santoro · Anthony Ingraffea

The New York Times — Business Day — Energy & Environment

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINIO

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Studies Say Natural Gas Has Its Own Environmental Problems

By TOM ZELLER Jr.
Published: April 11, 2011

Natural gas, with its reputation as a linchpin in the effort to wean the nation off dirtier fossil fuels and reduce global warming, may not be as clean over all as its proponents say.

RECOMMEND
TWITTER
E-MAIL

- Howarth et al. from Cornell University published a study that received a lot of media attention that suggested that shale gas has greenhouse gas emissions equal to or greater than coal, largely due to methane emissions
- The lead author is a biologist and anti-fracking activist who does not appear to have much knowledge of gas and coal industry practices which led to some significant errors including:
  - An unrealistic assumption about how much gas was lost during drilling and completion (it would have been about $1 million worth per well but he stated that it was only worth $75)
  - Did not know that most gas that is lost is flared and released as CO_2 not methane
  - Did not realize that most gas lost in pipelines is from extracting non-methane and also using methane to run compressors (which release CO_2 not methane)

GHG Emissions

- Subsequent studies by more knowledgeable groups at NETL, Carnegie Mellon, University of Maryland, and several others all find that on a life-cycle basis shale gas emits about 55% of the GHGs that coal does per unit of energy created
- This is very important, because the policy implication of Howarth et al.'s work would be to keep burning coal instead of switching to much cleaner burning gas (for GHG's as well as mercury, particulates, etc.)

A Broader Point

- Many people writing news articles and some academics writing papers on shale gas have little or no knowledge of how gas wells are drilled, completed, hydraulically fractured, or subsurface geology and other important background information
- Most of the people who do know something about these topics are either in the industry or regulators of the industry (like the DEC) with a few in academia and it is very easy to make mistaken interpretations without this knowledge
- These are complex topics that require time and an interest in science and engineering to understand – this makes fertile ground for misinformation to grow

Conclusions

- Shale gas is a game changer for US and global energy future
- It is enabling a shift from coal to cleaner-burning natural gas and causing the price of gas to move substantially lower
- There is high potential for the Marcellus Shale to produce large quantities of gas in NY
- Some misinformation has worked its way into this issue – there are real problems but much focus has been on issues that aren't significant problems