The Marcellus and Utica Shales: Geologic Considerations

Presentation for Marcelllus Summit, 2011

By

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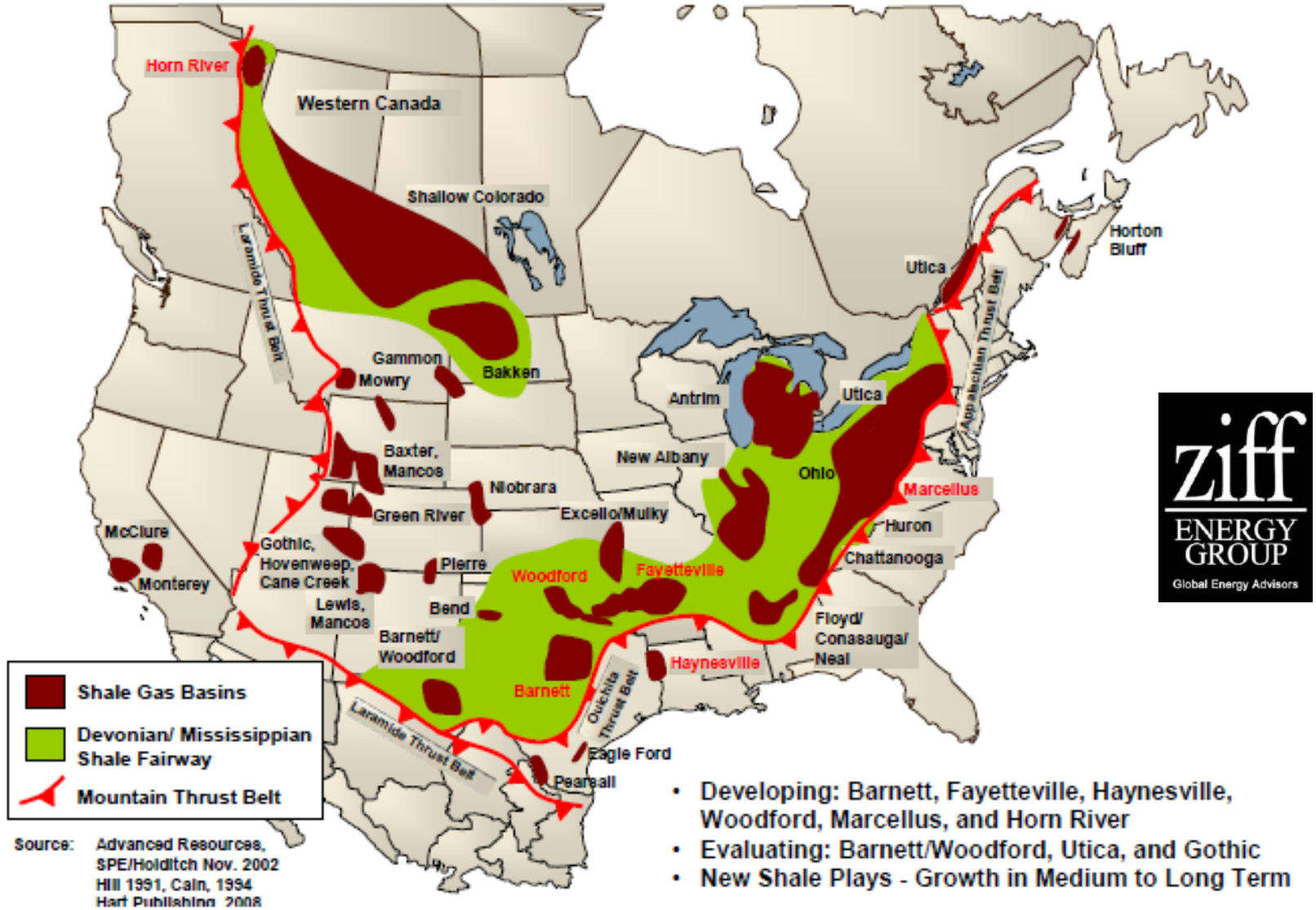
Marcellus Center for Outreach and Research

Pennsylvania State University

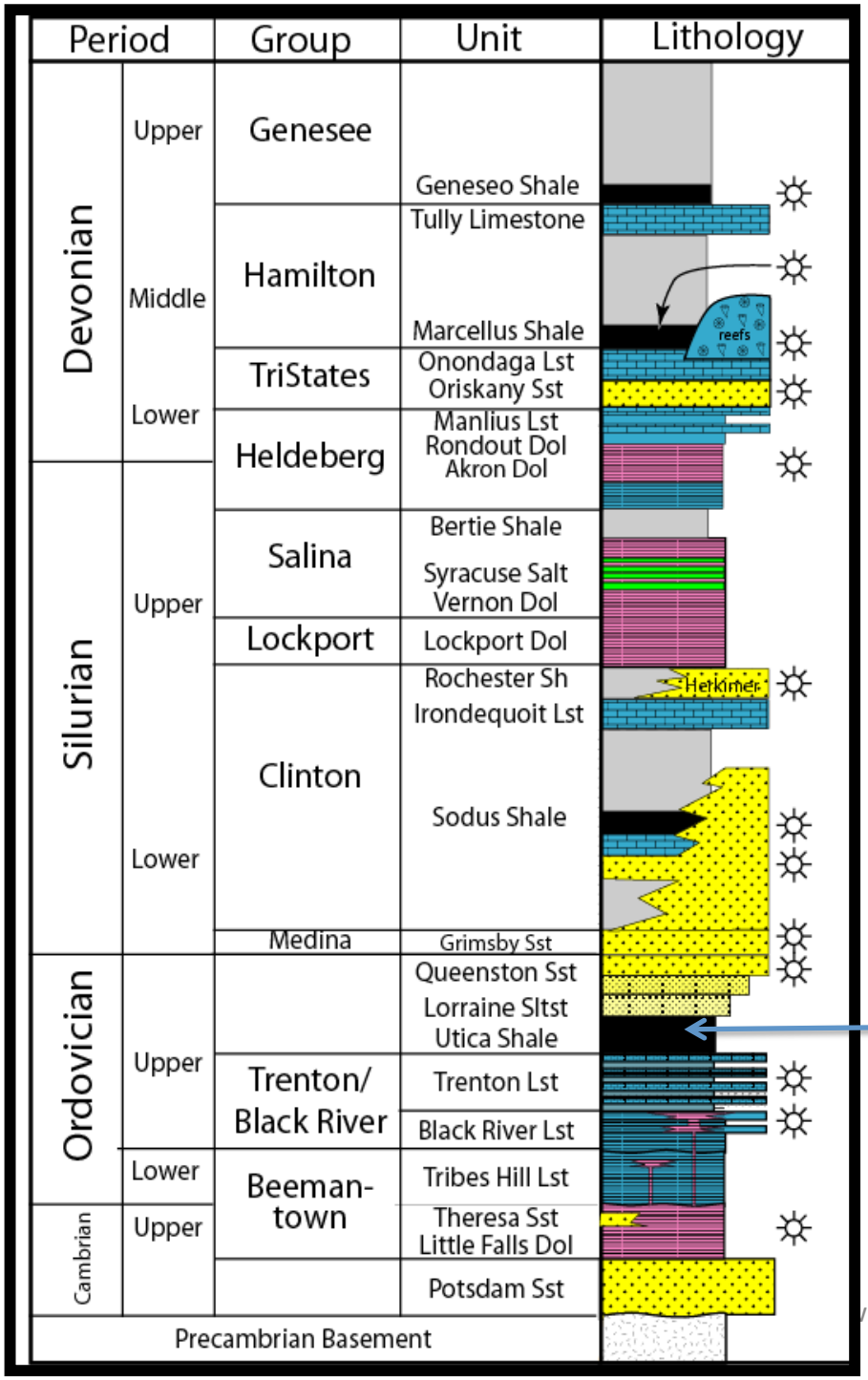
North American Shale Gas Plays



Source: Advanced Resources, SPE/Holditch Nov. 2002 Hill 1991, Cain, 1994 Hart Publishing, 2008

- Developing: Barnett, Fayetteville, Haynesville, Woodford, Marcellus, and Horn River
- Evaluating: Barnett/Woodford, Utica, and Gothic
- New Shale Plays - Growth in Medium to Long Term

ziff ENERGY GROUP
Global Energy Advisors



Acadian 2

Acadian 1

?

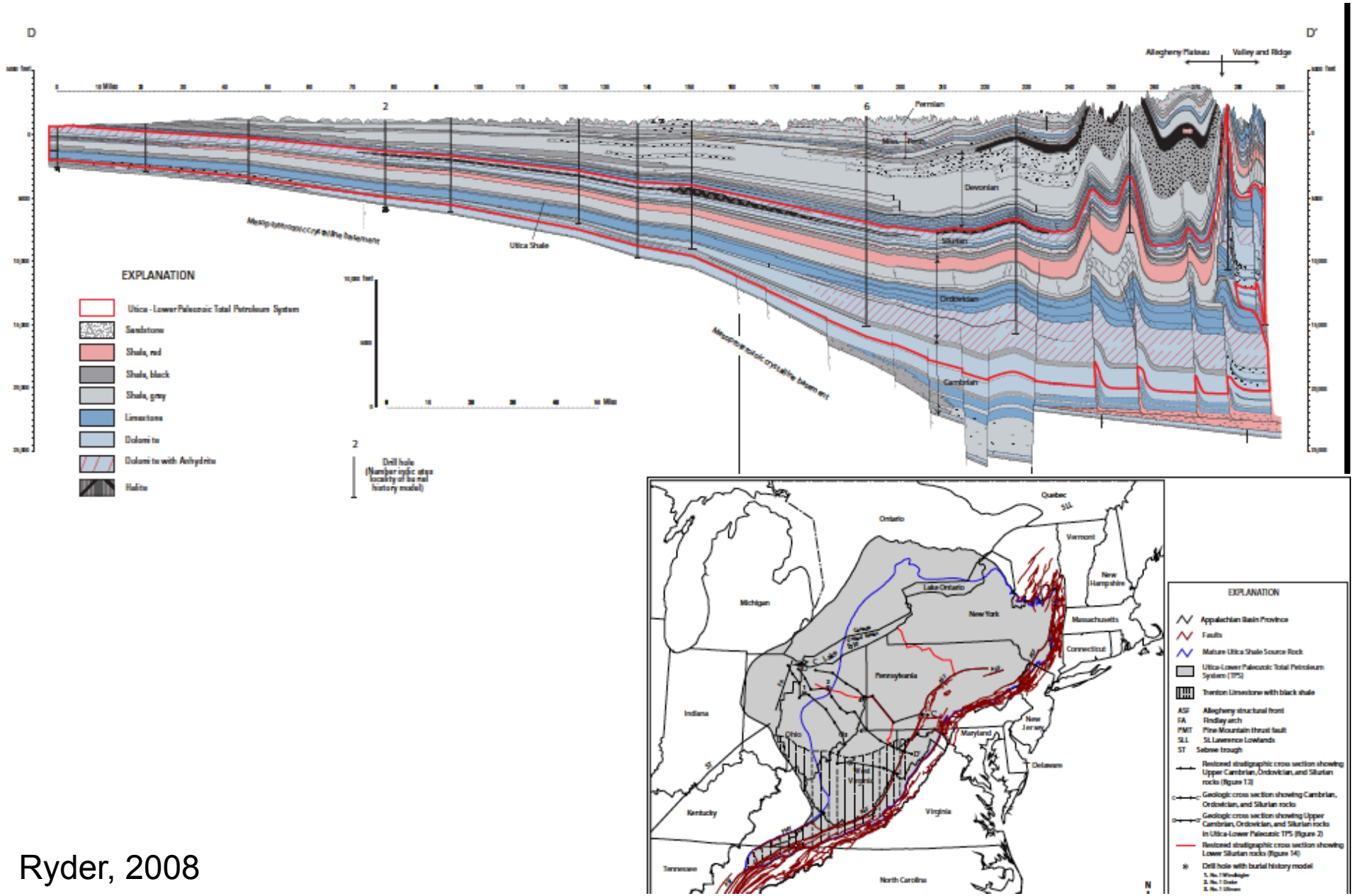
Taconic 1

Tectonic Events with Mountain Building & Basin Subsidence

Other Potential Major Targets

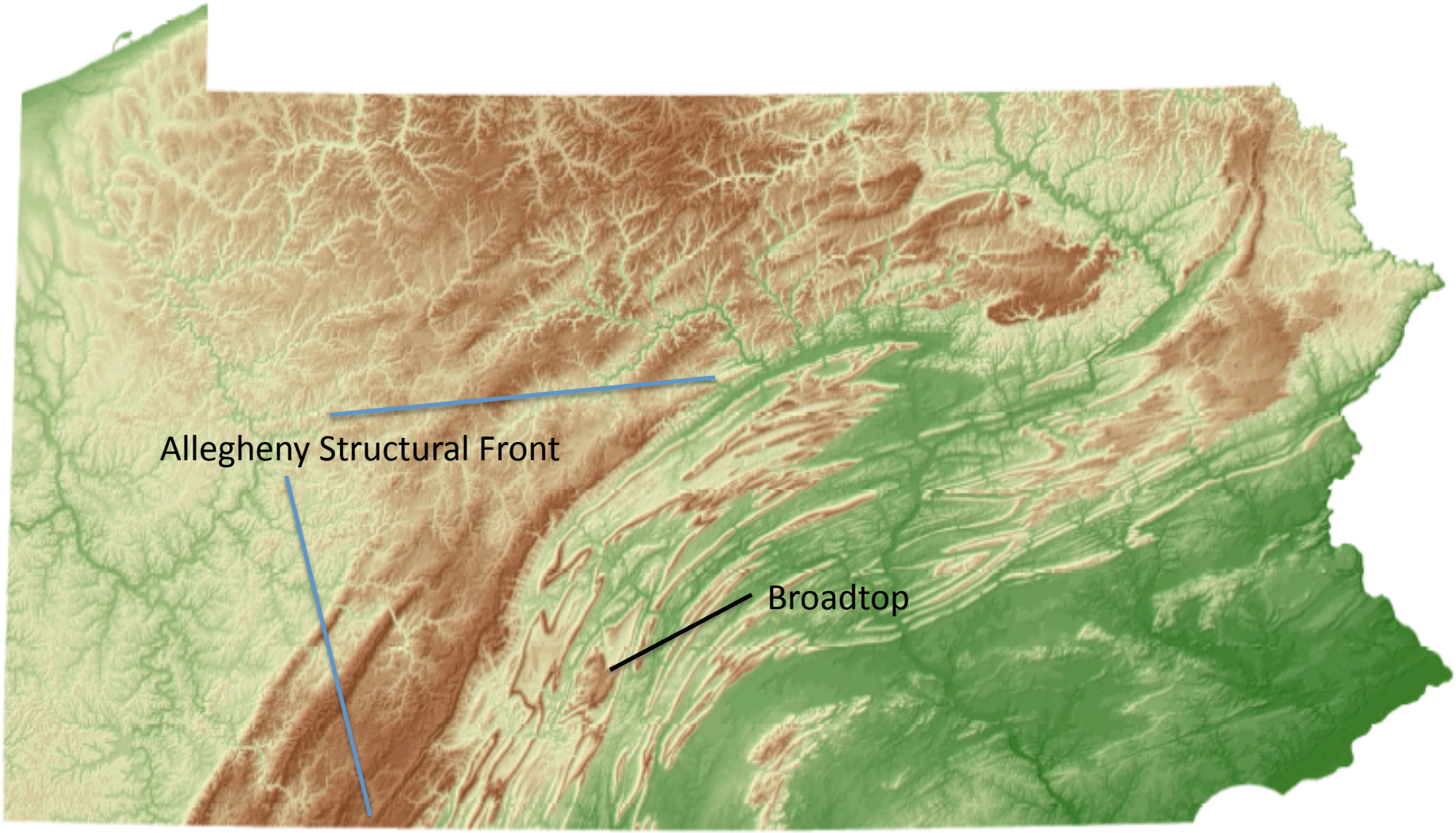
The Ordovician Utica Shale—Greater than 2000 feet deeper than Marcellus Shale, but with the same general distribution.

Geologic Cross Section



Ryder, 2008

Topography of PA



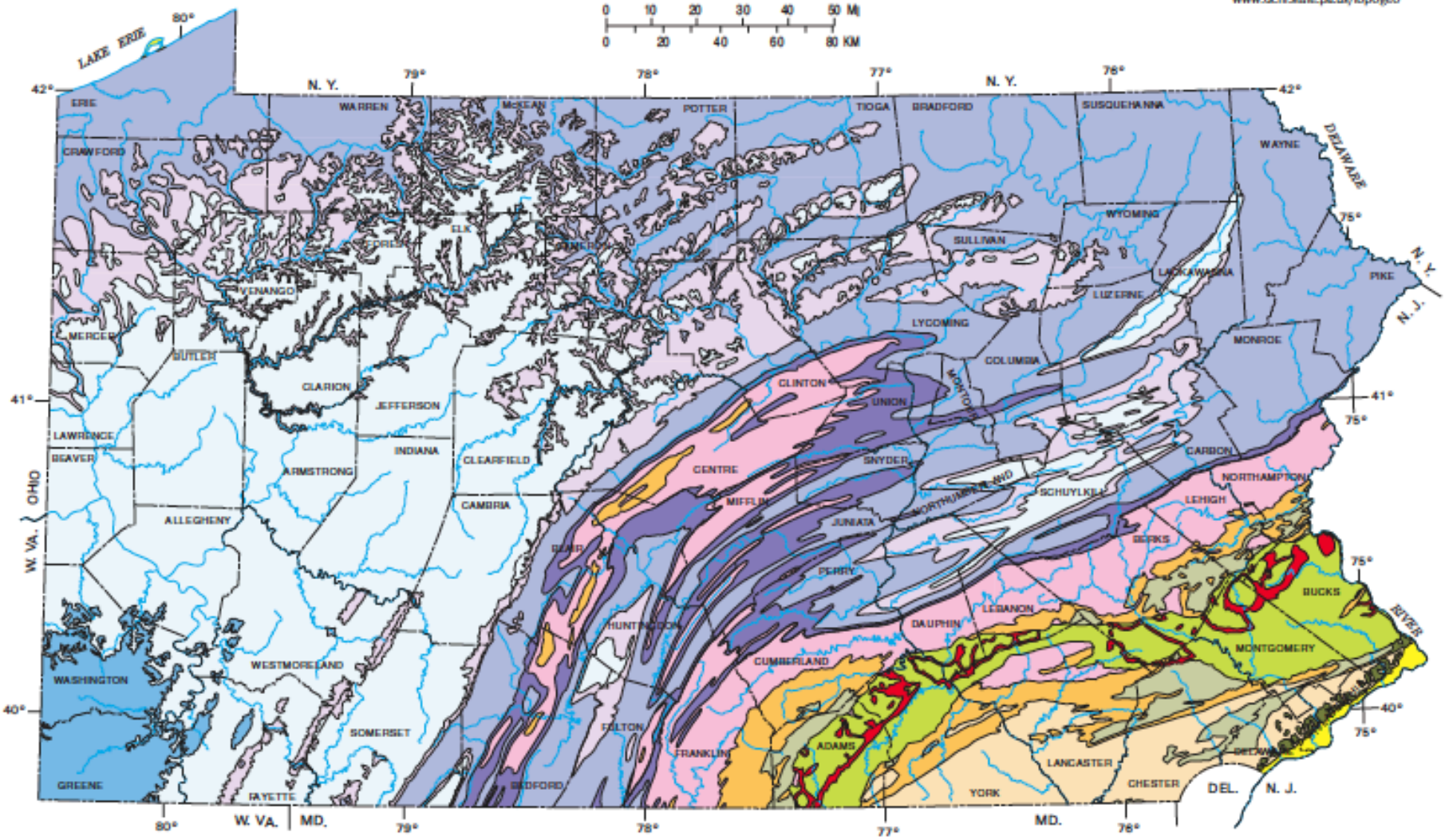
MAP 7

GEOLOGIC MAP OF PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF
CONSERVATION AND NATURAL RESOURCES
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
www.dcnr.state.pa.us/topogeo

SCALE 1:2,000,000

0 10 20 30 40 50 MI
0 20 40 60 80 KM



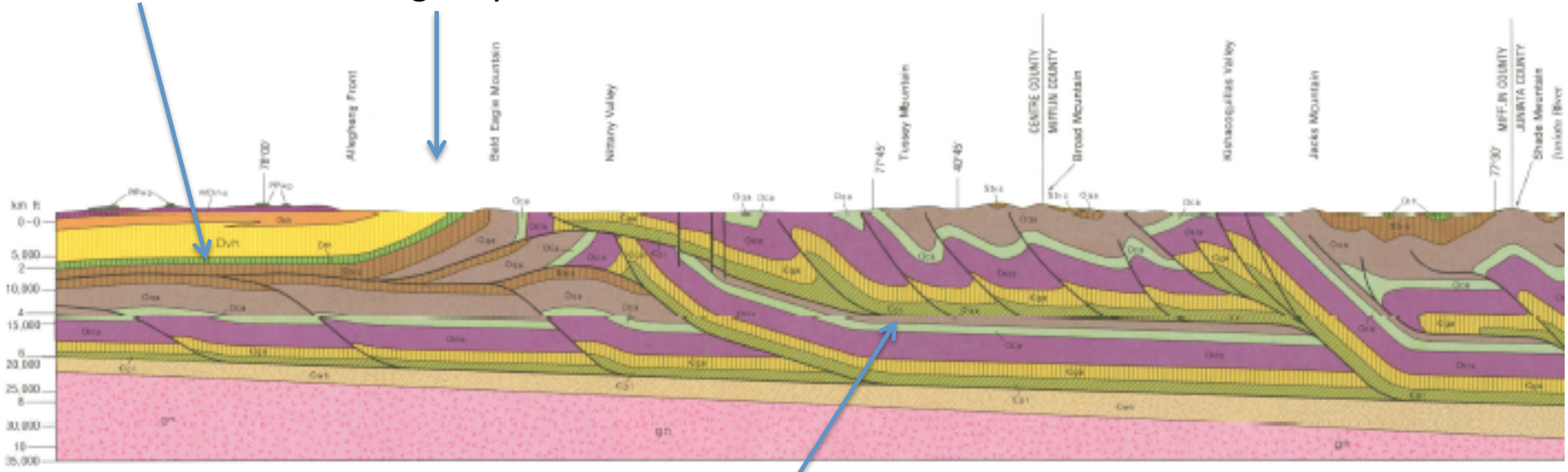
EXPLANATION

QUATERNARY (0–1.8 mil. yrs.) Sand, gravel, and silt. Sand and gravel.	TERTIARY (1.8–65 mil. yrs.) Sand, gravel, silt, and clay. Sand and gravel.	* JURASSIC AND TRIASSIC (144–248 mil. yrs.) Red sandstone, shale, and conglomerate (green), intruded by diabase (red). Building stone, iron.	PERMIAN (248–290 mil. yrs.) Cyclic sequences of shale, sandstone, limestone, and coal. Lime, clay.	PENNSYLVANIAN (290–323 mil. yrs.) Cyclic sequences of sandstone, red and gray shale, conglomerate, clay, coal, and limestone. Coal, clay, lime, building stone.	MISSISSIPPIAN (323–354 mil. yrs.) Red and gray sandstone, shale, and limestone. Flagstone, limestone, clay.	DEVONIAN (354–417 mil. yrs.) Red sandstone, gray shale, black shale, limestone, and chert. Flagstone, silica sand, clay, lime.	SILURIAN (417–443 mil. yrs.) Red and gray sandstone, conglomerate, shale, and limestone. Lime, building stone.	ORDOVICIAN (443–490 mil. yrs.) Shale, limestone, dolomite, and sandstone. Slate, limestone, zinc, clay.	CAMBRIAN (490–570 mil. yrs.) Limestone, dolomite, sandstone, shale, quartzite, and phyllite. Lime, building stone.	LOWER PALEOZOIC (443–570 mil. yrs.) Metamorphic rocks (metasedimentary and meta-igneous): schist, gneiss, quartzite, serpentine, slate, and marble. Building stone, talc.	PRECAMBRIAN (older than 570 mil. yrs.) Gneiss, granite, anorthosite, metadiabase, metabasalt, metarhyolite, and marble. Building stone, graphite, sericite.

Geologic Cross Section
Mifflin through Centre County

Marcellus Shale

Allegheny Front

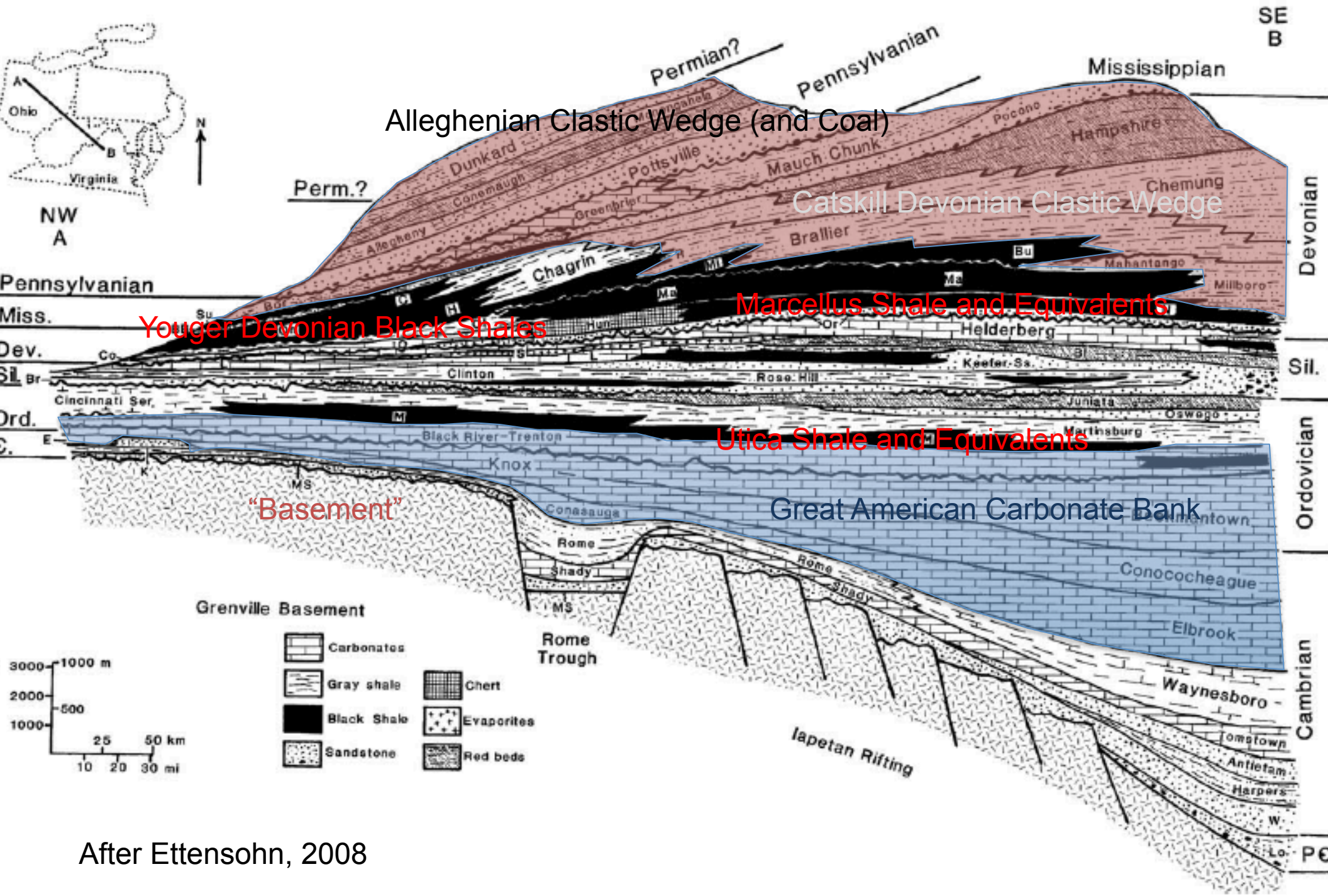


NW

SE

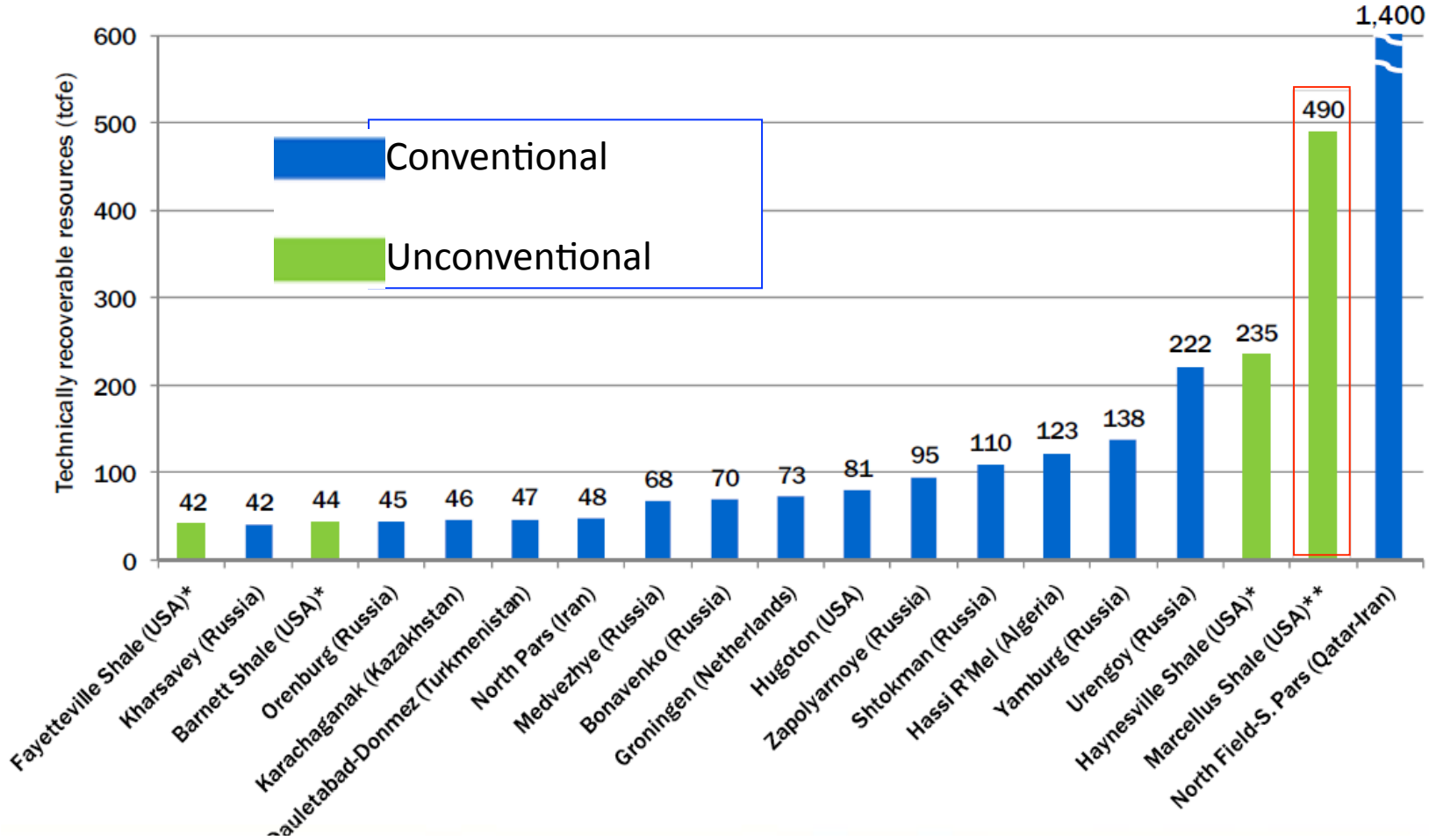
Utica Shale

Based on Berg et al. 1980; PA map



After Ettensohn, 2008

The Marcellus Shale—World Class!



*U.S. Department of Energy (April 2009): Modern Shale Gas Development in the United States: A Primer, p. 17

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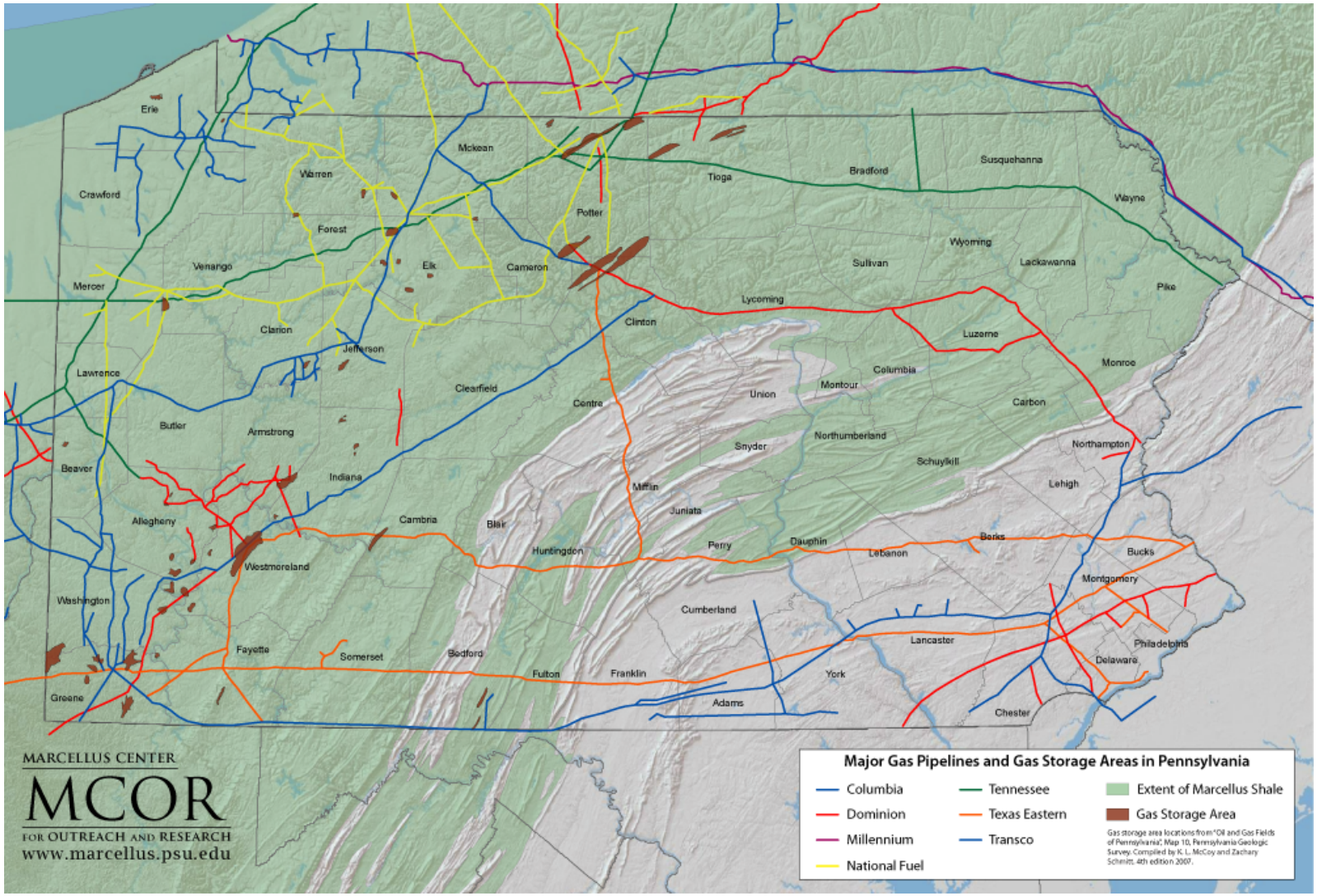
Interstate Pipeline and Storage



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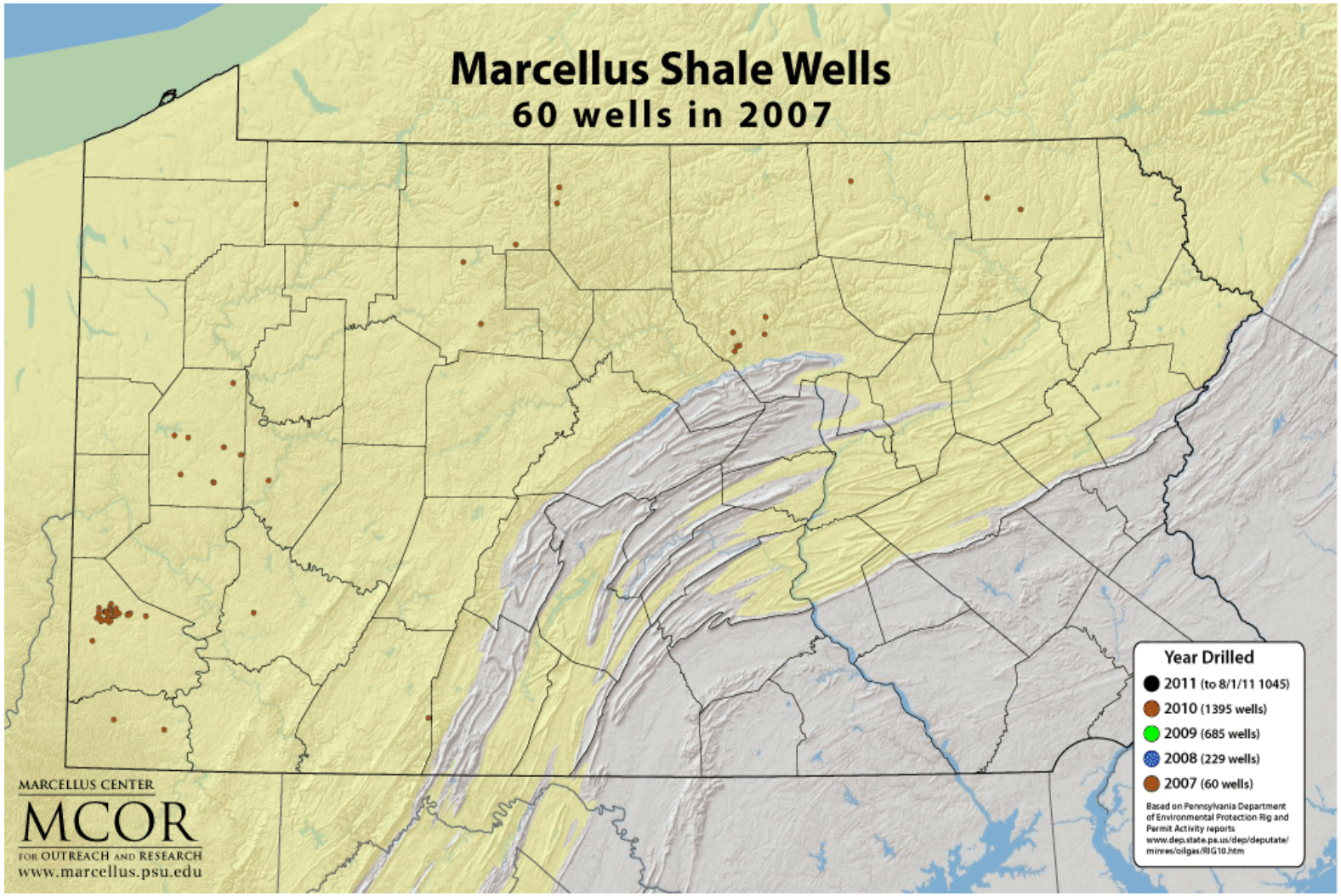
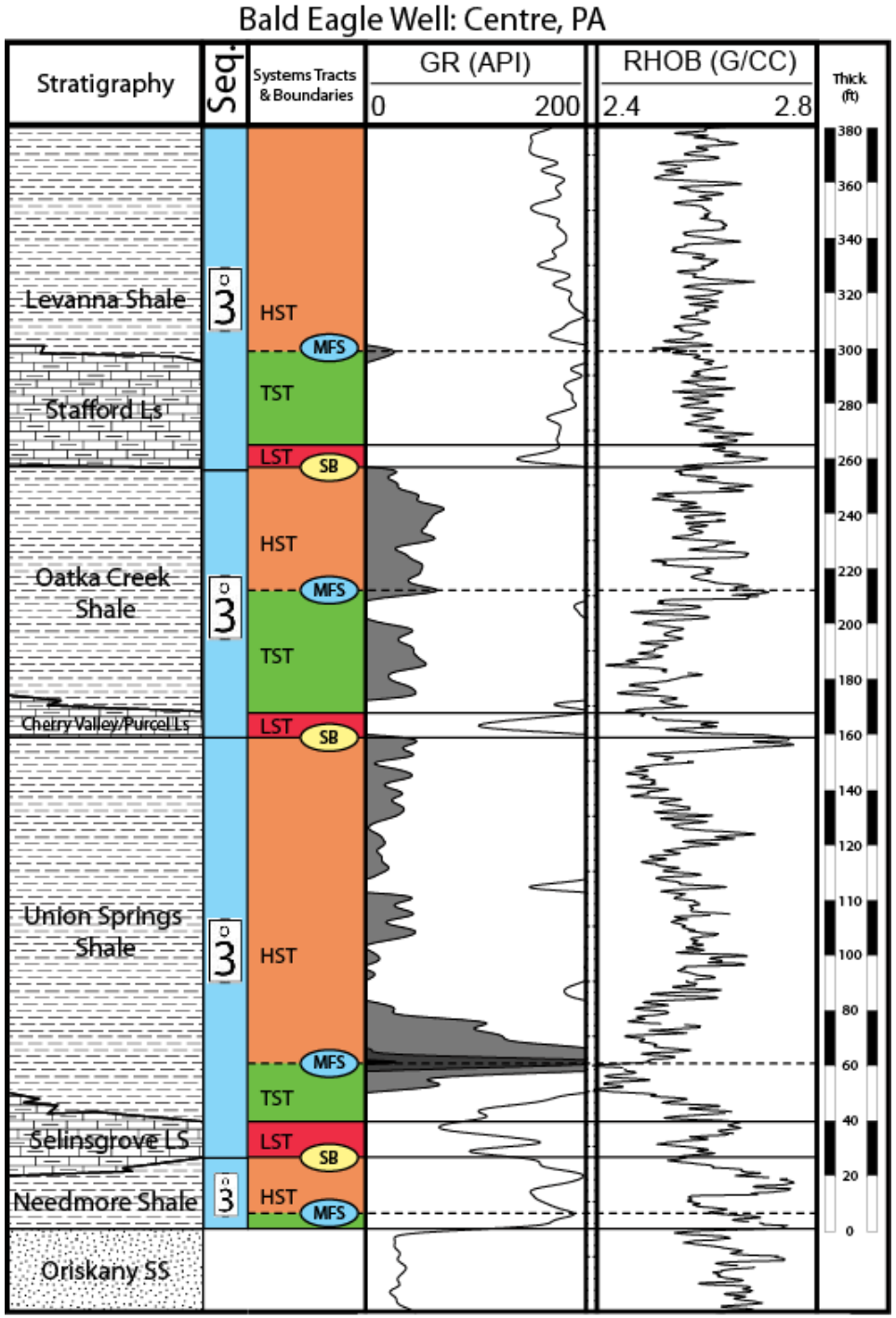
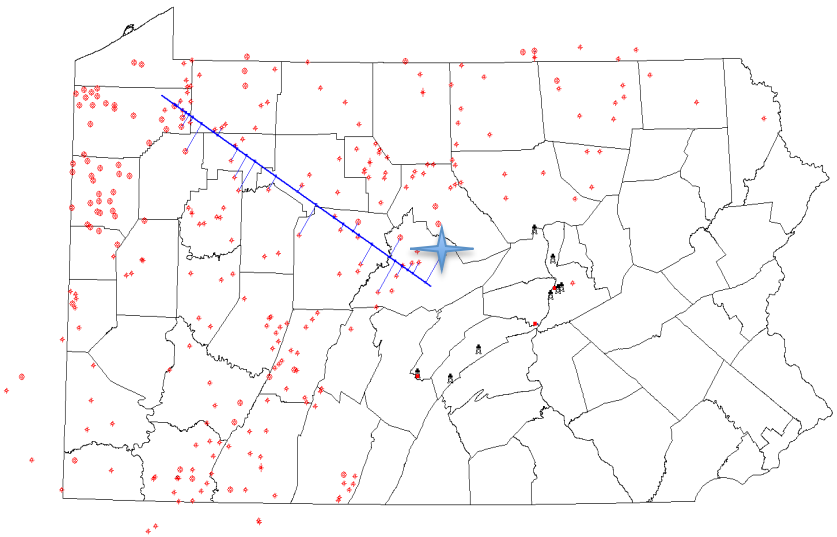
Marcellus Wells Drilled



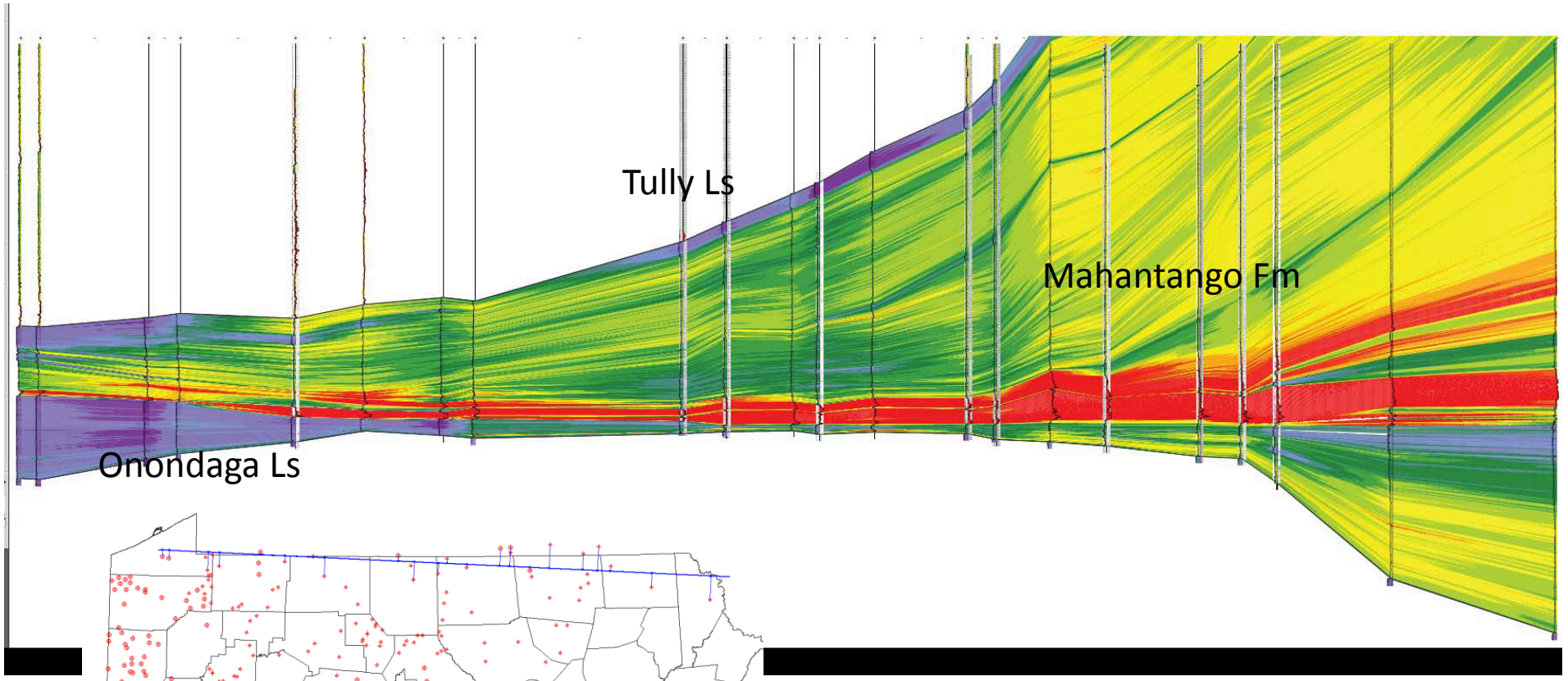


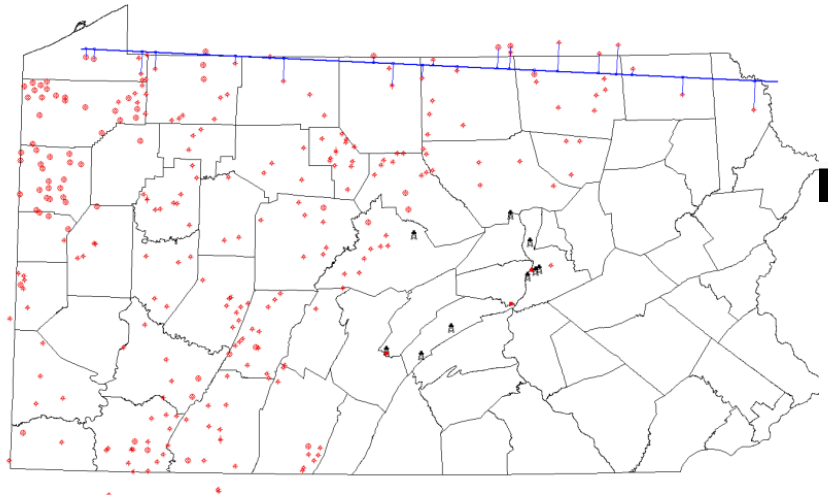
Geophysical Logs for Lower Hamilton Group, Central PA



PSU ABBS Group, 2011

Middle Devonian Hamilton Group "Clinothem"

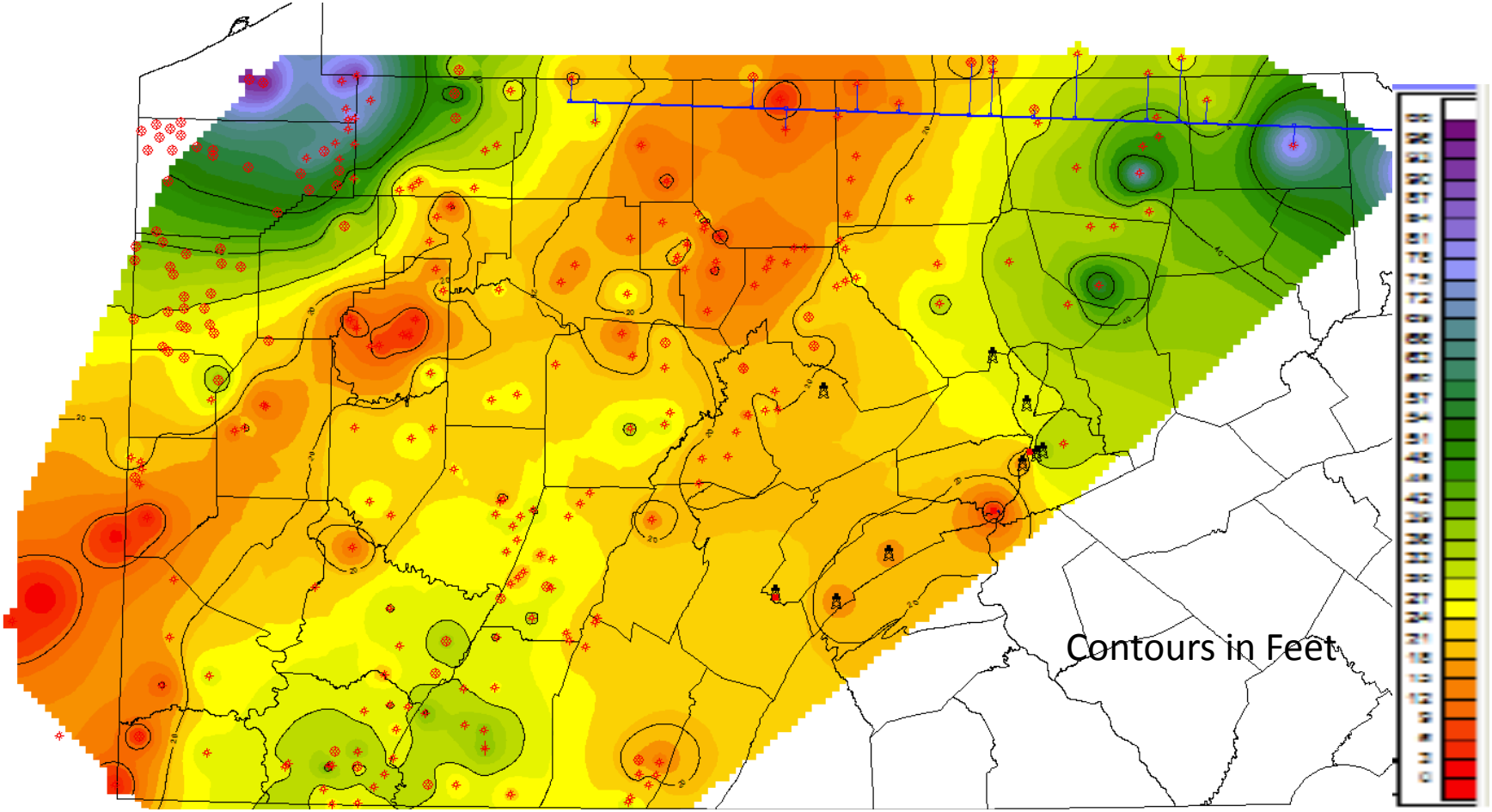




Marcellus and related Black Shales
red (high gamma)

PSU ABBS Group, 2011

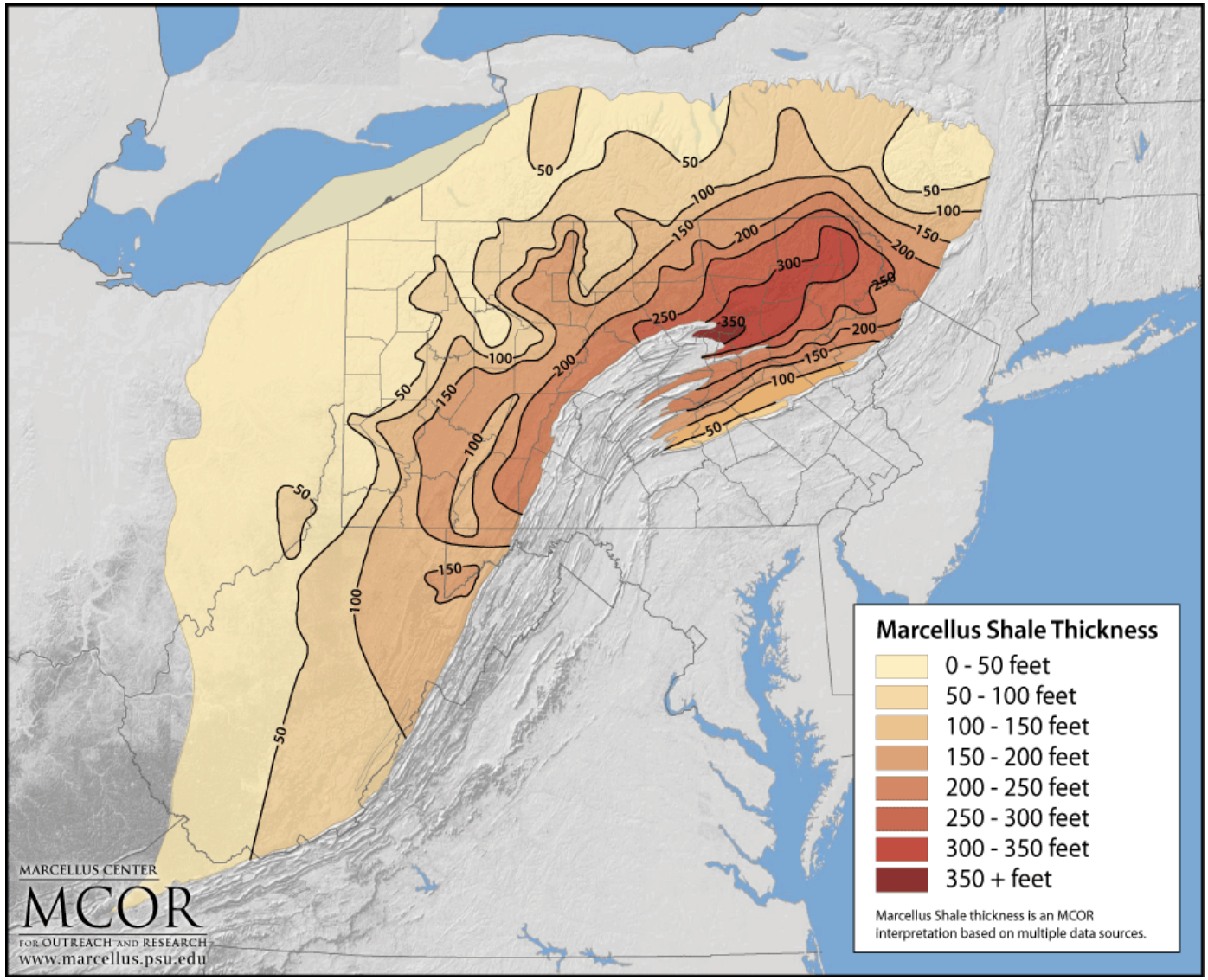
Isopach of lower Union Springs Fm



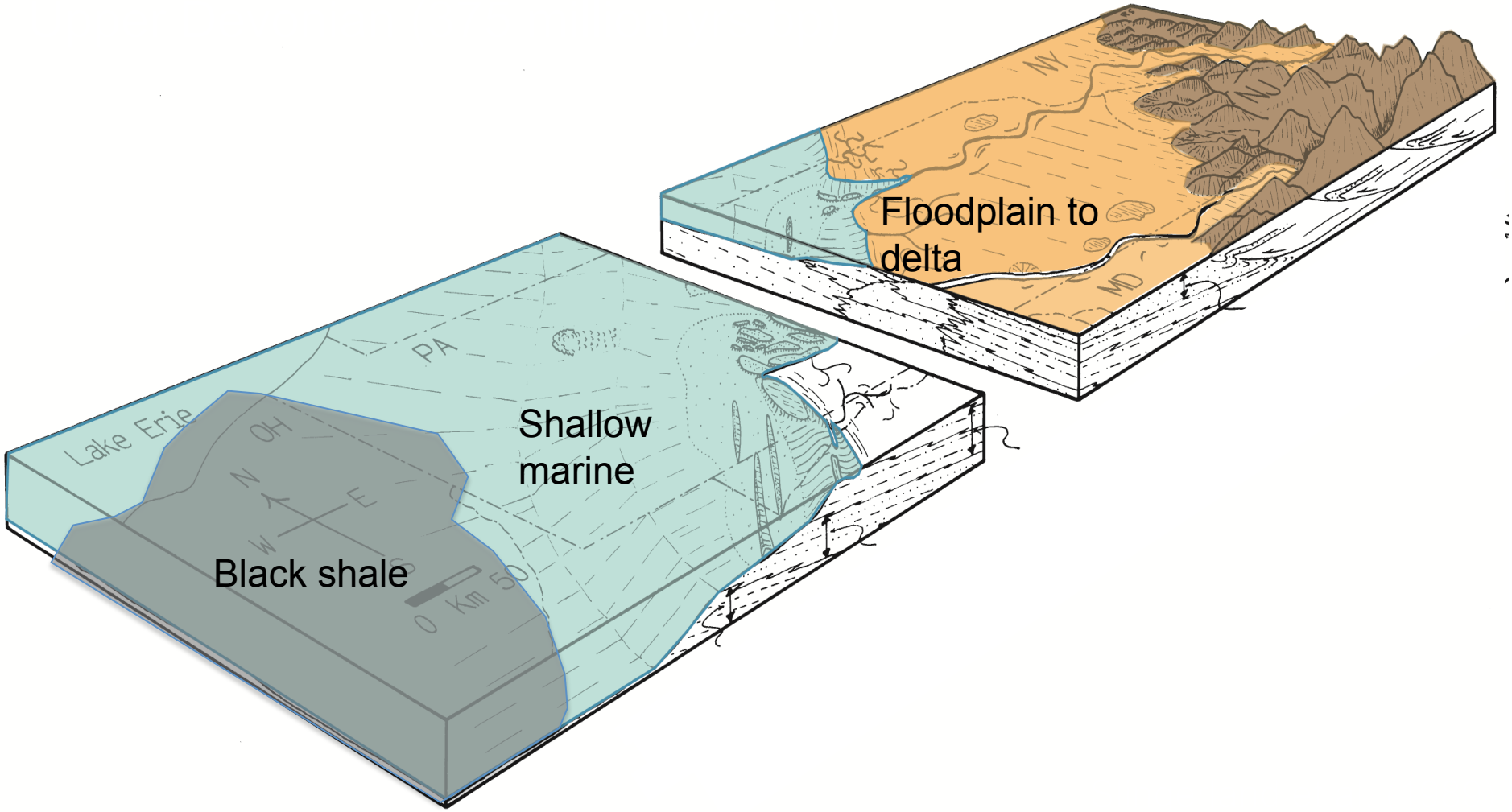
Hamilton Transgressive System Tract 1

PSU ABBS Group, 2011

Generalized Thickness Marcellus Shale



The Middle to Late Devonian Paleogeography in PA/Ohio



Slingerland et al. 2009

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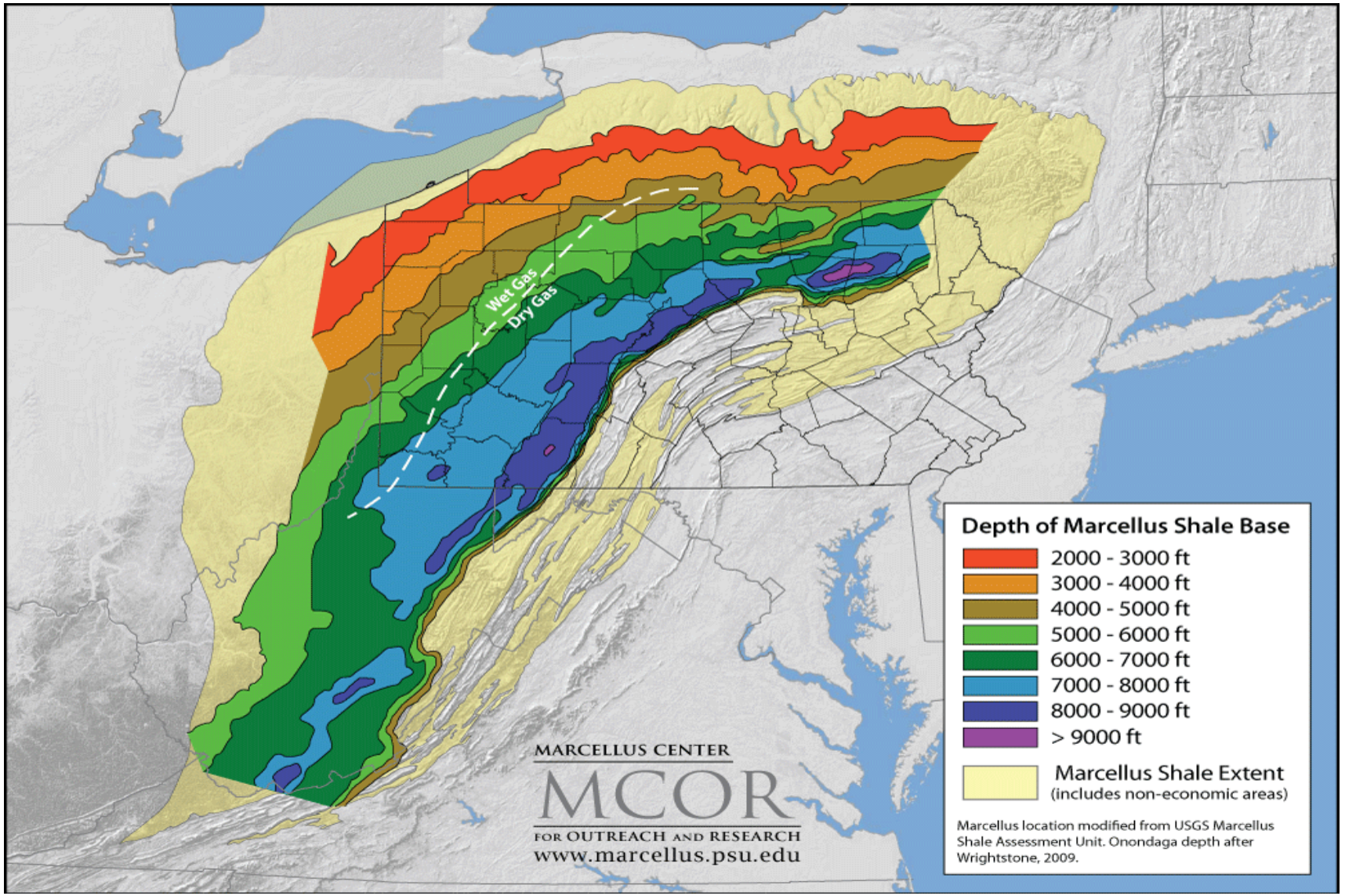
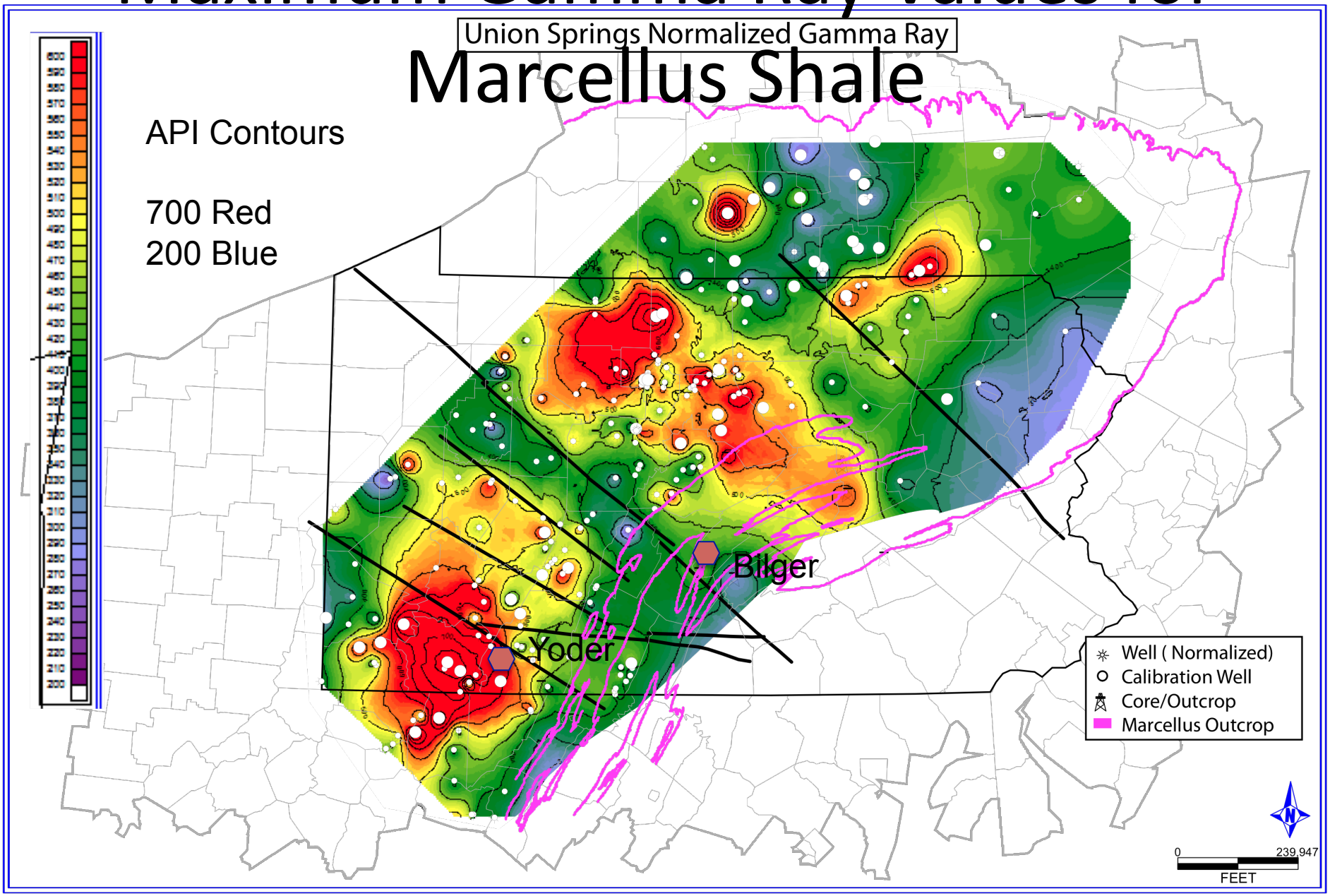
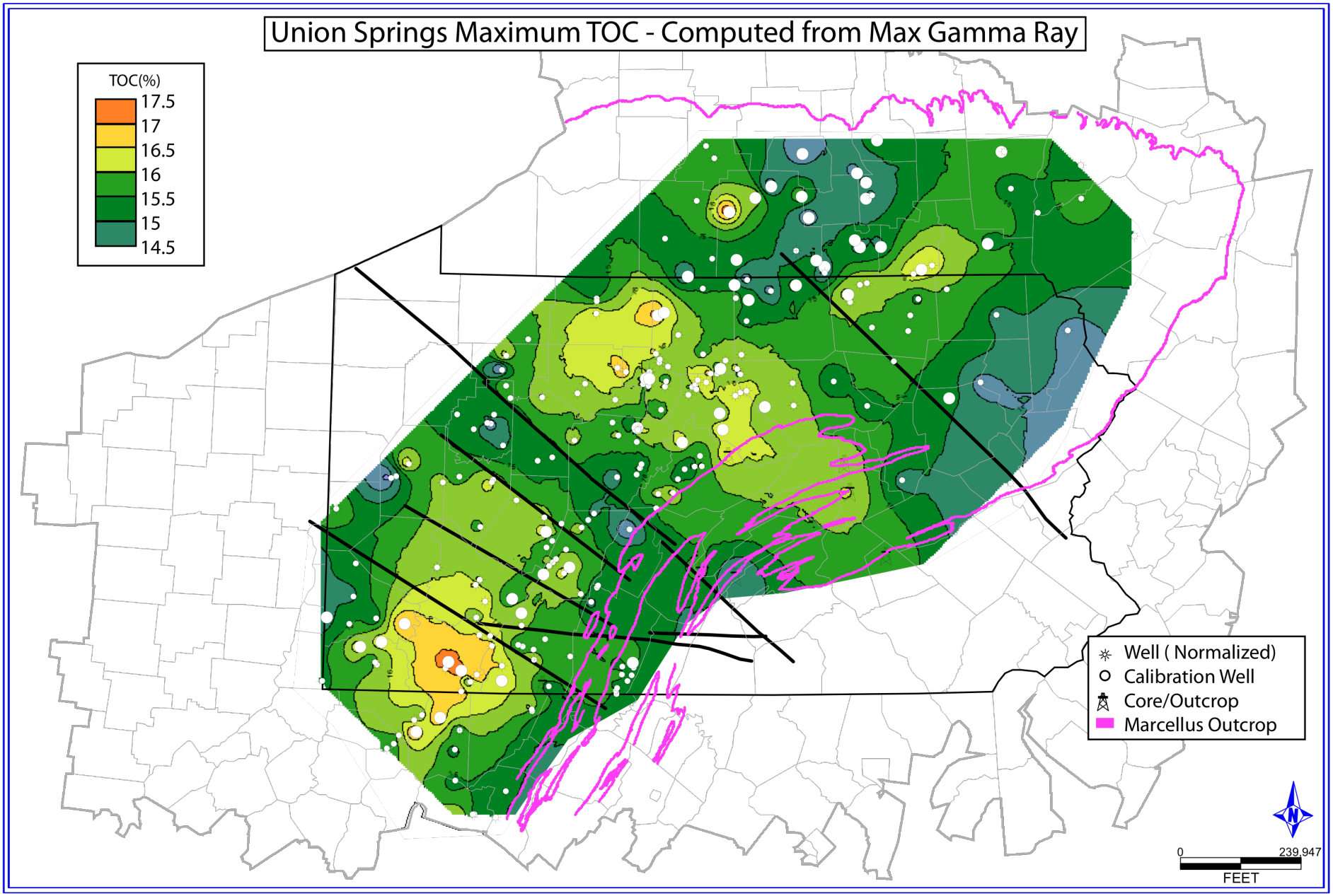
Depth to Marcellus Shale & Wet/Dry Gas Zones



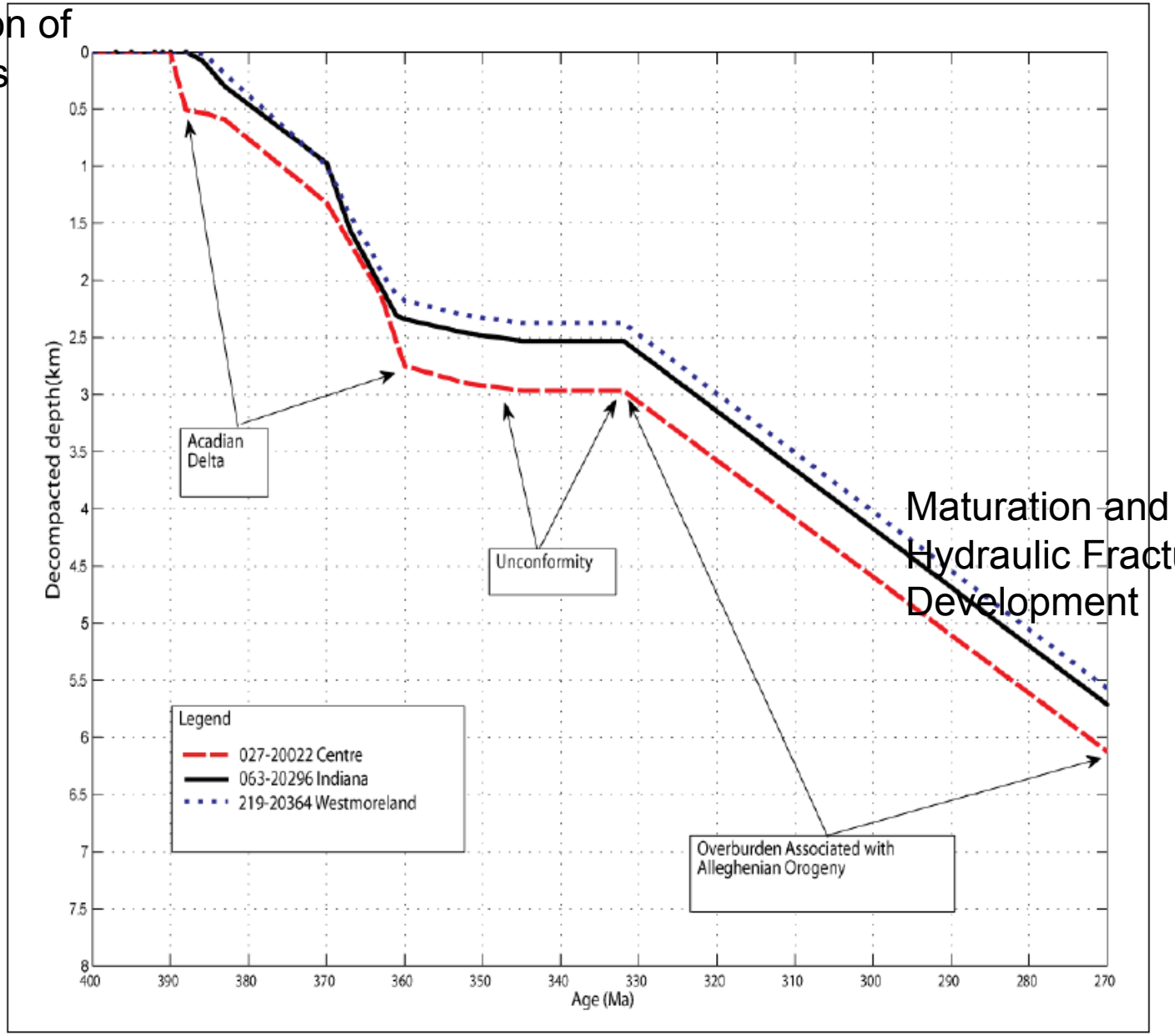
Maximum Gamma Ray Values for



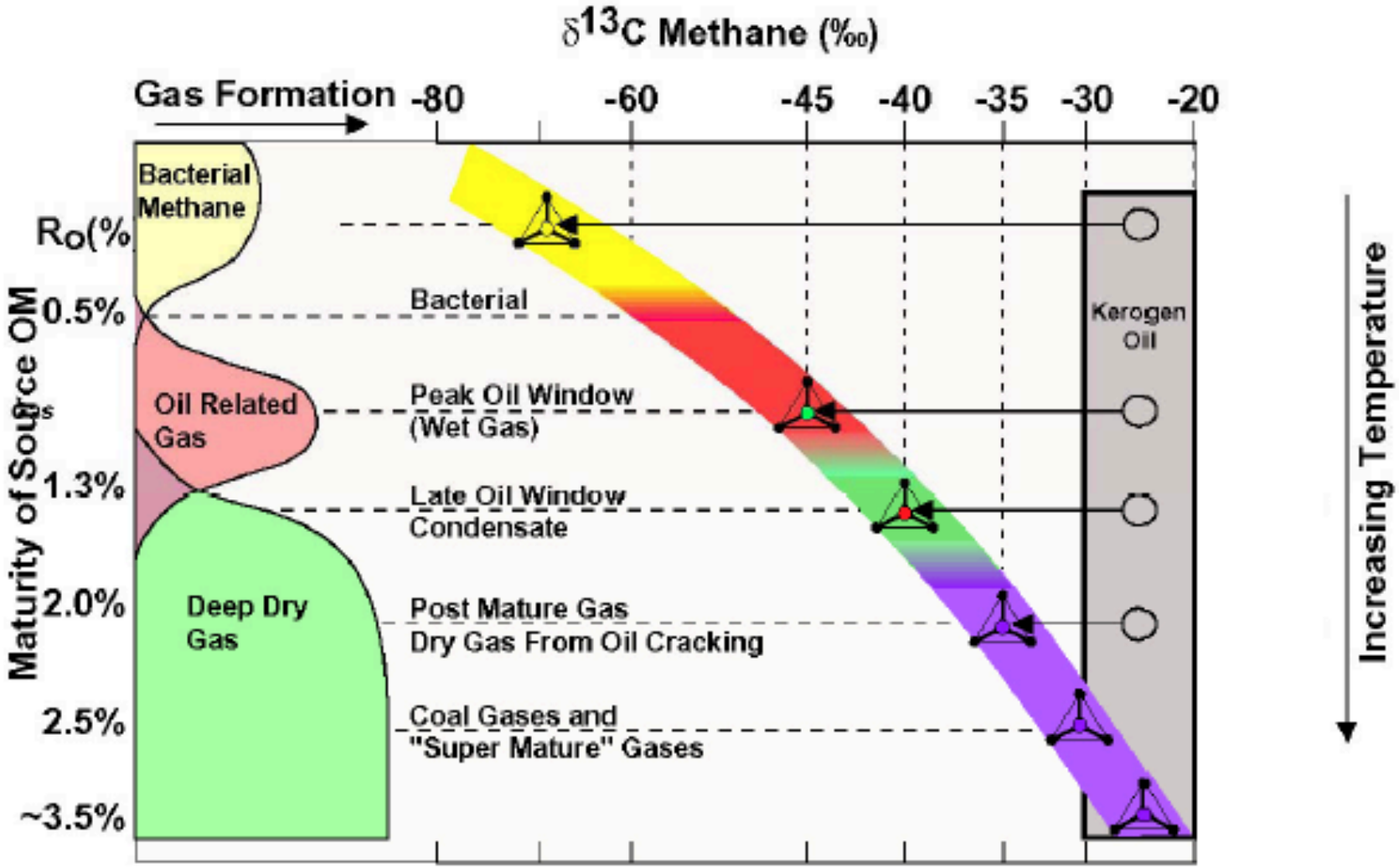

Union Springs Maximum TOC - Computed from Max Gamma Ray
TOC(%)
17.5
17
16.5
16
15.5
15
14.5
Well (Normalized)
Calibration Well
Core/Outcrop
Marcellus Outcrop
N
0
239,947
FEET

Marcellus Shale Burial History

Deposition of Marcellus



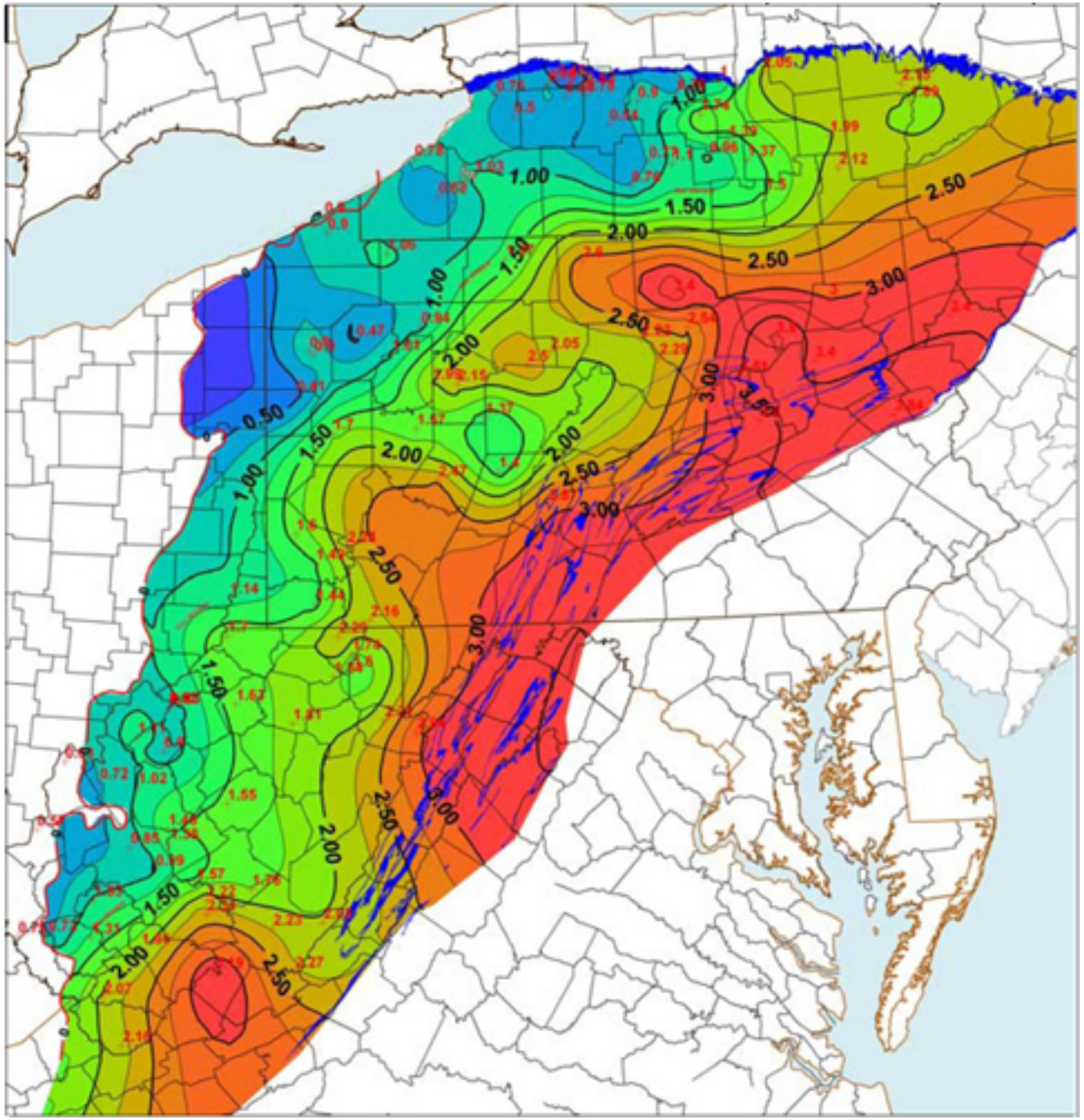
Maturation and Natural Hydraulic Fracture Development



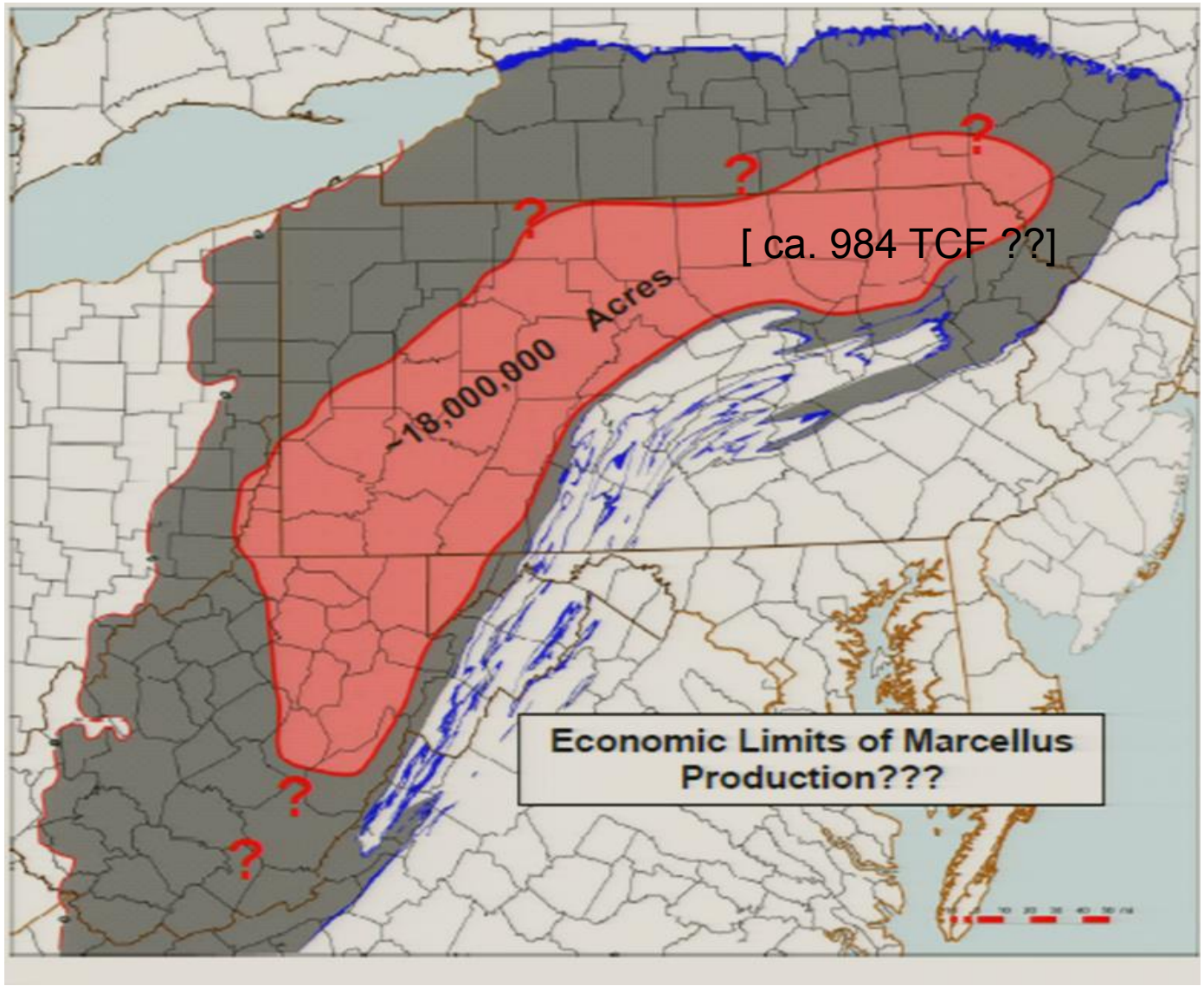
Tracing sources of methane through carbon (and hydrogen) isotope values

Vitrinite Reflectance Marcellus Shale

Wrightstone, 2008



The Marcellus “Fairway”



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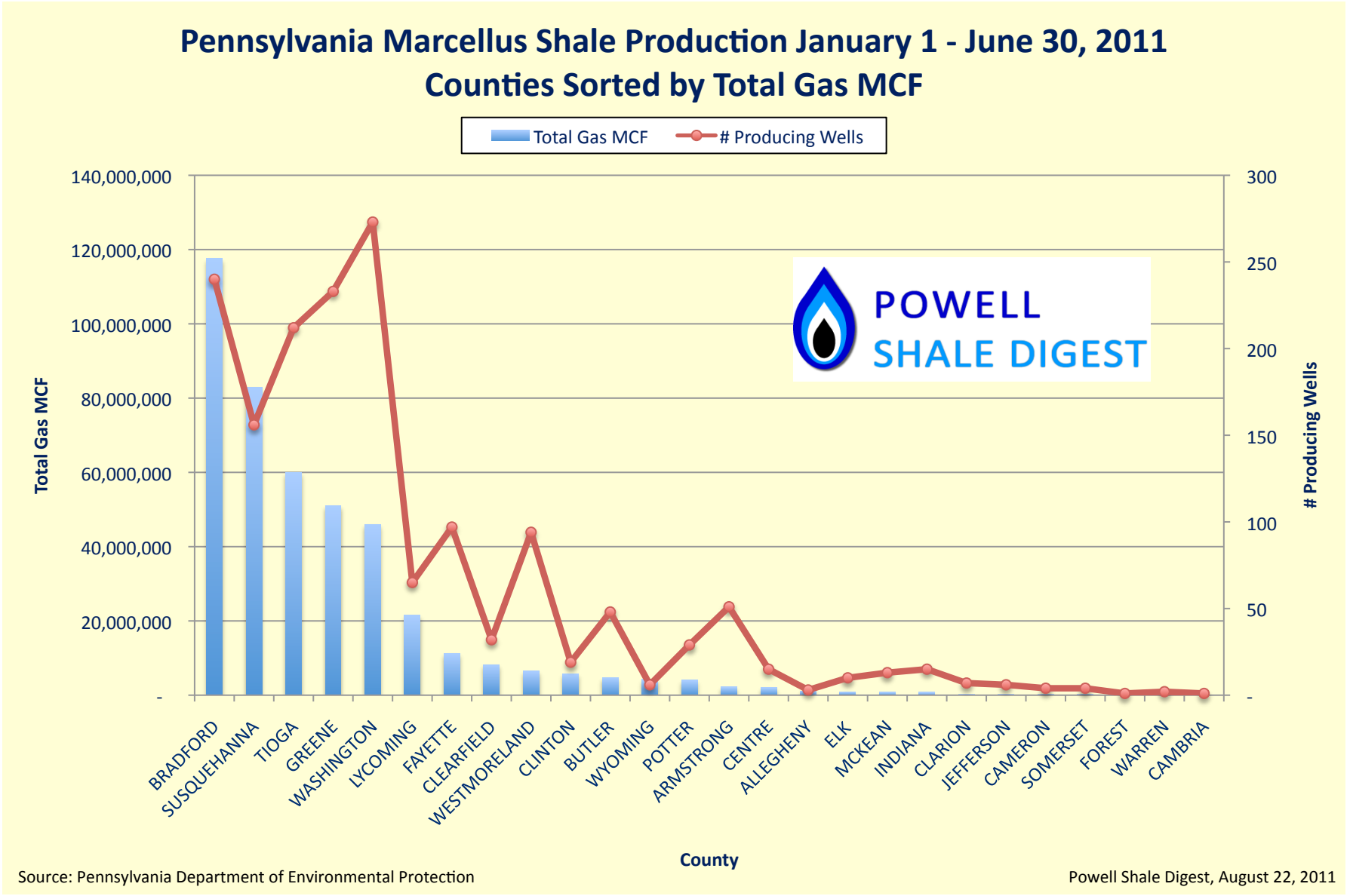
Marcellus Production in PA



Source: Pennsylvania Department of Environmental Protection

Powell Shale Digest, August 22, 2011

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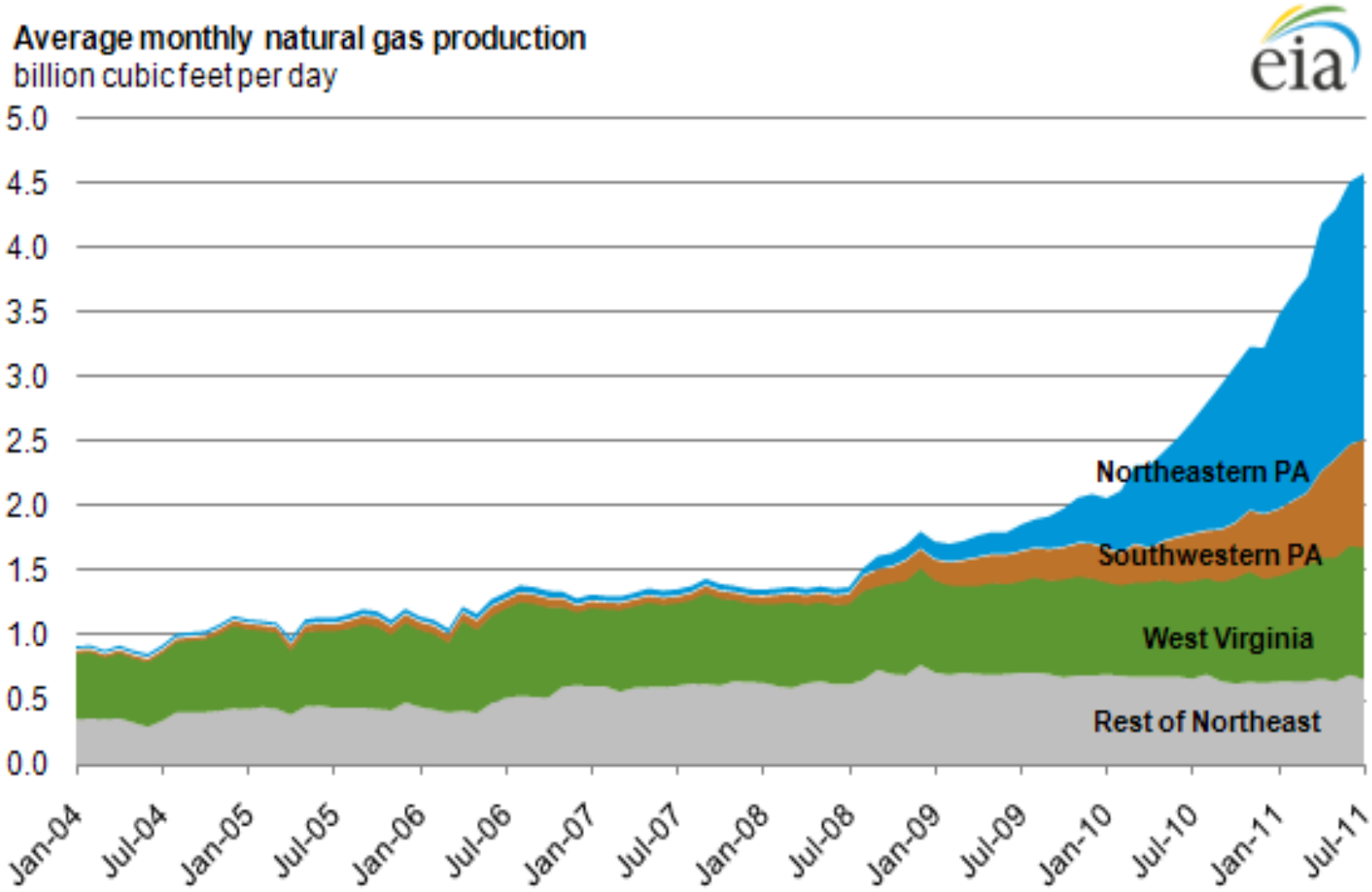
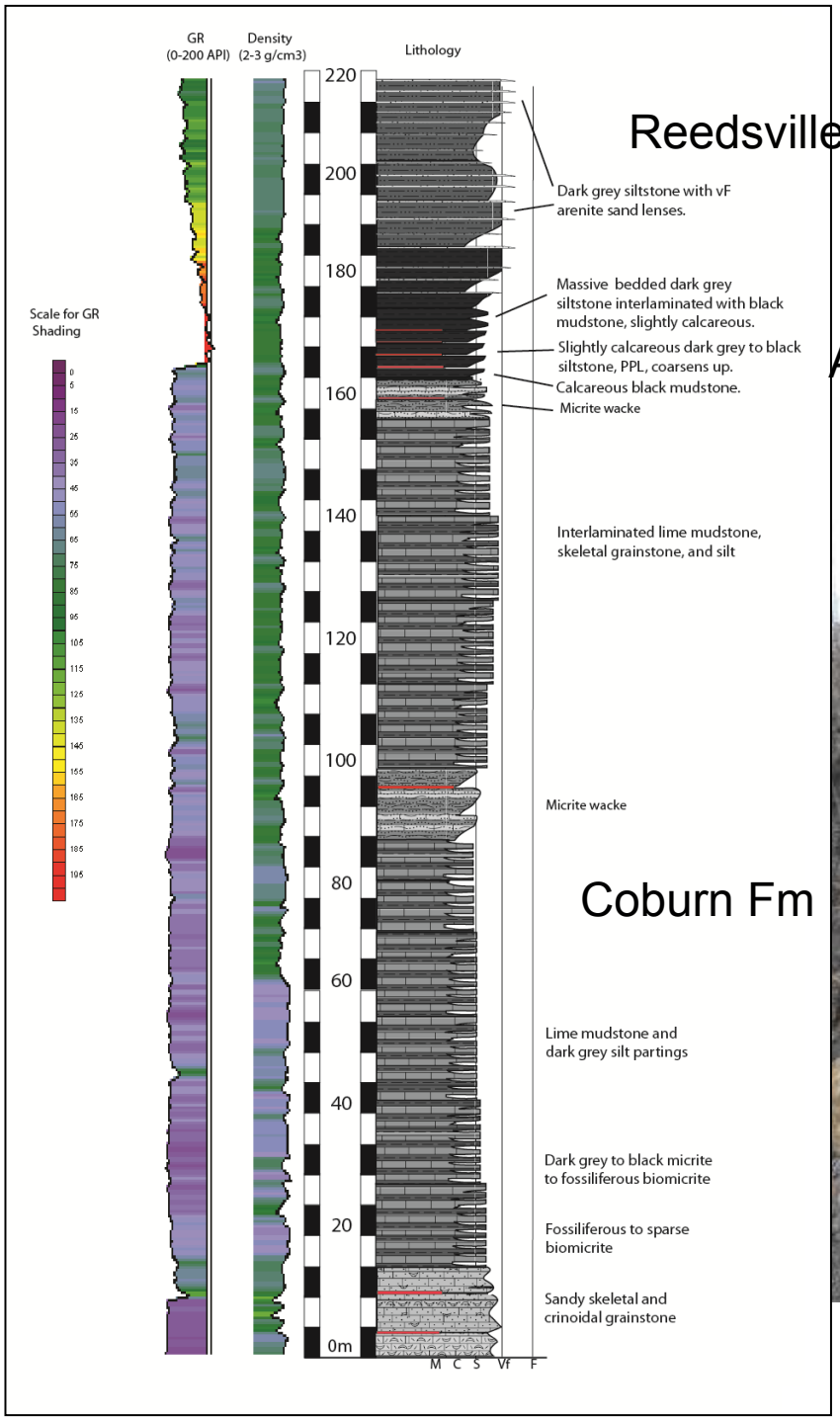
PA Production



Source: U.S. Energy Information Administration based on Bentek Energy, LLC.
Note: Rest of Northeast includes KY, MD, NY, OH, TN, VA.

“Utica Shale” in Central PA



Taylor McClain, ABBSgroup Undergrad.

OGS CO2 No. 1 well

Tuscarawas Co.

API - 3415725334

Cincinnati gp

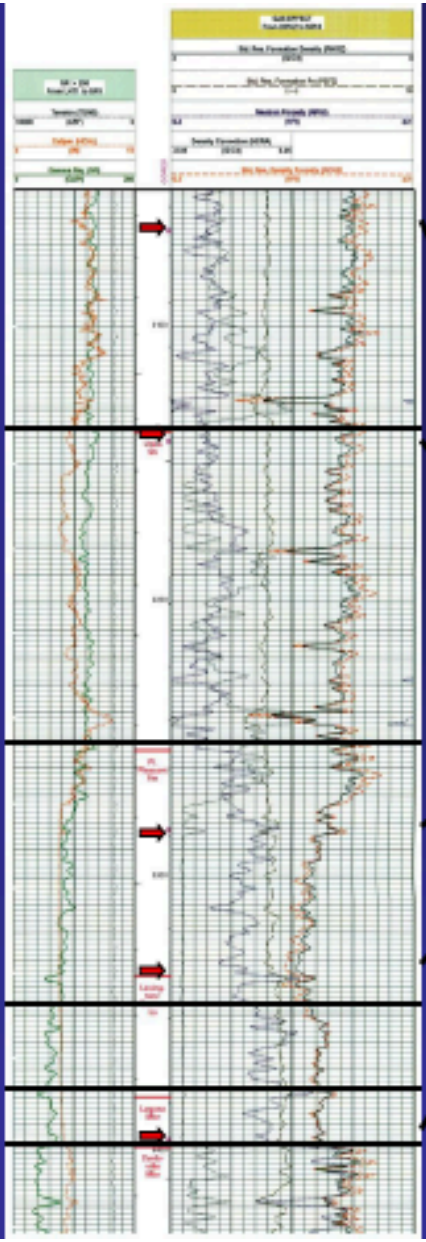
Utica Sh

Point Pleasant Fm

Lexington/Trenton Ls

Logana Mbr

Curdsville Mbr



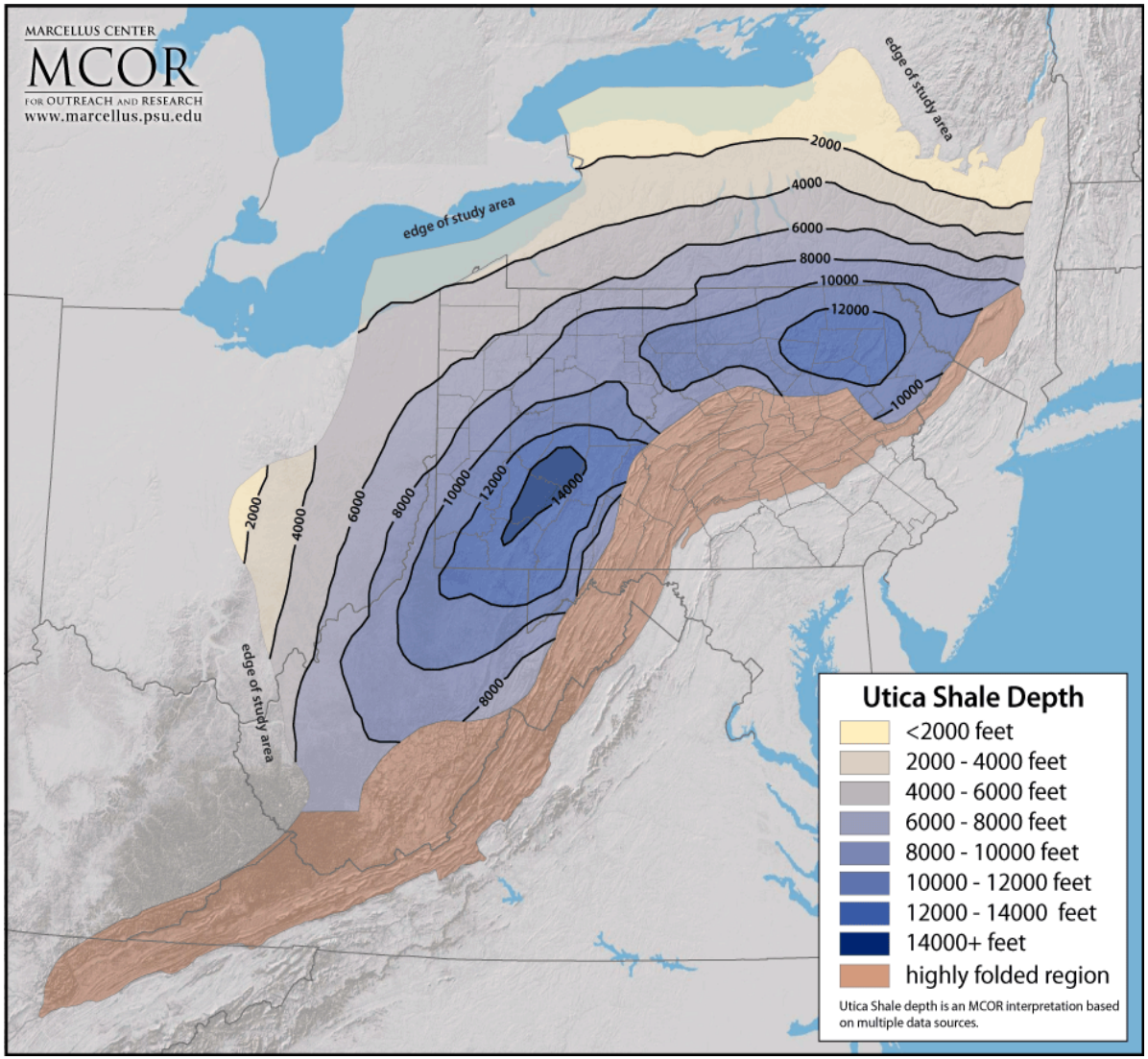
Source Rock Analyses

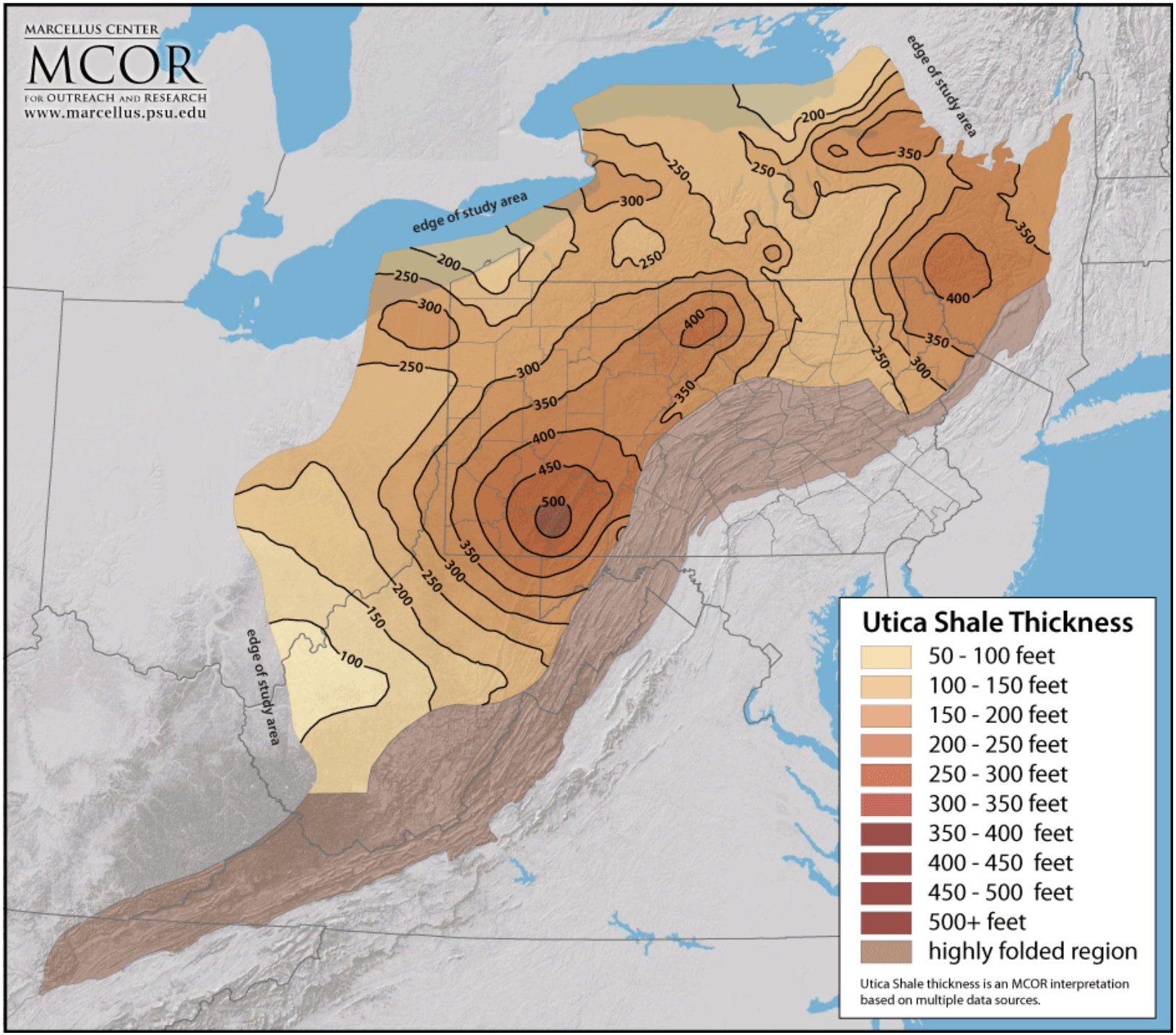
Depth (ft)	Sample Type	TOC	Rock Unit
6064	core	0.48	Cincinnati gp
6141	core	2.72	Utica Sh
6282	core	2.41	Point Pleasant Fm
6336	core	3.73	Point Pleasant Fm
6396	core	1.61	Logana Mbr
7192	core	0.11	Wells Creek Fm
7579	core	0.14	Copper Ridge dol
8274	core	0.23	Conasauga gp

www.OhioGeology.com

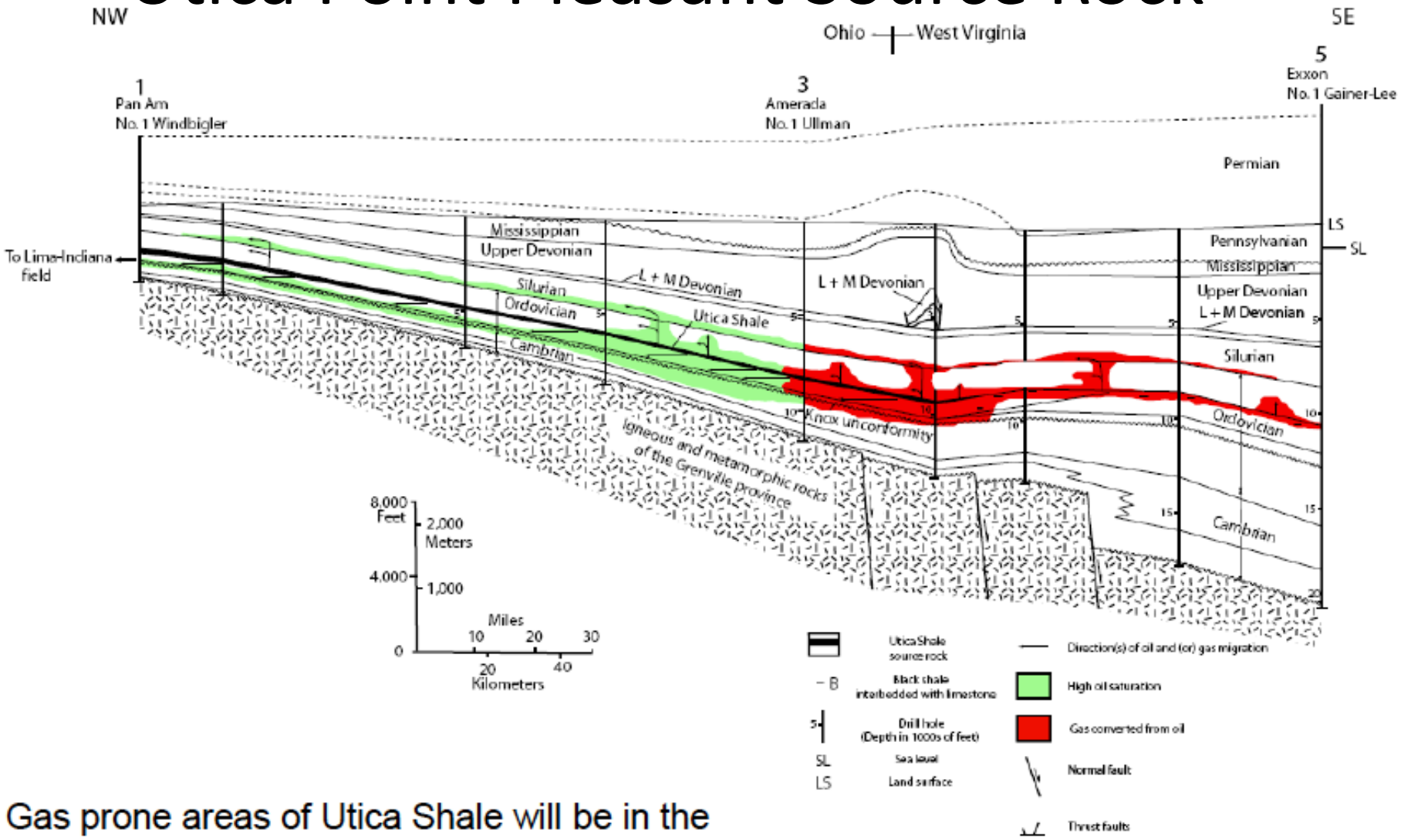
Riley, 2010

Depth to Utica Shale Top




MARCELLUS CENTER
MCOR
FOR OUTREACH AND RESEARCH
www.marcellus.psu.edu
edge of study area
edge of study area
edge of study area
Utica Shale Thickness
50 - 100 feet
100 - 150 feet
150 - 200 feet
200 - 250 feet
250 - 300 feet
300 - 350 feet
350 - 400 feet
400 - 450 feet
450 - 500 feet
500+ feet
highly folded region
Utica Shale thickness is an MCOR interpretation based on multiple data sources.

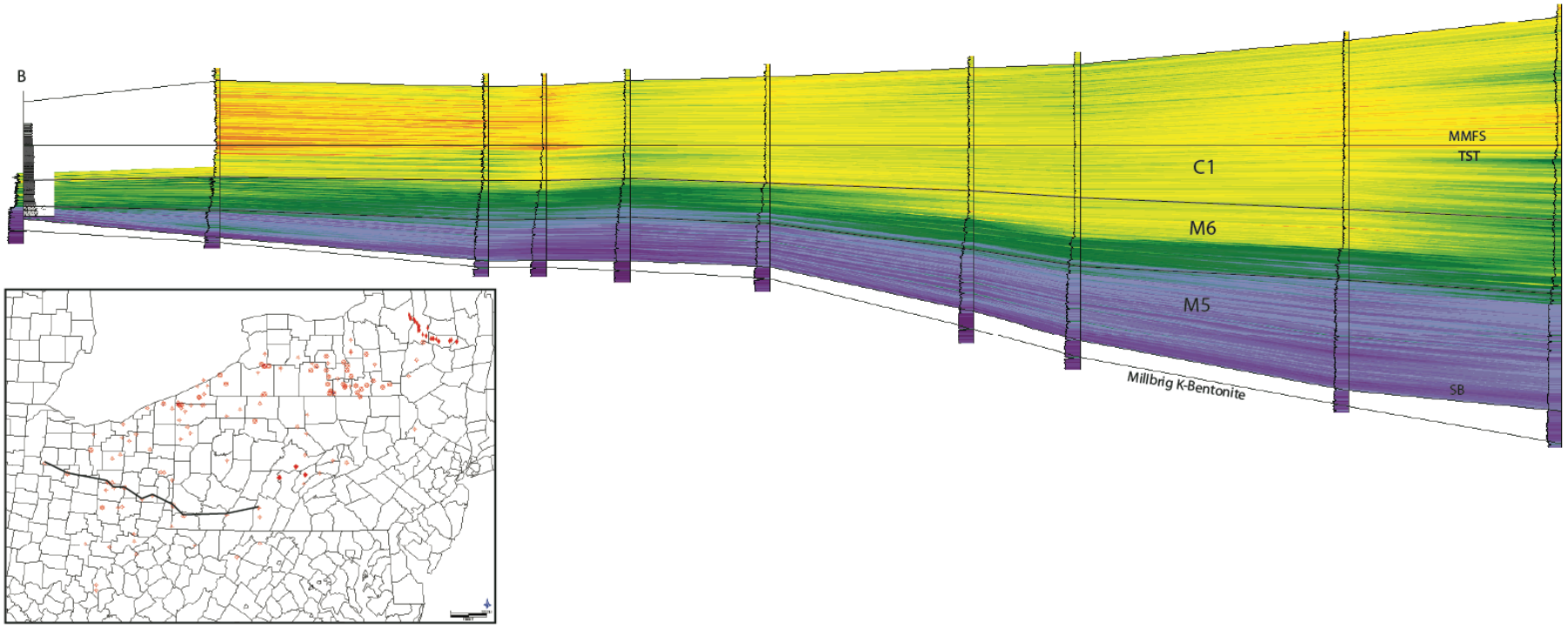
Utica Point Pleasant Source Rock



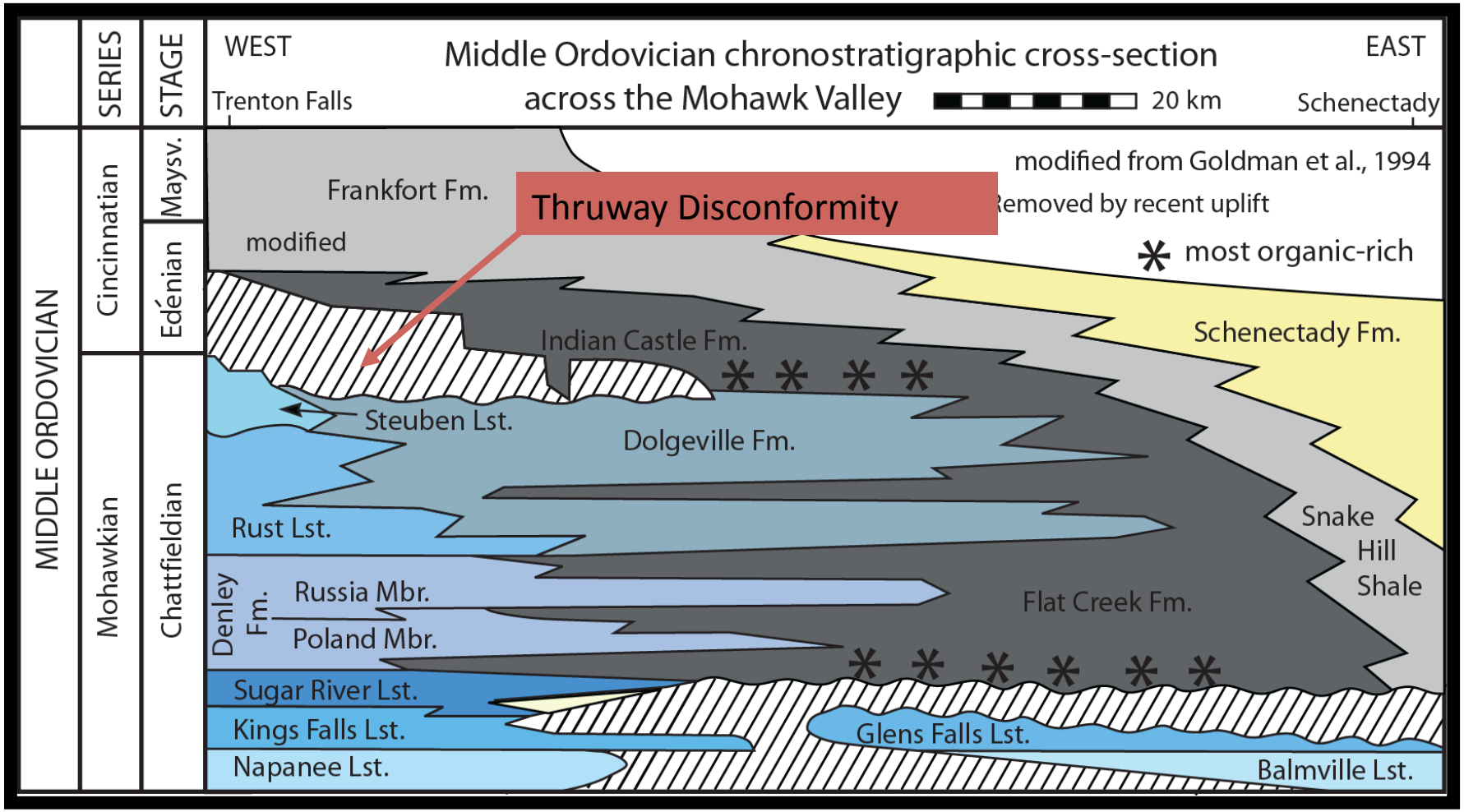
Gas prone areas of Utica Shale will be in the deeper portion of the basin. Much of Ohio may contain appreciable amounts of oil within Utica Wells

Figure source: R.T. Ryder, USGS OFR 2008-1287

Pennsylvania-Ohio Utica Shale



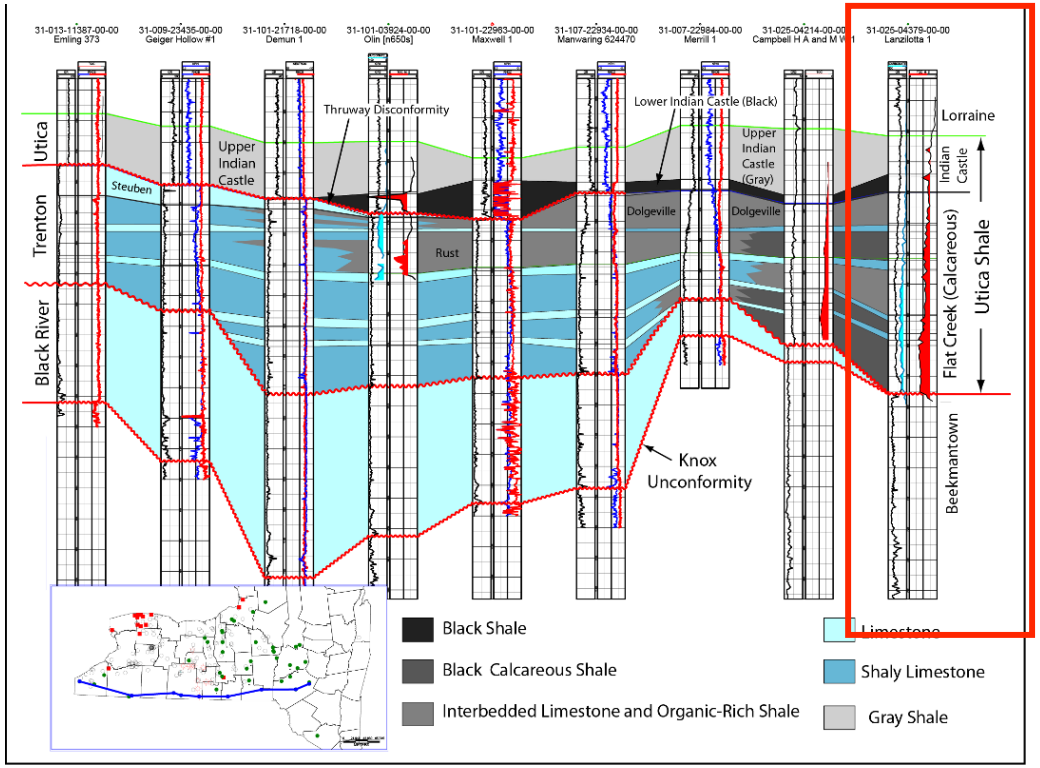
McClain, 2011 ABBSgroup

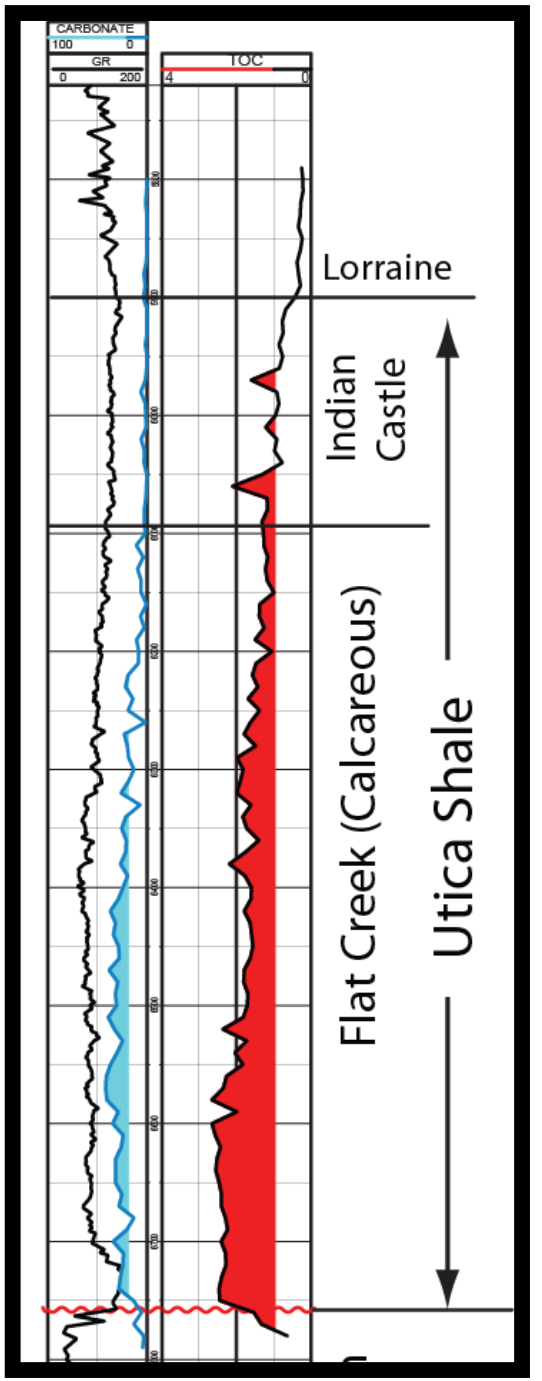


T. Smith, NY State Museum

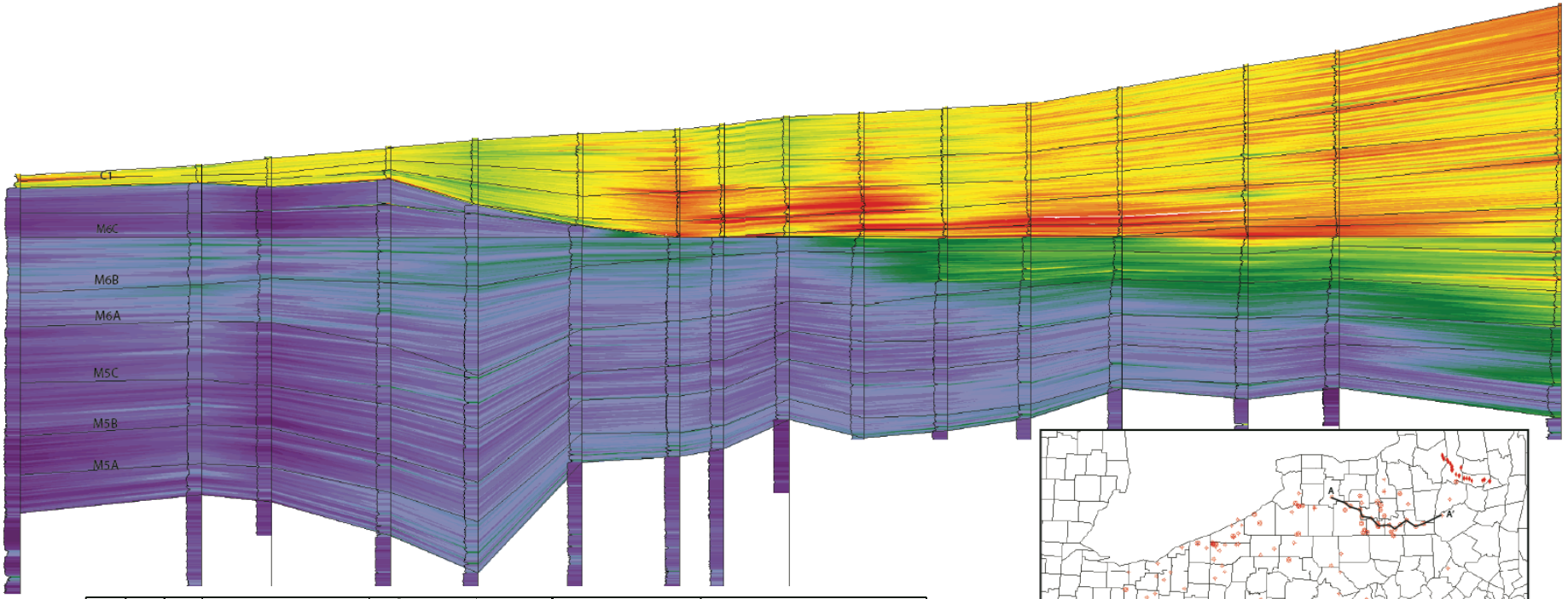
Outcrop Stratigraphy from Mohawk Valley – Utica consists of Flat Creek (which is time-equivalent to Trenton Limestone) and Indian Castle Shales (which postdates Trenton) – the beds with the highest TOC immediately overlie or are laterally-equivalent to unconformities

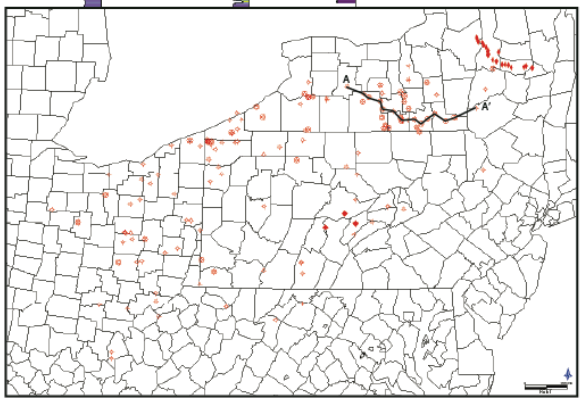
Wells to east have Flat Creek Shale which is a calcareous shale with relatively high carbonate content (25-50% bit also pretty high TOC of 1.5-3.5%

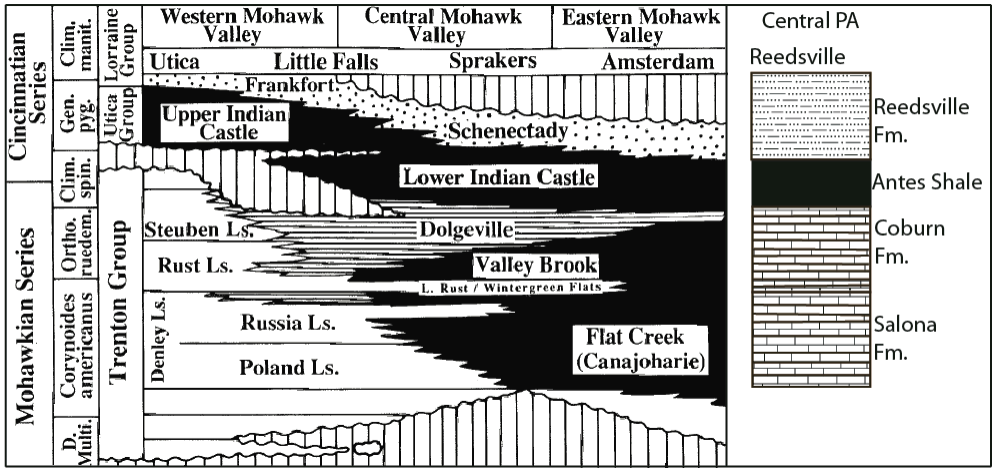




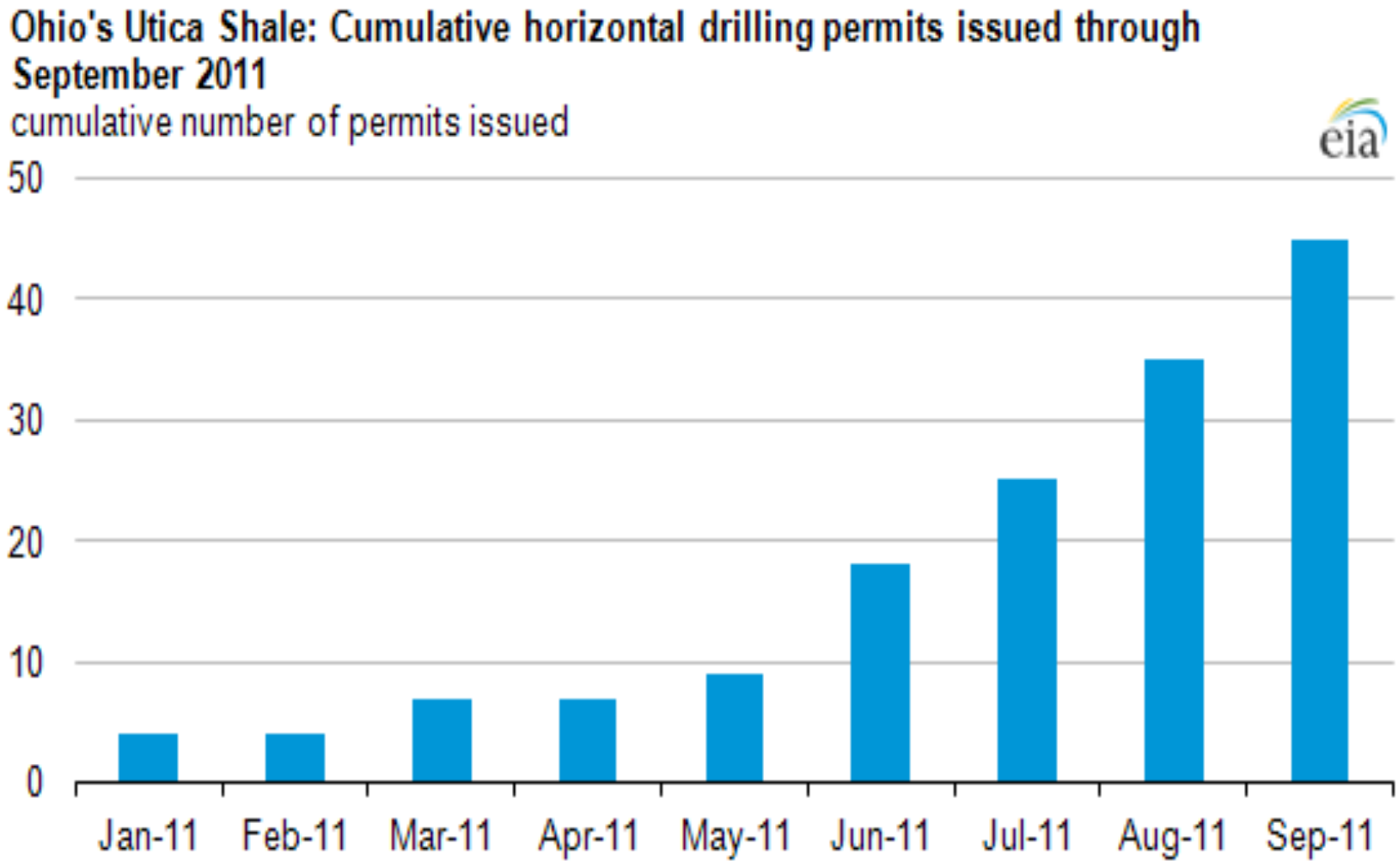
Gamma Ray Log Based Lithostratigraphy for Utica Shale







Ohio Oil and Gas Drilling Permits



Source: U.S. Energy Information Administration, based on Ohio's Department of Natural Resources

Utica-Pt Pleasant Summary

- The Ordovician age Utica Shale and Point Pleasant Formation is believed to be the source rock for over 300 million barrels of oil and 3 trillion cubic feet of gas reserves from overlying Silurian age Clinton sandstones and deeper Cambrian-Ordovician age Knox carbonates and sandstones in Eastern Ohio.
- In Western Pennsylvania and Eastern Ohio, the Utica Shale is over 150 feet thick and the underlying Point Pleasant Formation is 140 feet thick.
- Mixed carbonate/shale sequence, containing total organic carbon content ranging from 2.4% to 3.7%. Not rich compared to Marcellus Shale, but effective due to the very thick section of potential source rock.
- The Point Pleasant exhibits high resistivities on geophysical logs, indicating the section is hydrocarbon bearing. Log analysis indicates that porosities in the Point Pleasant Formation range 8% to 12%.

Acreage Positions Principle Players

- Anadarko Petroleum 300,000 acres in Ohio
- Devon Energy 110,000 acres Ohio
- Exxon-Mobil (purchased Phillips w/ 45,000 acres Ohio (now have ca. 75,000 acres w/ first well expected 2012)
- Chesapeake ca. 1.5 million acres OH/PA
- Hess (purchased Marquette, 85,000 acres), then agreement with ConSol on ca 200,000 acres
- Rex Energy 11,000 acres OH
- Devon Energy 300,000 acres Michigan

Utica Exploration to Date

- Quebec: (Collingwood Fm): Questerre produced 12 MMcf/d

  Also Gastem, Canbriam Energy, Forest Oil, Talisman Energy, and Quantum. Estimates 5 to 25 tcf recoverable.

  Michigan: Collingwood Fm.—Encana, one well 2.5 MMcf/d
- OH: ConSol- one rig devoted to Utica in Ohio, 4-6 wells anticipated; Belmont Co., 1.5 MMcf/d "unstimulated"
- PA: Seneca, McKean Co, no results
- Chesapeake (see next slide)
- Rex plans Butler Co. well
- EQT: Greene Co., 2008, 14,464 ft.!
- Range Resources: Beaver County (2/11)
  - 12,700 feet; 4.4 Mmcf/d

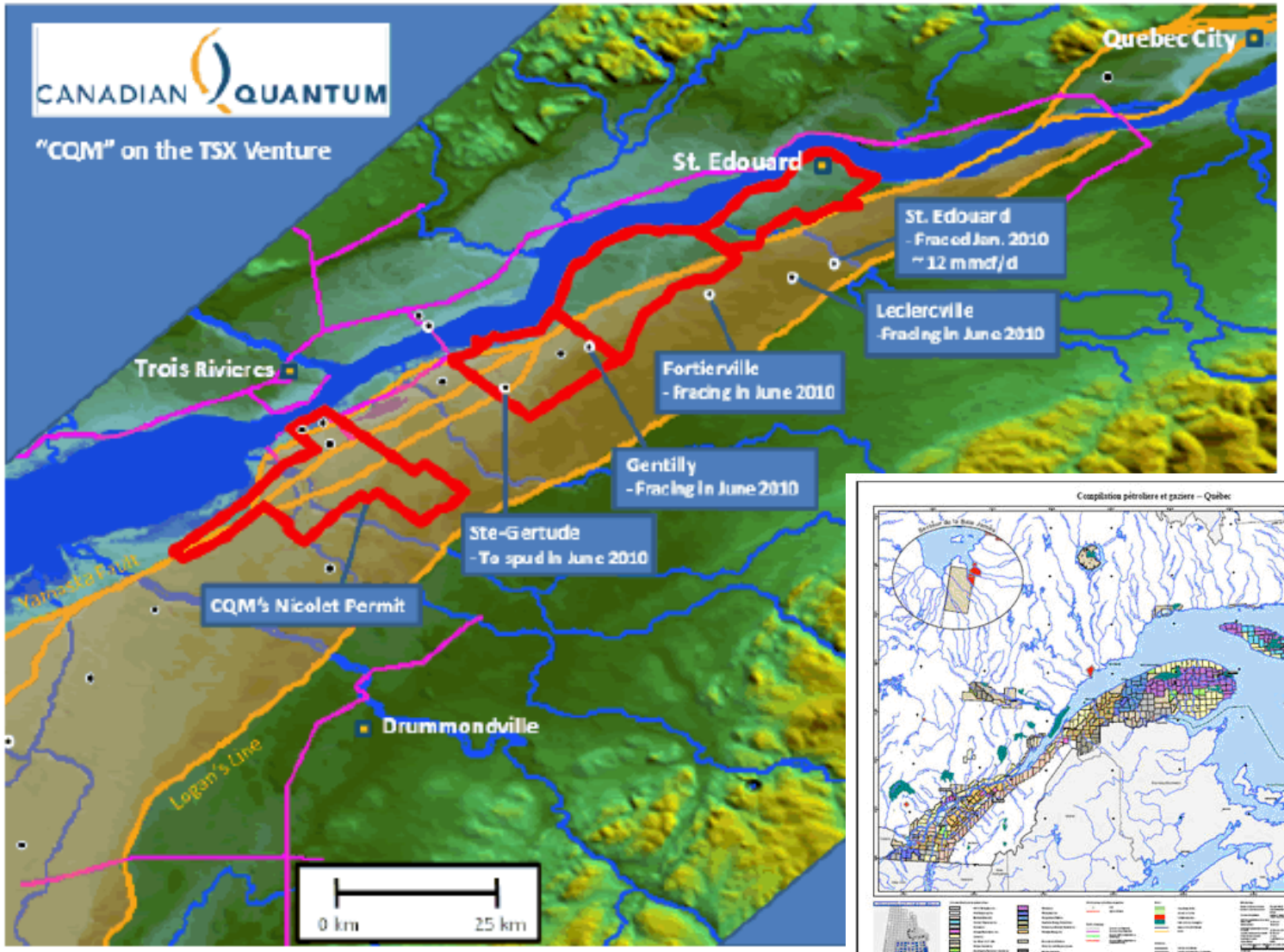
OH geol surv (Wickstrom) suggests about 17.5 Tcf gas and 5.5 Bboil

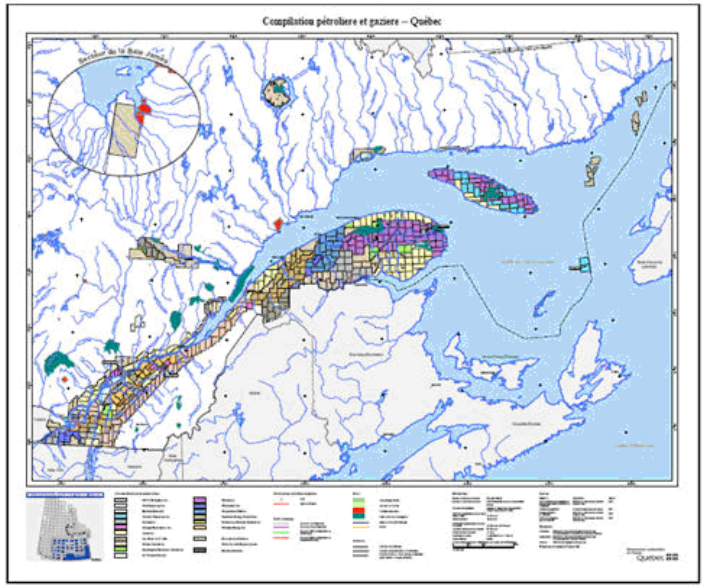
Chesapeake's Utica Play

- Chesapeake currently drilling in the Utica Shale with 5 operated rigs, anticipates increasing its rig count to 8 by the end of 2011, and 16-20 rigs by year-end 2012. Drilling effort of at least 40 rigs by year-end 2014. Just announced an agreement with Enervest and an unnamed foreign company for >650,000 acres in Utica!
- Harrison County, eastern Ohio, avg. 9.5 MMcf natural gas and 1,425 barrels liquids.
  Two wells in Carroll County, eastern Ohio. #1: 3.1 MMcf natural gas and 1,015 barrels of natural-gas and oil liquids. #2: 3.8 MMcf and 980 barrels liquid.
  Utica well in Beaver County, Pa. yielding 6.4 MMcf/d, (liquids?)

Quebec Utica

- St. Lawrence lowlands, 5000 sq km (1800 sq mi), 1.1 million acre fairway
  - Drill depth <2500 ft
  - Thickness 75-300 ft
  - 93 BCF/section
  - @15% recovery= 14 BCF/section
  - Total estimated 25 TCF

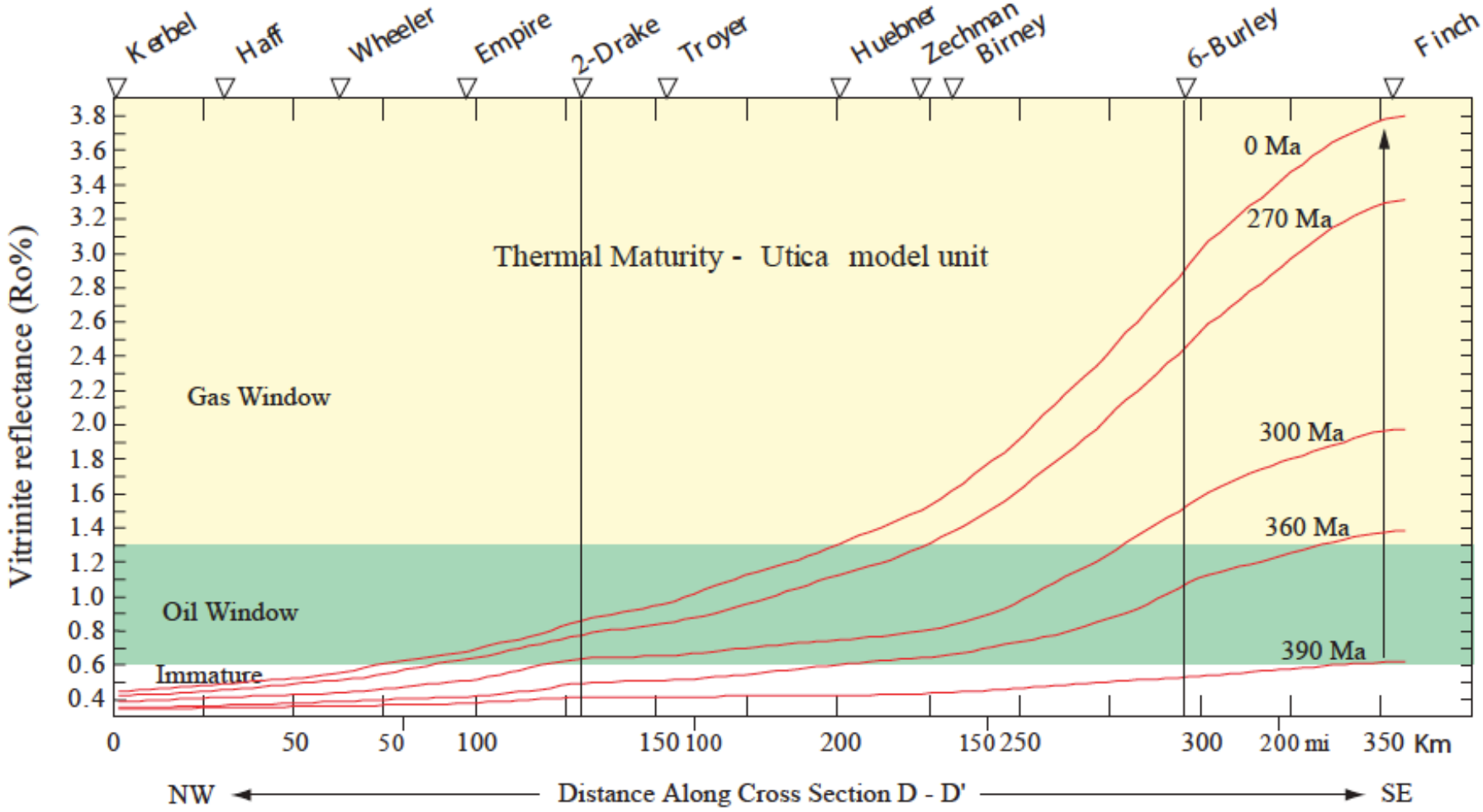




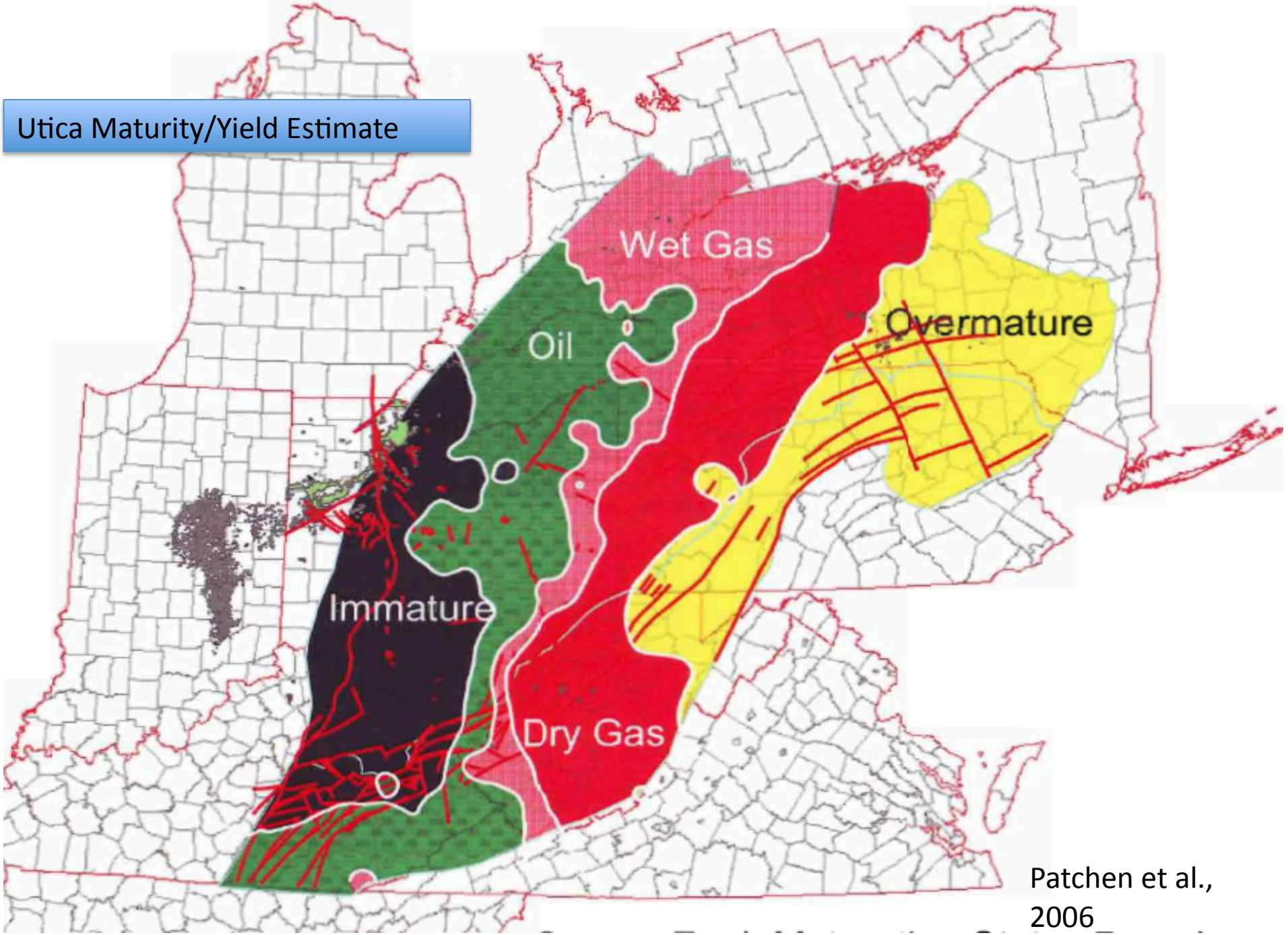
The Utica Play may extend throughout much of the northern Appalachian Basin and on the other side of the Adirondack Mtns within the St. Lawrence River lowlands. The Utica Play in Quebec has been unfolding since at least 2007 with wells testing as high as 12 million cubic feet of gas/day .

Source: www.marketoracle.co.uk

Utica Model Thermal Maturity

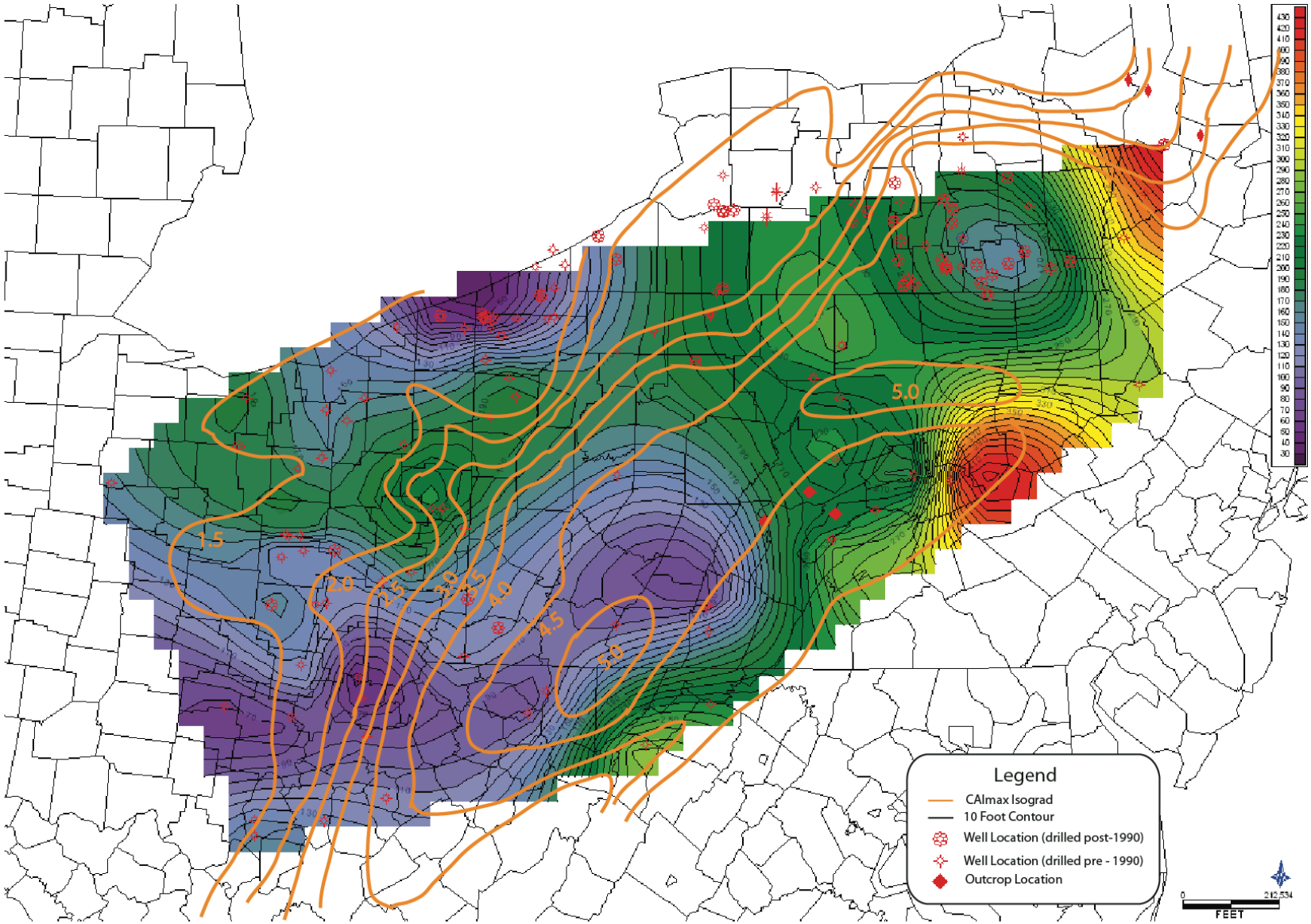


Rowan, 2006



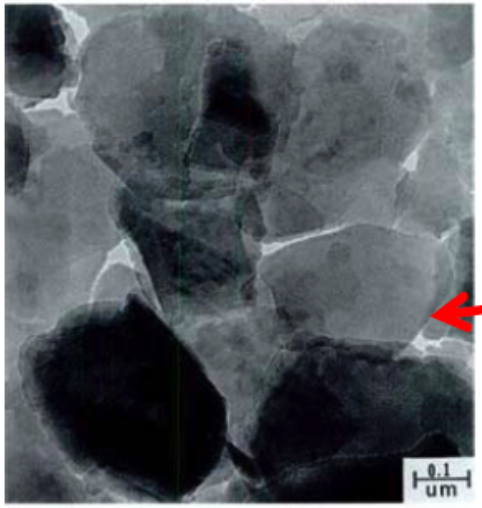
Patchen et al., 2006

Carbonate Marl Facies Isopach



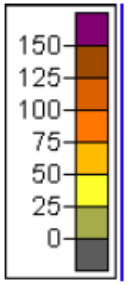
McClain, 2011 ABBSgroup

Where is the Gas in a Gas Shale?

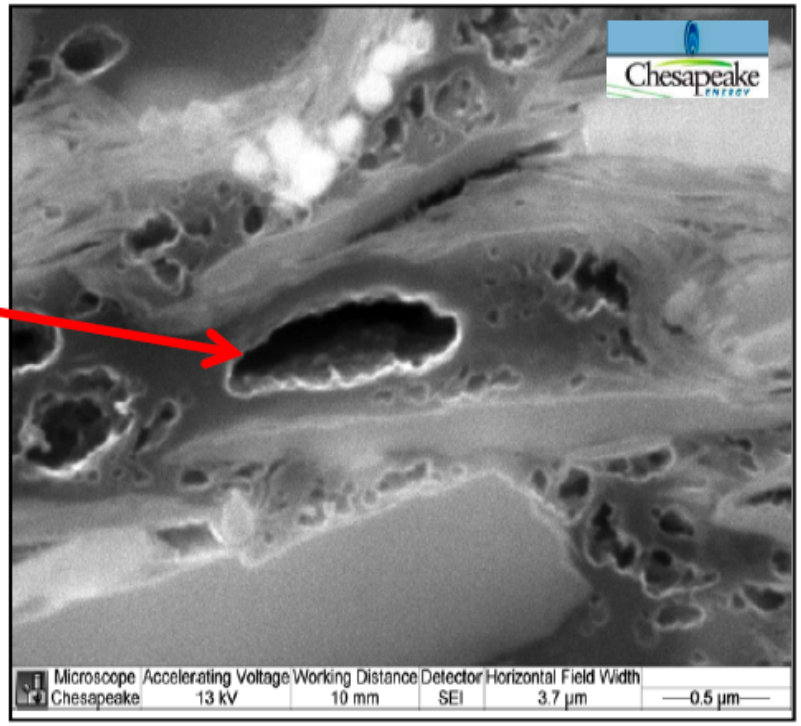


Two Main Pore Types
Kerogen Intrapatricle (organic pores)
Matrix Intergranular (inorganic pores)

Inorganic Porosity
Between Grains, Fractures



Organic Porosity
Within Diagenetically Altered Kerogen

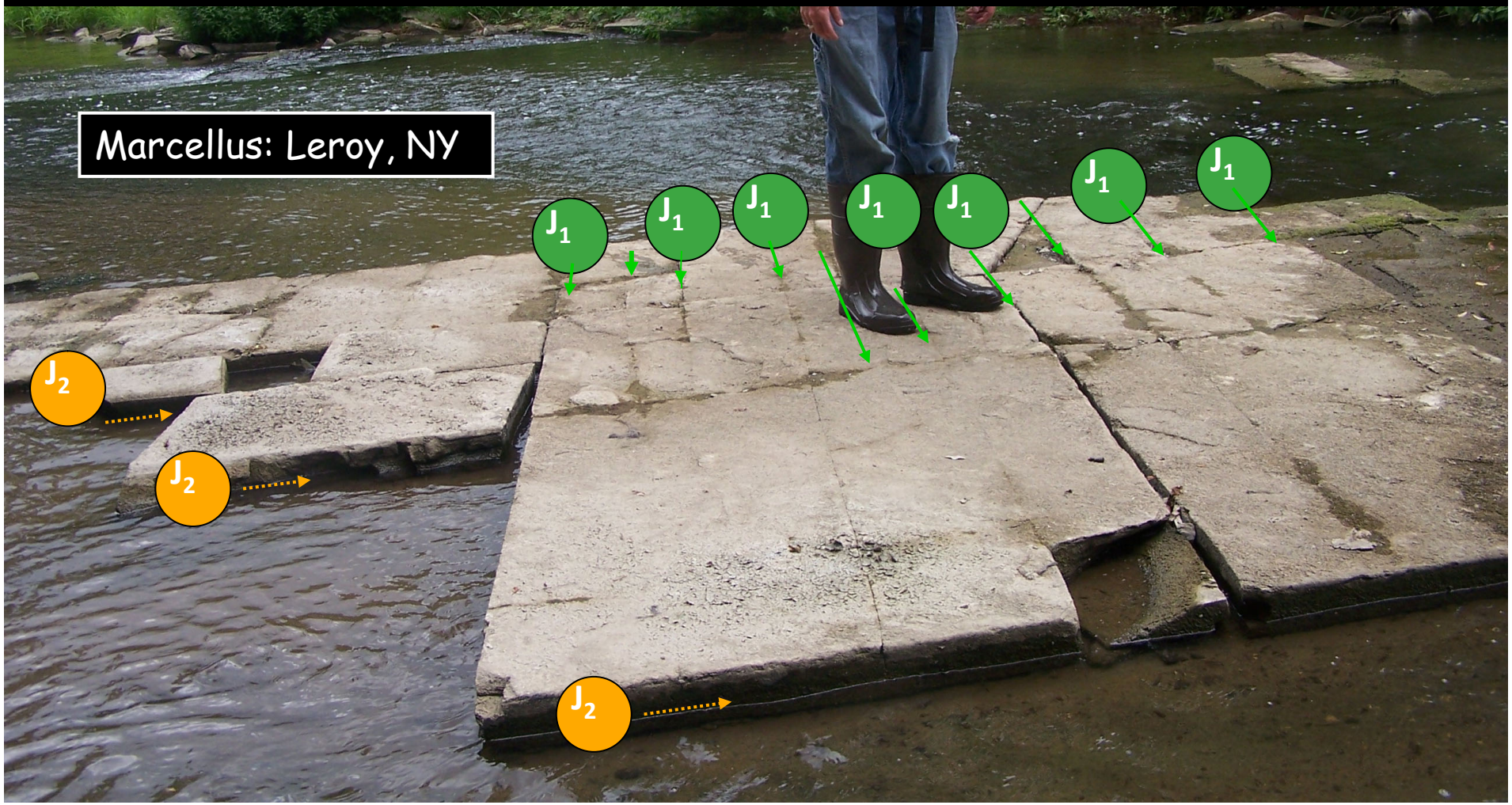


On the microscale, gas is sorbed on matrix and kerogen surfaces, as well as in the “free” state within pores, and difficult to extract. Joints and hydrofrac-induced fracture networks connect matrix porosity for enhanced production.

Fractures (Joints) Matter

J_1 Best developed in black shales

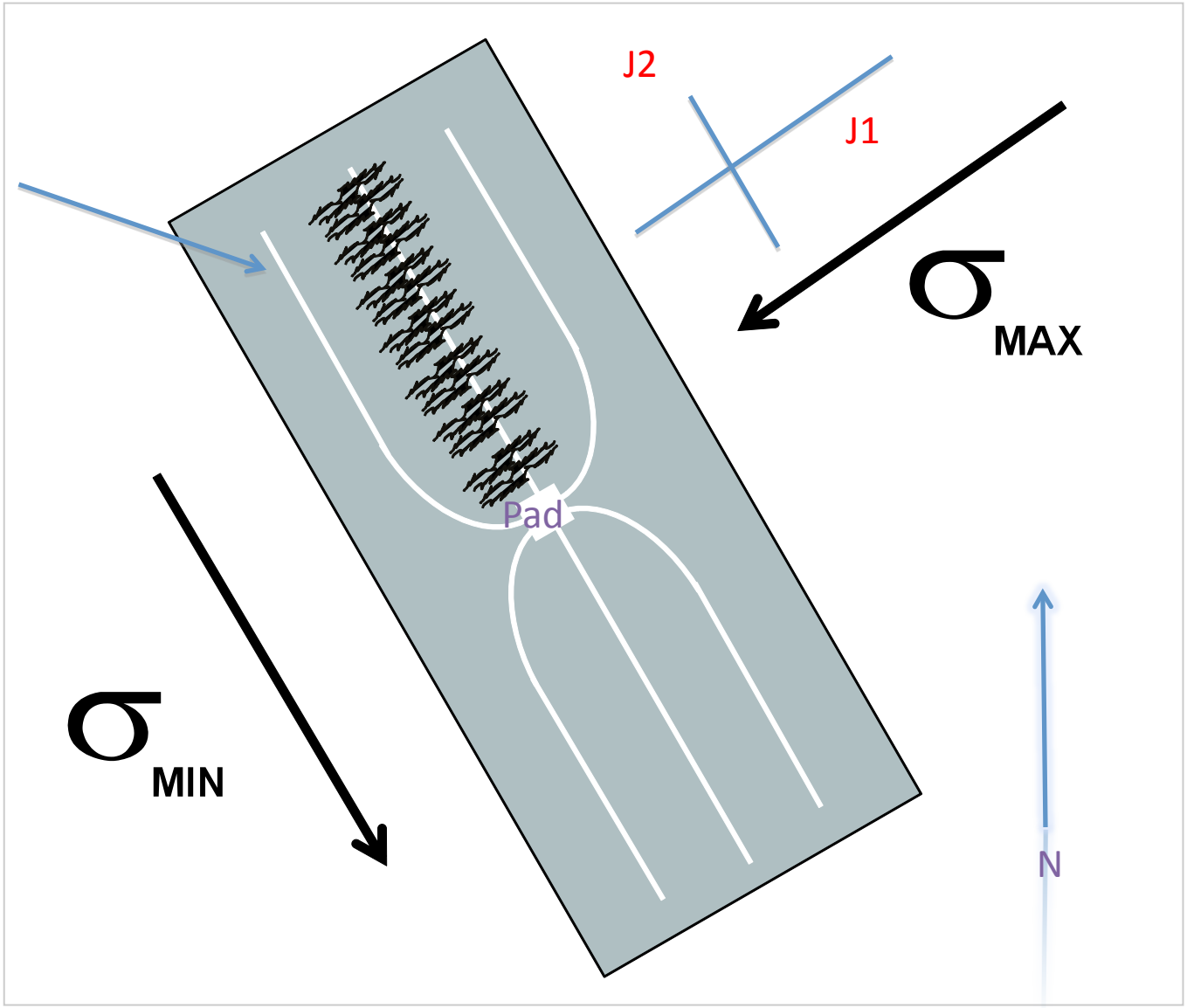
J_2 Best developed in gray shales



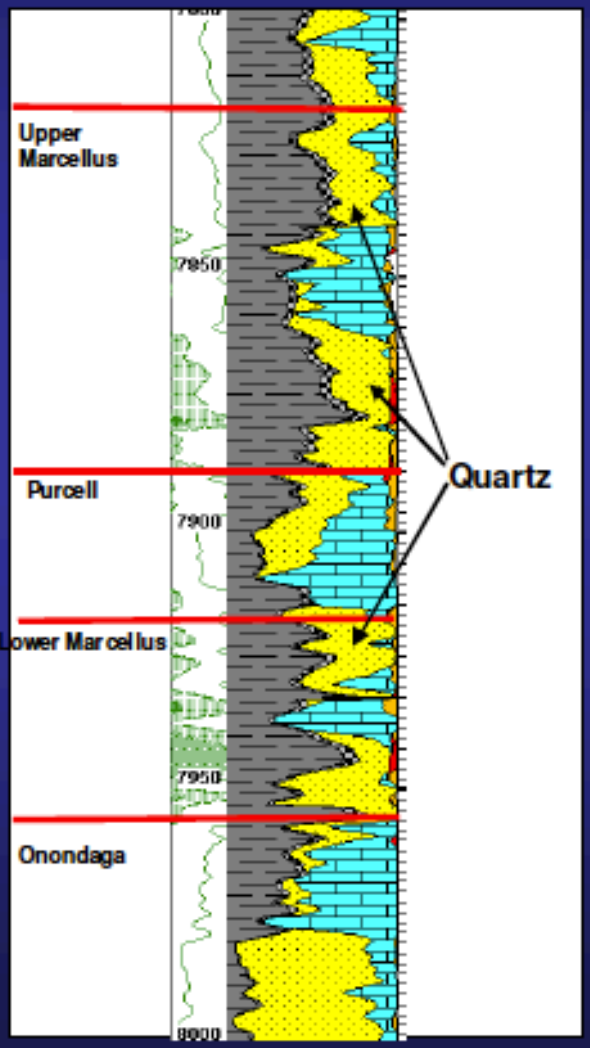
Marcellus Well Layout from Single Pad

Horizontal "laterals" 2000 to 7000 ft long

Pattern can "drain" natural gas from up to 640 Acres (1 sq. mile)



Fracability



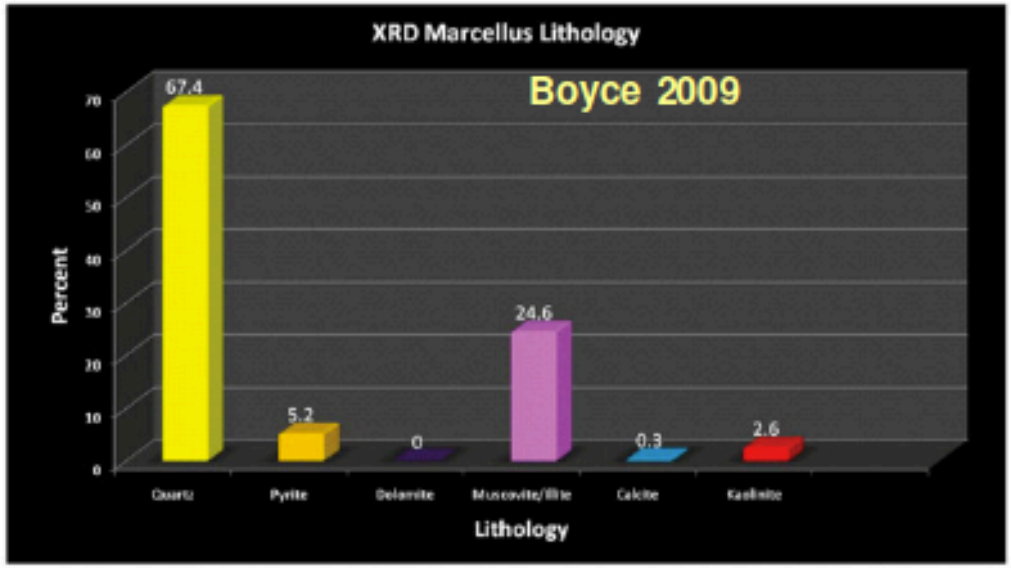
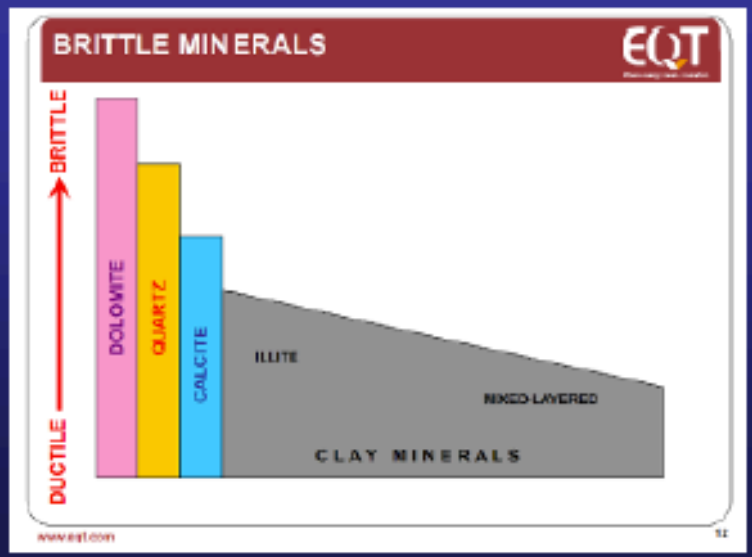


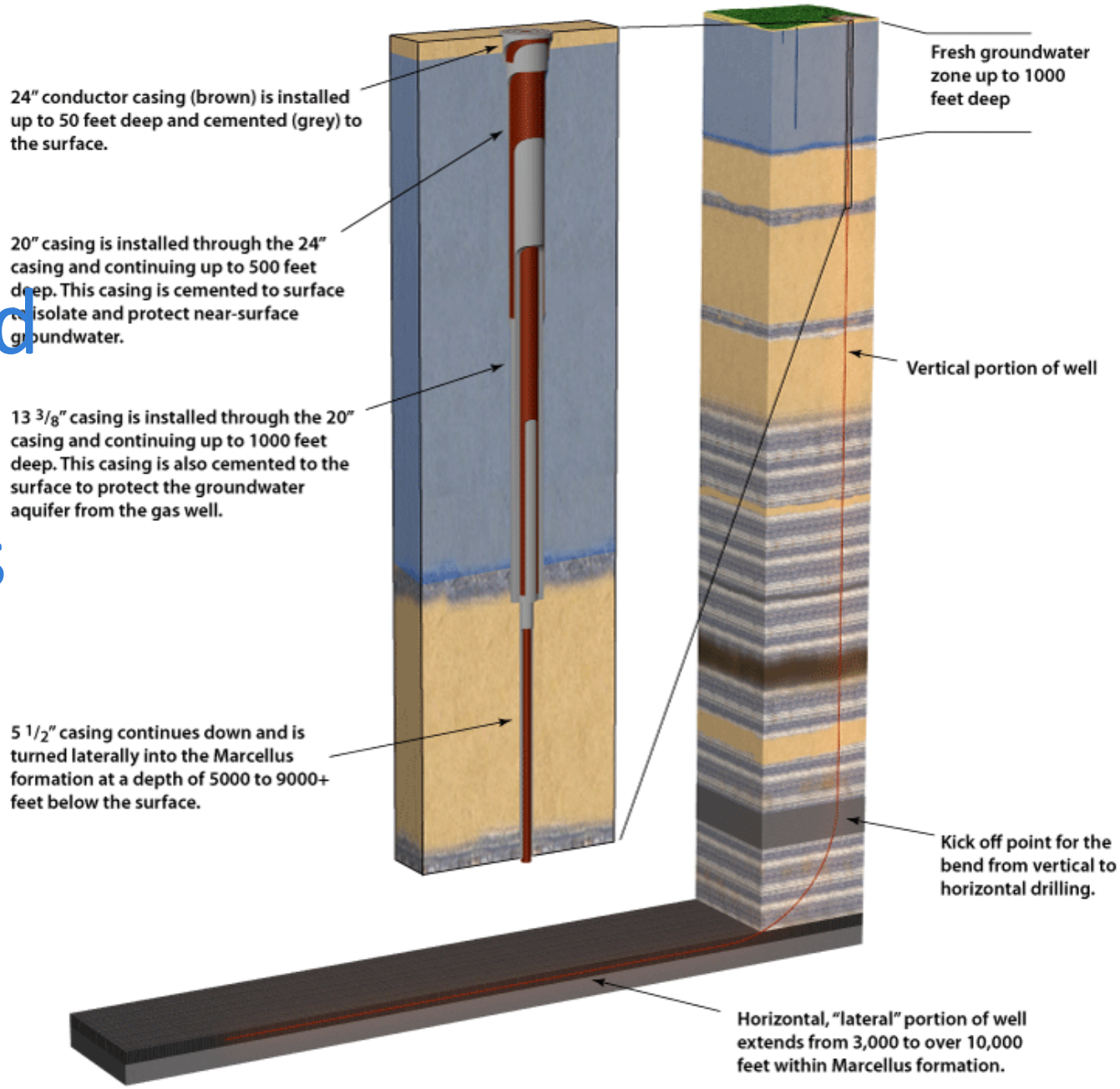
Figure 5.- Example of X-Ray Diffraction (XRD) results for a single core sample from the Marcellus in the study area (Figure 7). This sample has a high amount of quartz (67%) and fairly low amount of clay (24%), which is characteristic of the 36 Marcellus Shale core samples examined throughout the study area. Also it is important to identify the significant amount of pyrite. This sample has about 5% but the samples can range from 5-10% pyrite.



Fracability

- A key play element is the brittleness of the target shale
- Ability to hydrofracture is directly related to brittleness
- High quartz content and low clay content yields high brittleness quotient
- High quartz content in Marcellus may be related to deposition of wind-blown silt

Drilling and Casing Marcellus Wells



Marcellus Center for Outreach and Research, Penn State - www.marcellus.psu.edu

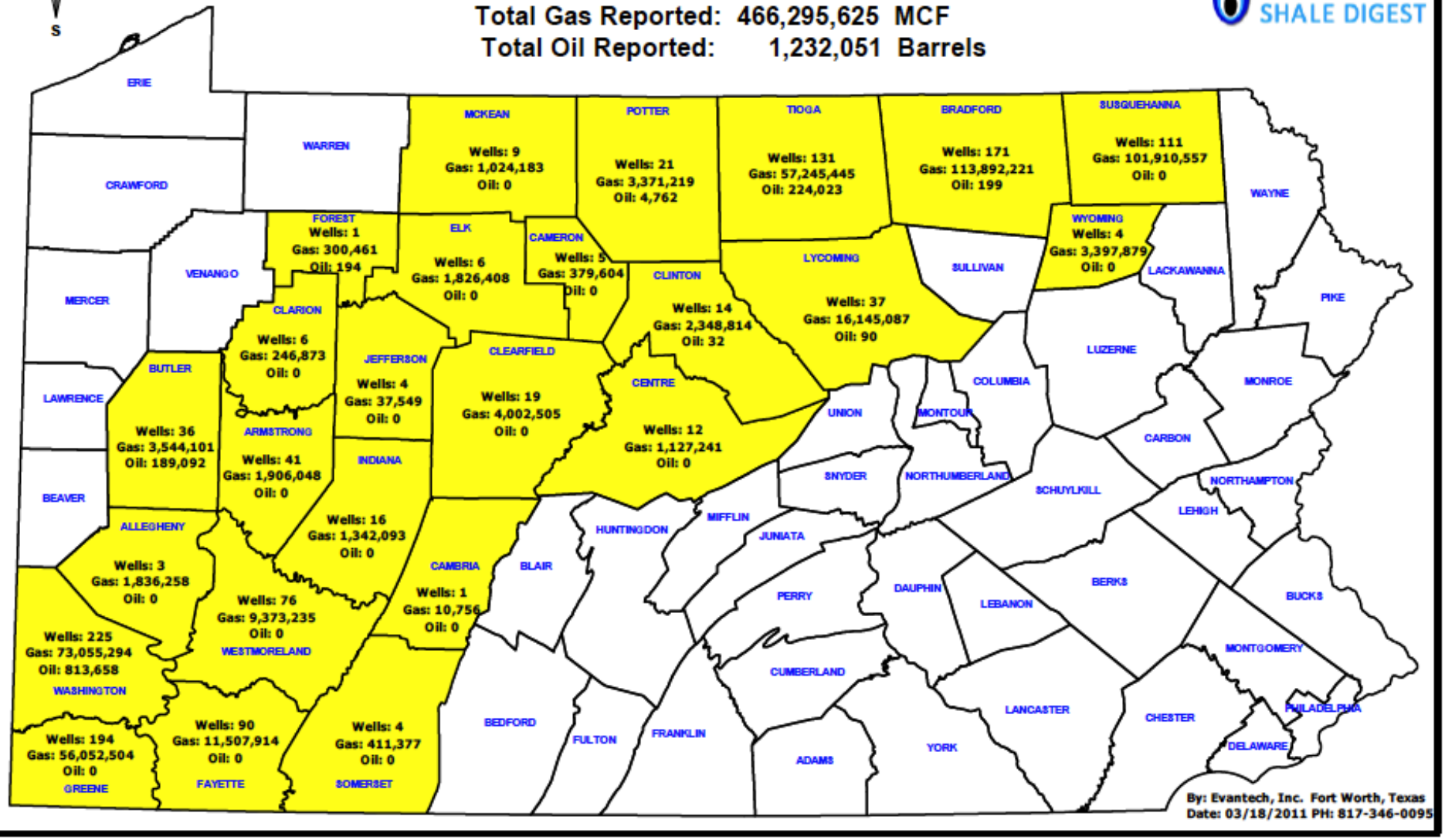
PENNSYLVANIA COUNTIES REPORTED MARCELLUS PRODUCTION

TOTALS FROM 7-1-2009 TO 12-31-2010

Total Gas Reported: 466,295,625 MCF

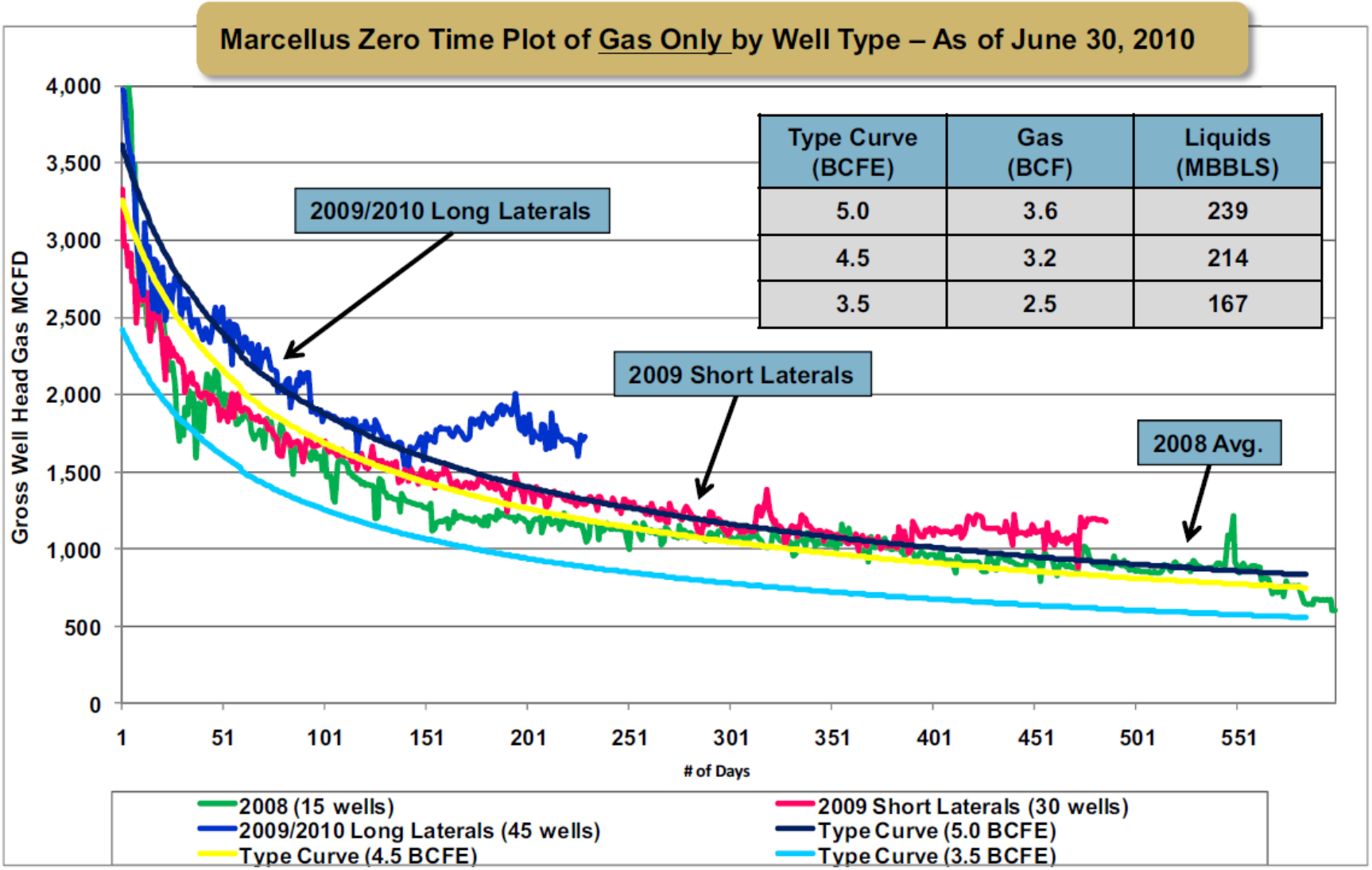
Total Oil Reported: 1,232,051 Barrels

POWELL SHALE DIGEST



By: Evantech, Inc. Fort Worth, Texas
Date: 03/18/2011 PH: 817-346-0095

Well Performance Continues to Improve



Resources

Fact sheets, publications, presentations @

- www.msetc.org (Penn College)
- www.naturalgas.psu.edu (PSU Ag Extension)
- www.marcellus.psu.edu (MCOR)