# The Marcellus Shale Play: Geology, History, and Oil & Gas Potential in Ohio


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Ohio Geological Survey

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# Outline

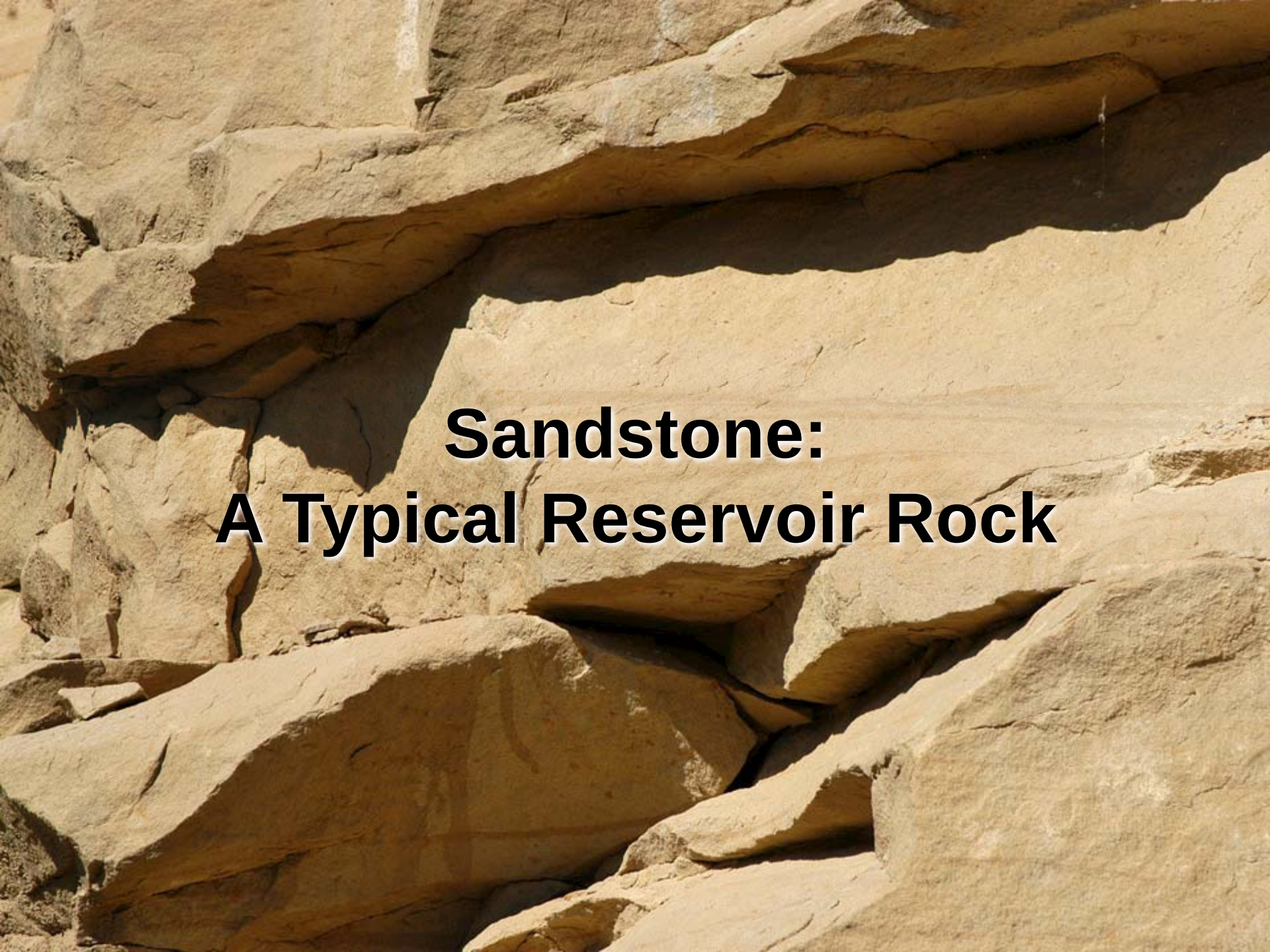
- Important Concepts:
  - Conventional reservoirs vs. shale
  - Vertical vs. horizontal drilling & fracturing
- History of Marcellus Play
- Marcellus Shale Geology & Potential

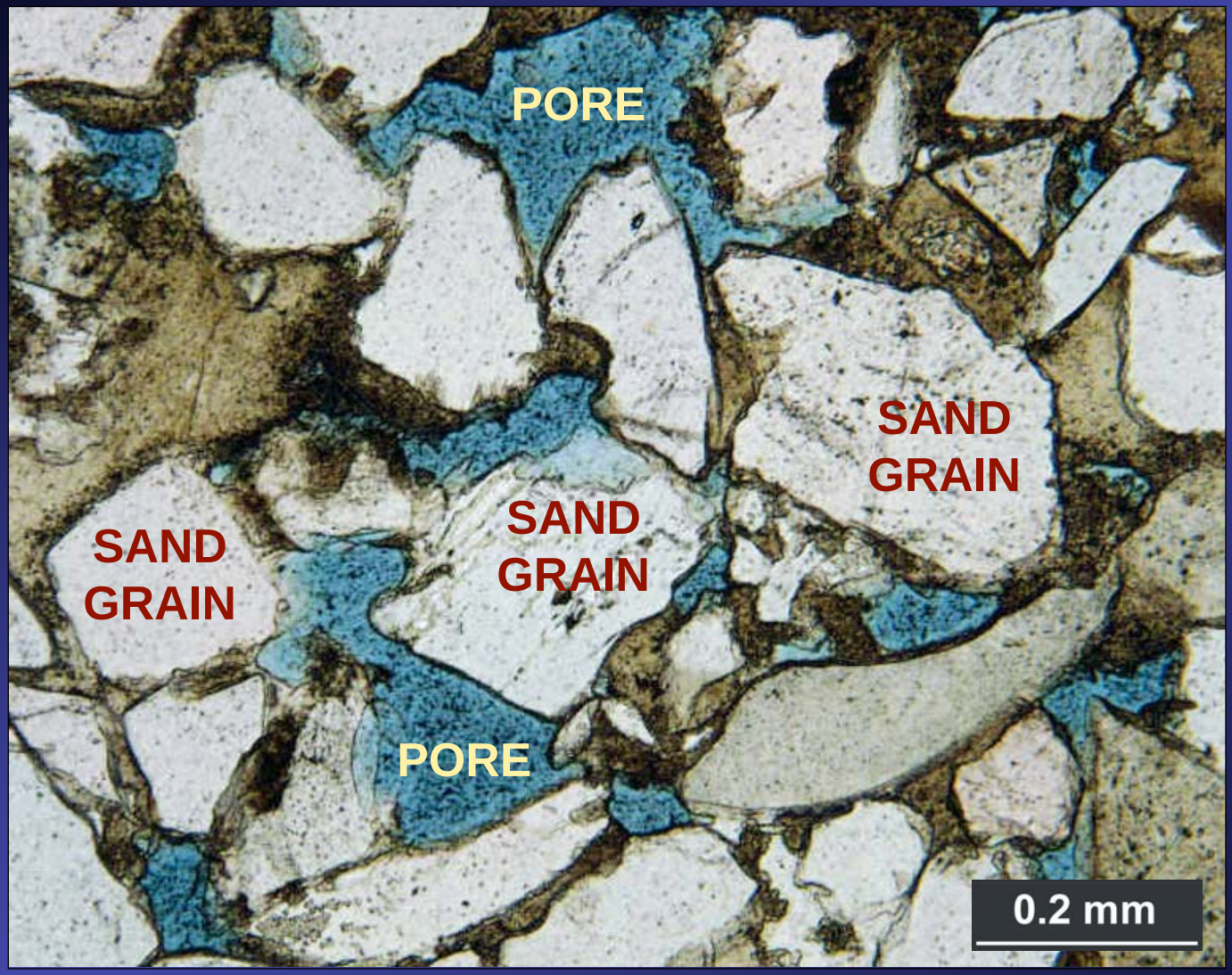
# Some Basics on Reservoirs

- Reservoirs are deeply buried rocks containing oil or gas (or both) that can be economically extracted.
- Historically, sandstones and carbonates have been the best performing reservoirs because they are more porous and permeable.
- Shales were once considered as only the source of much oil and gas—slowly “squeezed” out into surrounding reservoirs over millions of years. They are typically low in porosity and have very low permeability.
- Recent technological innovations allow some shales to be considered reservoirs or “unconventional” reservoirs.

# Conventional Reservoirs

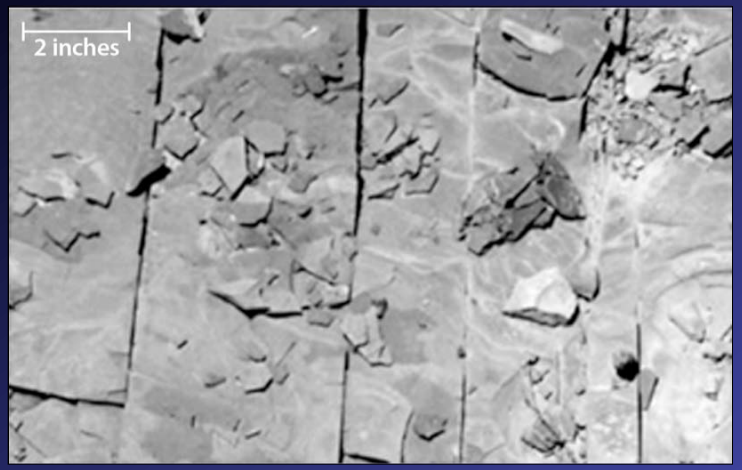
Reservoirs are **NOT** holes in the ground (e.g., caves and caverns). They are solid rock. To the naked eye, it is difficult to see much porosity in many reservoir rocks.


Sandstone:
A Typical Reservoir Rock

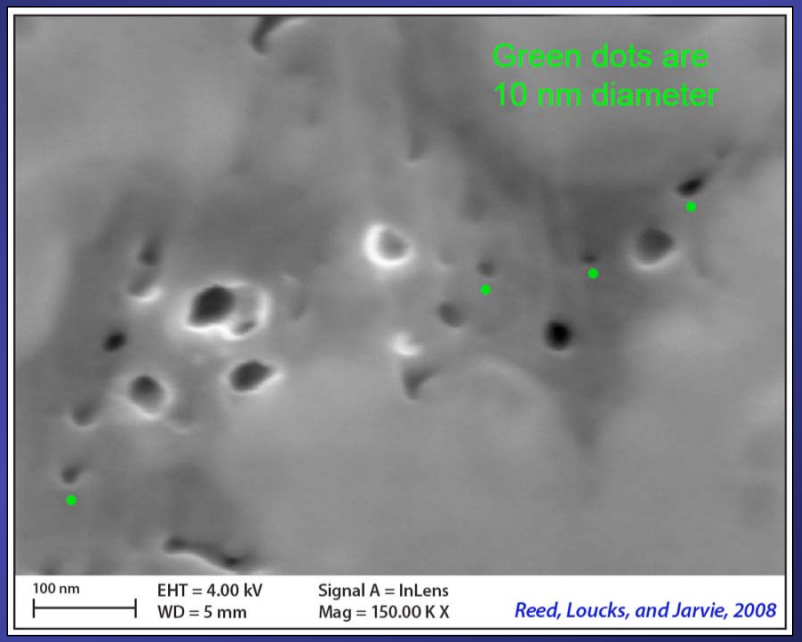



Graphic from Kostelnick (2010).

A porous sandstone prepared for viewing under a microscope reveals pore spaces (blue areas).




Natural fractures (“joints”) in Devonian-age shale, typical of fractures in Marcellus Shale. Image from Geology.com (2010).



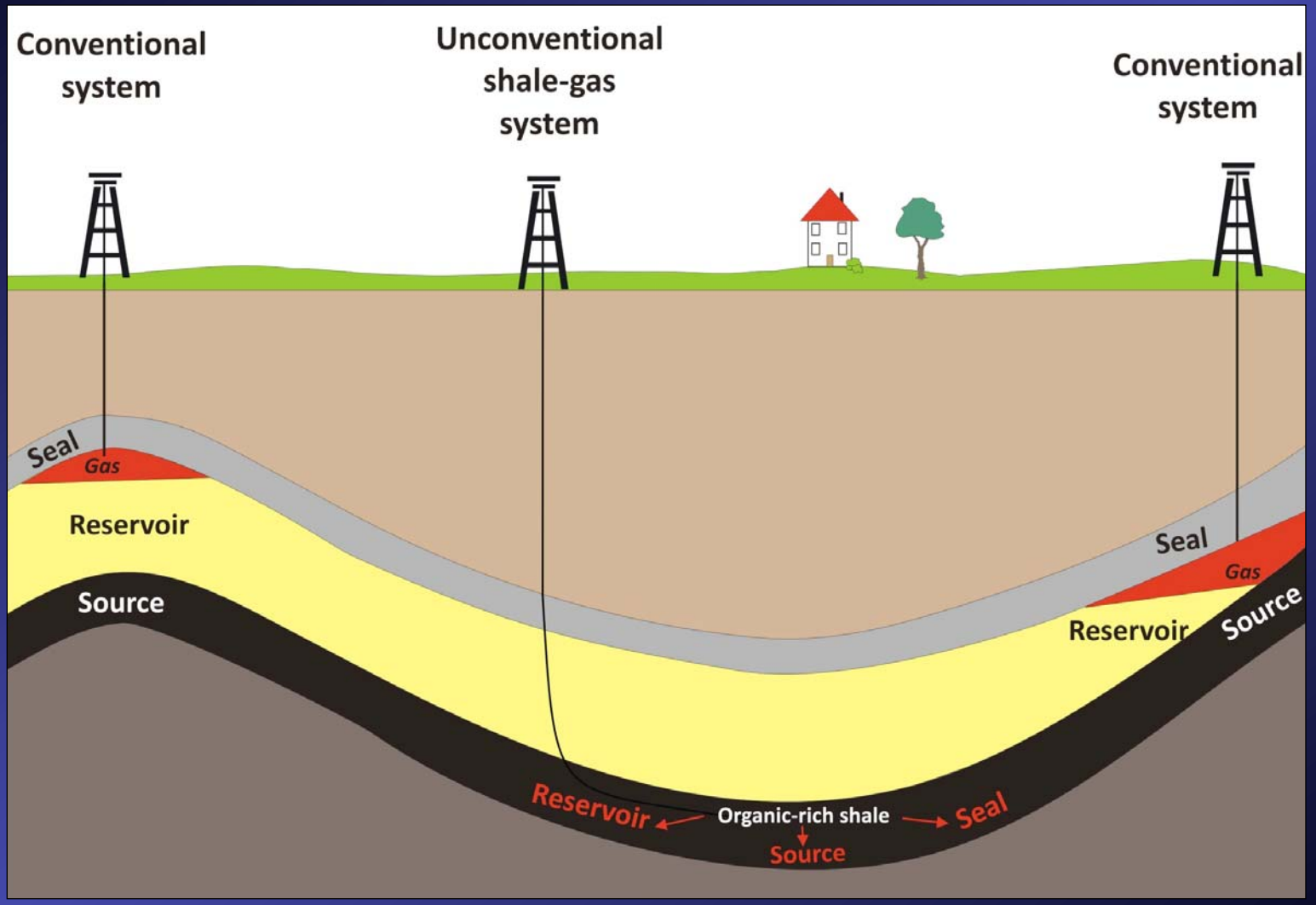

Secondary electron image of nanopores in the Barnett Shale. Nanopores are so small (20 nanometers [nm]) that they impact the passage of methane molecules. Figure attributed to Reed and others (2008) from Jarvie (2009).

Shale is extremely fine grained with many very small pore spaces.

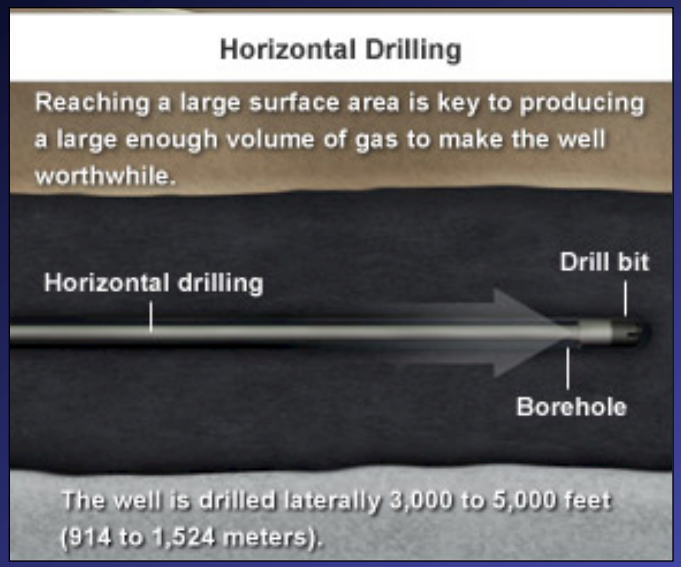
# Drilling and Producing

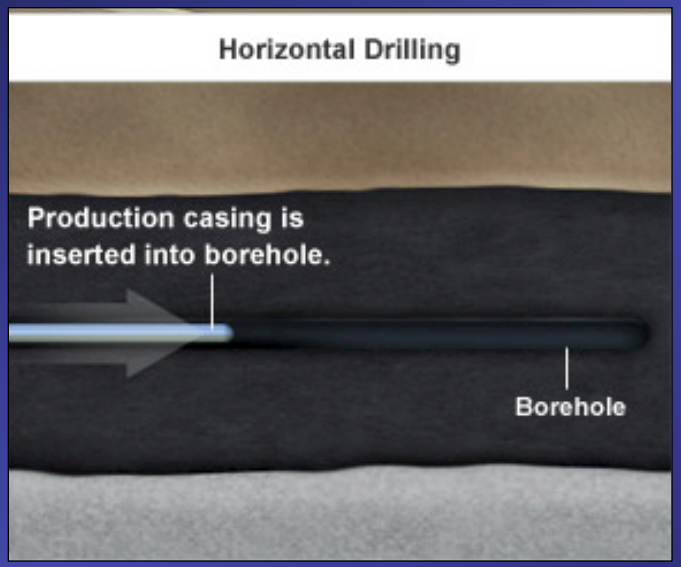
- Most drilling used to target only conventional sandstone and limestone reservoirs.
- Shales were not considered producible because they are impermeable, unless fractured. Shale reservoirs that have sufficient natural fractures are hard to find.
- Because gas and oil are present in shales, research has focused on trying to produce from them.
- Development/refinement of horizontal drilling and multistage hydraulic fracturing has advanced sufficiently to produce from some of the better candidate shale formations, such as the Marcellus.
- Thus far, the Utica Shale also appears to be a good candidate formation.

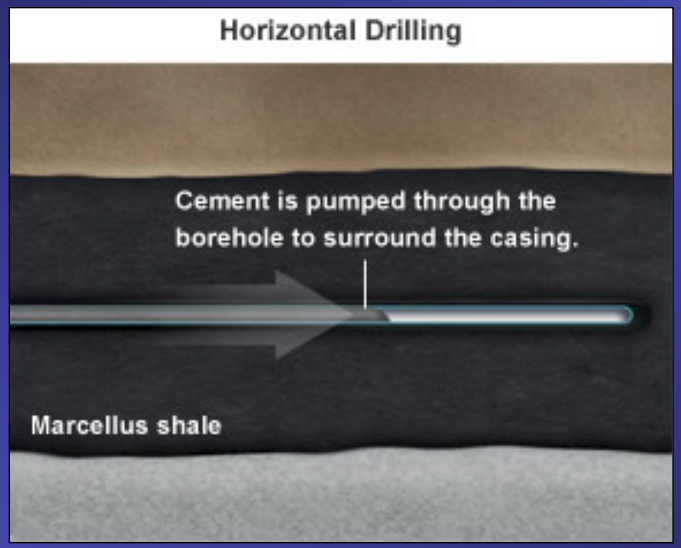
# Petroleum and Drilling Systems

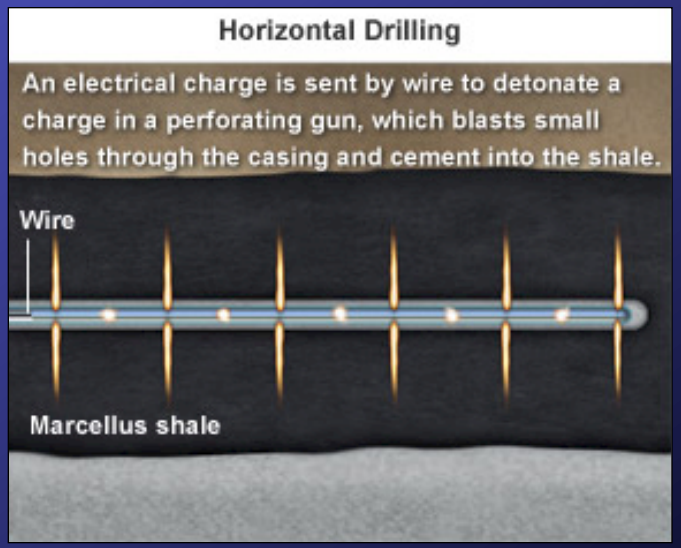



From Kostelnick (2010), modified from Schmoker and Oscarson (1995).

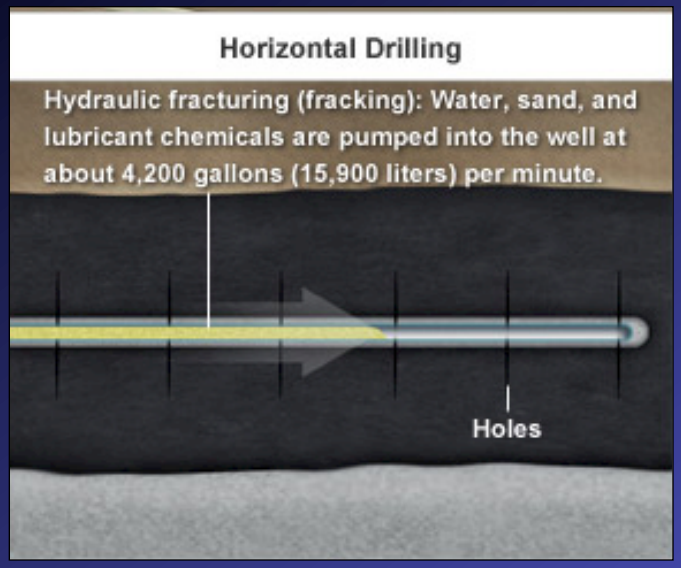


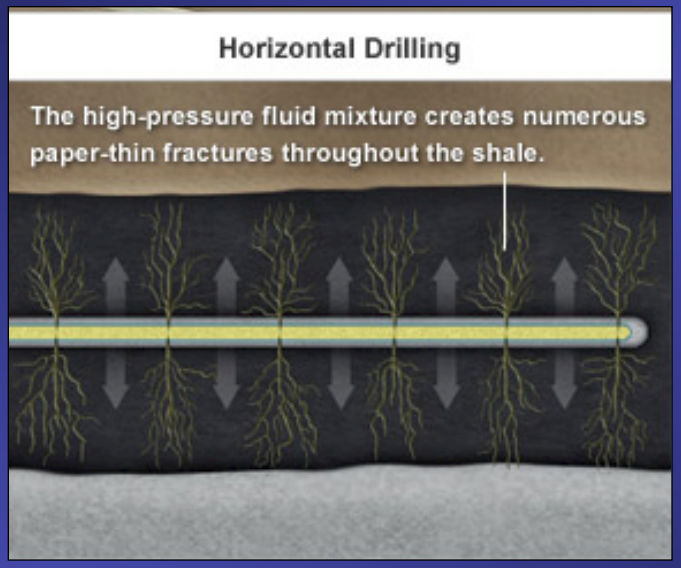



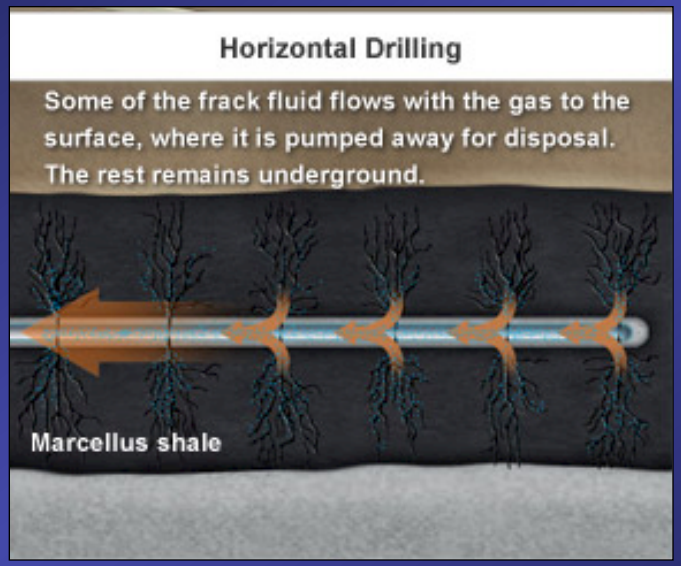



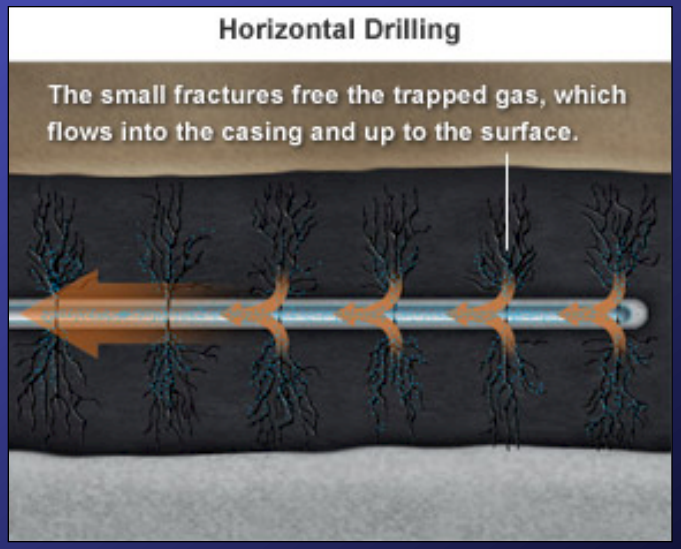




Graphics from National Geographic (2010).



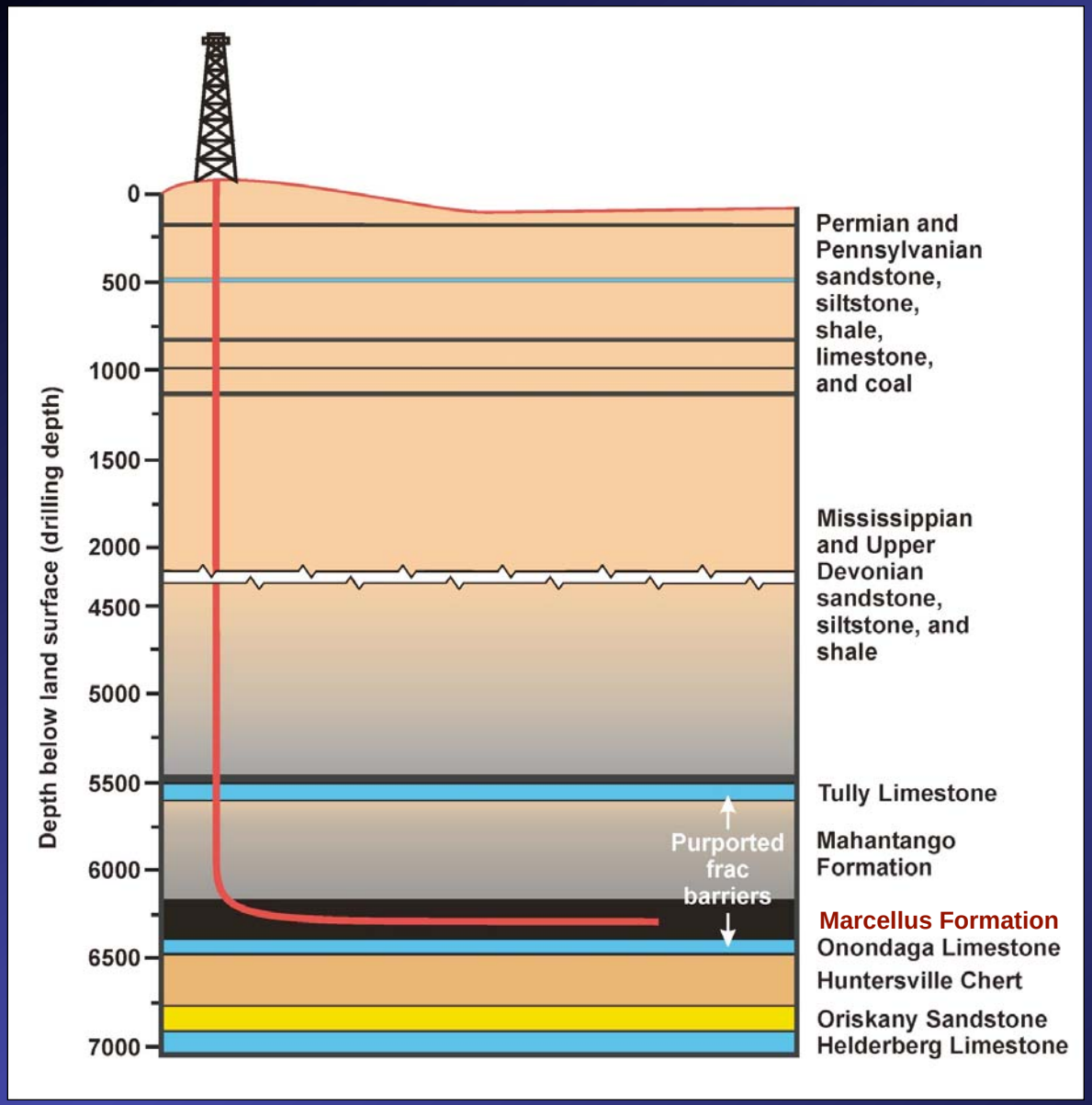




Graphics from National Geographic (2010).

# Frack Barriers



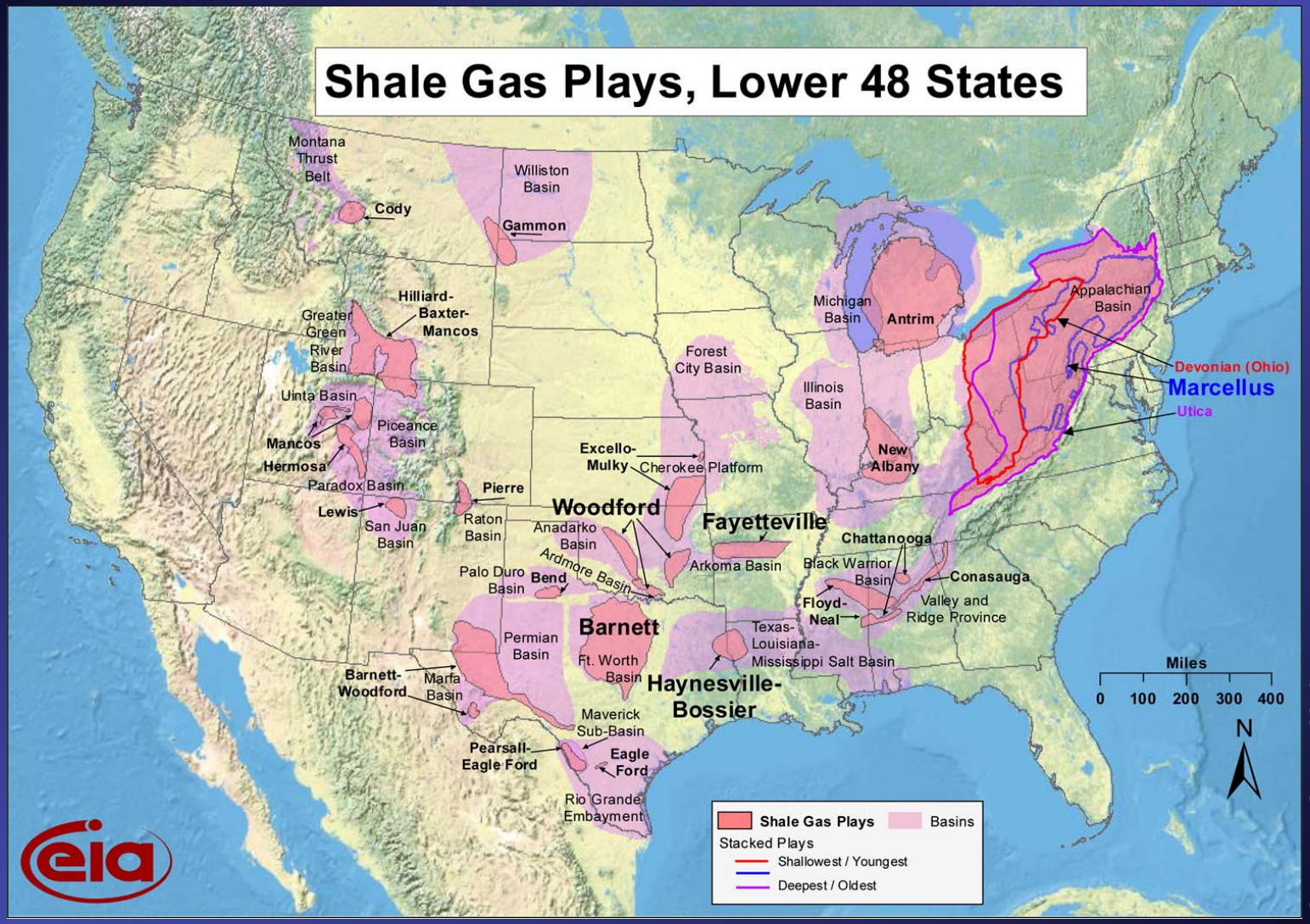

Graphic from Kostelnick (2010).

The horizontal leg of shale wells are thousands of feet below any ground-water layers. And thick layers of shale and limestone above and below the hydraulically generated fractures keep fractures from penetrating upward and downward into adjacent formations.

Graphic from Kostelnick (2010).

Pennsylvania: Aerial photo of a large Marcellus well frack job. The trailers contain the frack fluid to be used; the blue and white trucks are the pumping units.

# We are not alone….




Source: U.S. EIA, 2010.

Many shale gas plays are now developing across the United States and Canada.

# So, why is this a big deal?

- A “typical” conventional gas well in the Appalachian Basin produces 100–500,000 CF of gas per day and may produce 200–500 MMCF of gas in its life. (500 MMCF x $4/MCF* = $2M gross revenue.)

- Horizontal Marcellus wells may produce around 2–10 MMCF of gas per day and are projected to average around 4 BCF of gas over their life, per well. (4 BCF x $4/MCF* = $16M gross revenue.)

- So, due to large production increases, a play such as the Marcellus is reshaping our natural gas distribution networks and the way we ultimately may use natural gas. All of this new gas can lessen significantly our dependence on imported hydrocarbons.

*Calculations show total gas sales for life of typical example wells assuming sale price of $4 per MCF. Gas presently sells for $3.75 per MCF (10/28/10). Note that a typical horizontal well costs $3–5 million, and there are other significant costs to produce and transport gas to market.

**KEY** M = million MMCF = million cubic feet (or 1,000 MCF)
MCF = thousand cubic feet BCF = billion cubic feet

# A Brief History of the Marcellus “Play”

# So, how did the play happen?

- Devonian shale gas has been produced in the Appalachian Basin since the late 1800s. First known production was 1821 in Fredonia, New York.
- Most earlier Devonian Shale “plays” concentrated on shallower, high-organic zones, especially zones with high frequencies of natural fractures.
- The Marcellus had been noted for spotty areas of sustained production in Pennsylvania and with strong shows in Ohio.

# So, how did the play happen?
**(cont'd)**

- The "new" Marcellus shale play began in 2003, when Range Resources drilled a well through the Marcellus down to the Lower Silurian in Washington County, Pennsylvania. Targeted reservoirs were not productive, but the Marcellus showed promise and was successfully completed in 2004.

- Range drilled additional wells, experimented with drilling and hydraulic fracturing techniques first used in Texas, and began producing Marcellus gas in 2005. Since then, the company has permitted many Marcellus wells in Washington County alone.

- Competitors took note, followed suit, and began the lease play. Soon, there was a buzz in the industry.

# So, how did the play happen?

**(cont'd)**

- In late 2007, Penn State put out numerous press releases of research by Dr. Terry Engelder and SUNY collaborator Dr. Gary Lash; first estimate of recoverable gas was 50 trillion cubic feet (TCF).
- This helped bring mainstream media into play, which increased the visibility and hype tremendously.
- Lease prices, already getting very high, went through the roof —some reaching $6,000/acre.
- Since 2005, the Pennsylvania Dept. of Environmental Protection has issued over 4,500 permits for Marcellus wells.
- Engelder & Lash have increased their estimate to ~450 TCF.

# So, how did the play happen?
**(cont'd)**

- Leases—which for years had been a "standard" $25/acre for 5 years with a 12.5% royalty—began climbing.
- Leases eventually went through the roof with some as high as $6,000/acre with a 15–20% royalty. Major companies with larger budgets began taking an interest in the Appalachian basin.
- Ironically, for decades many major companies viewed the Appalachian Basin as not promising. Now these companies scramble to pick up leases, buy out existing operators, and learn the geology and engineering characteristics of the rocks.

# The Marcellus Shale: Some Basic Geology

# Typical Organic-Rich Shale

# Devonian Depositional Environments

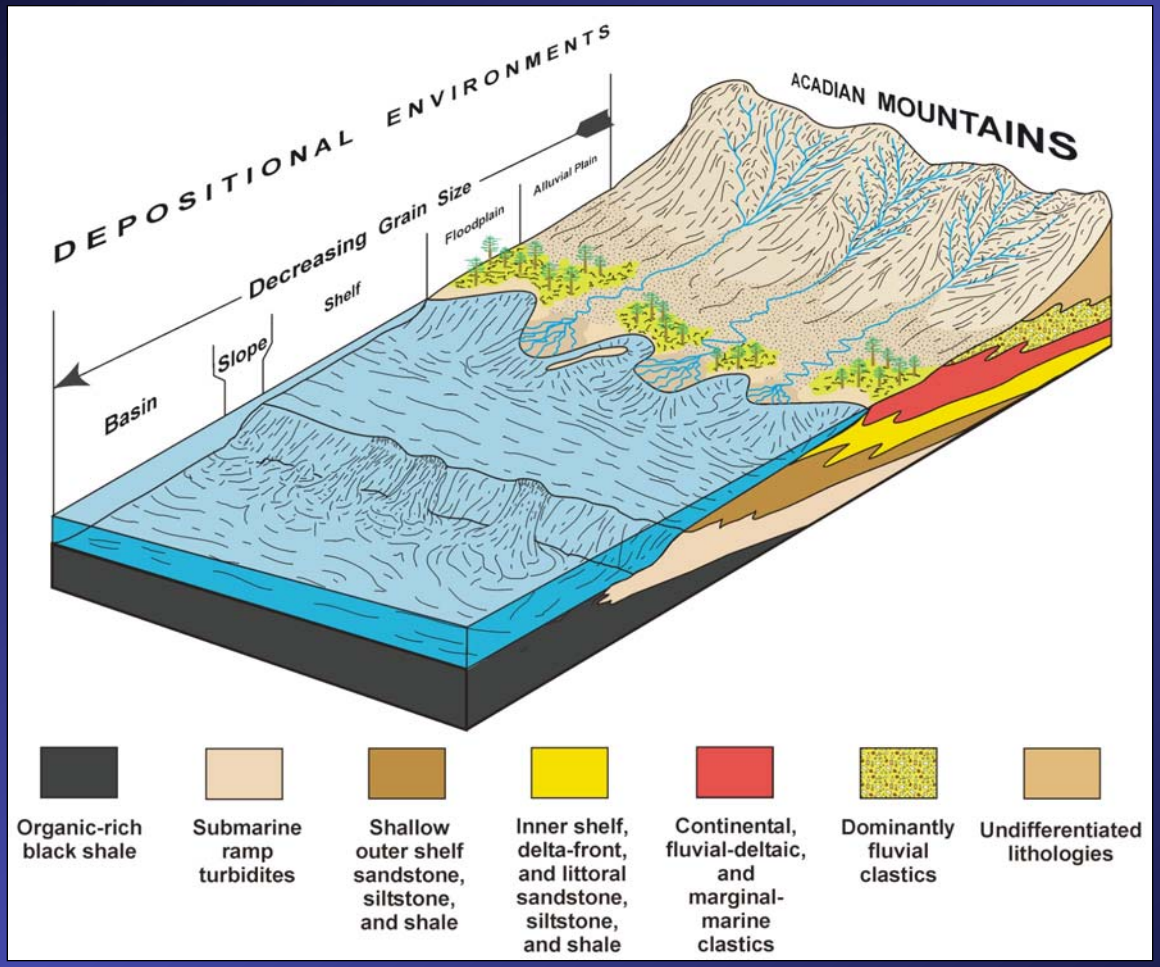


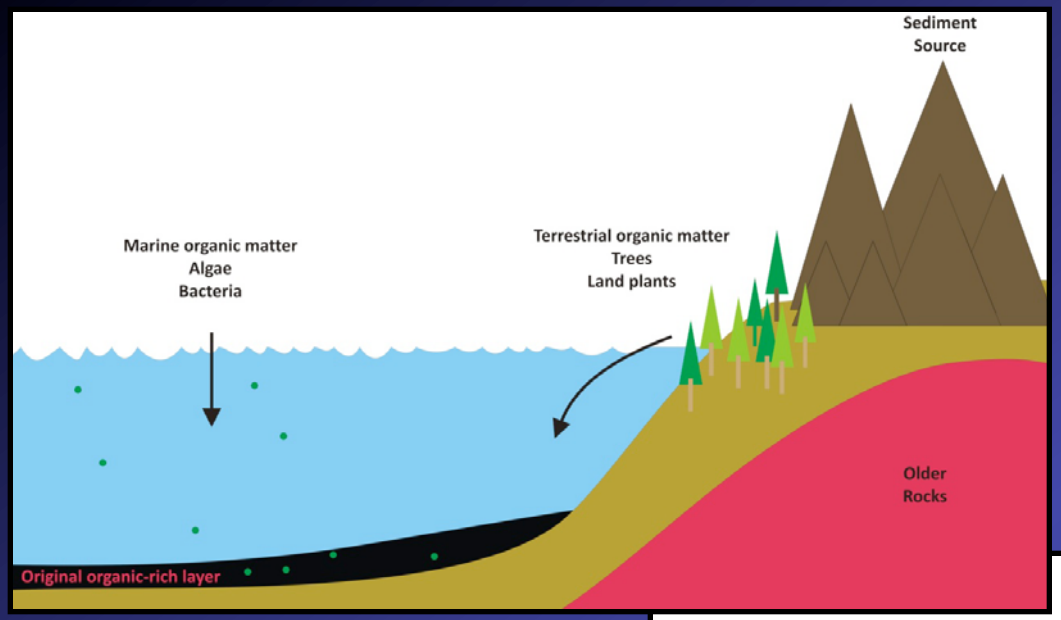

Figure attributed to Laughrey (2009) from Kostelnick (2010).

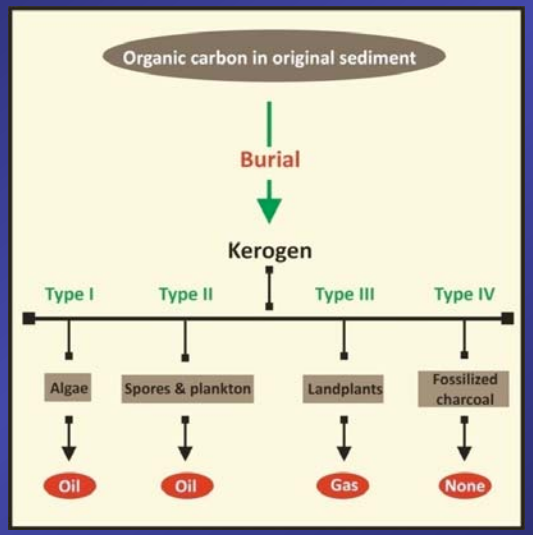
During the Acadian mountain-building event, sediments were shed from the highlands into a somewhat enclosed basin (resulting in lower amounts of oxygen available). The fine-grained sediments and organic remains that settled in the deeper part of this basin were later buried and became the gray and black Devonian shales we find today.

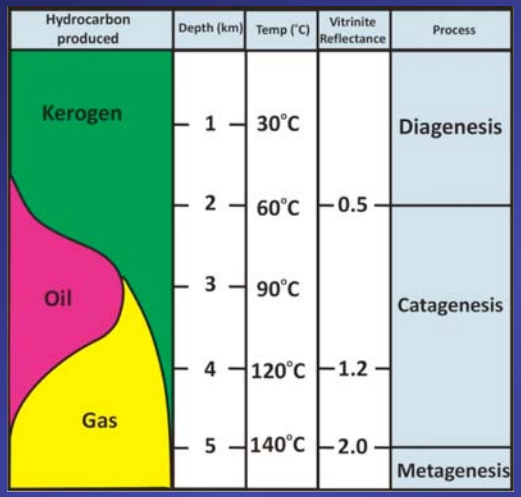
# Middle Devonian (385 MA) Paleogeography

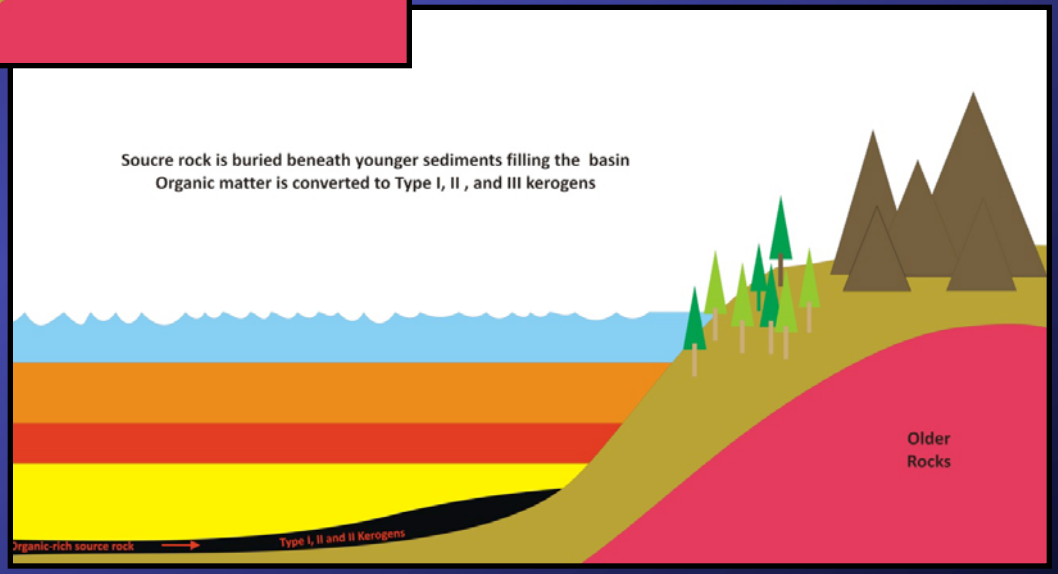

Graphic modified from Blakey (2009).

A view of what the geography of eastern North America is thought to have looked like during deposition of the Devonian shales.



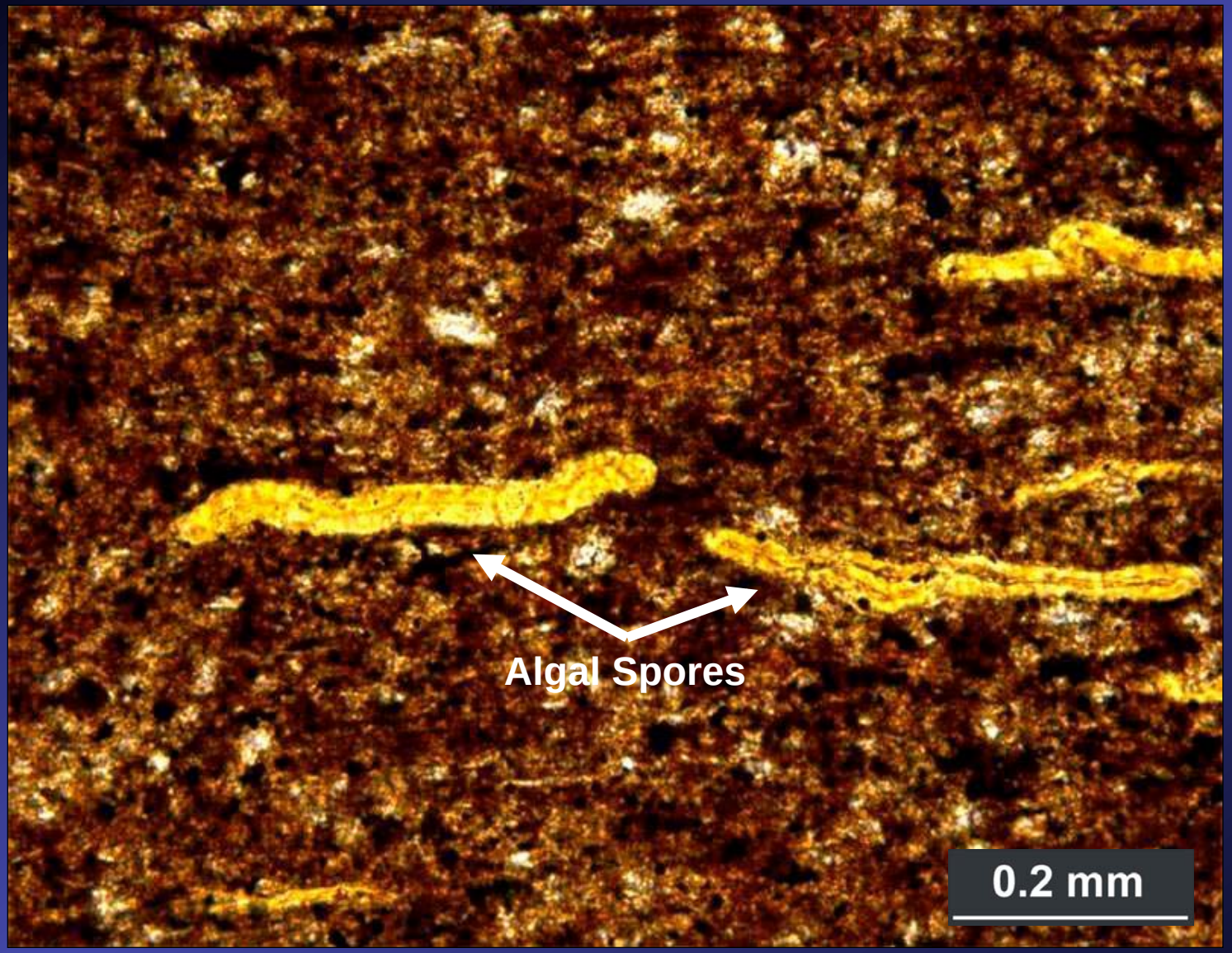

From Kostelnik (2010).

Shale must contain organic carbon to generate gas or oil. Organic-carbon type determines if shale is gas or oil bearing. Burial depth and maximum temperature also impact the amount of gas vs. oil present in a hydrocarbon-bearing shale.

# Important Shale Characteristics
## (Impact Likelihood of Recoverable Gas)

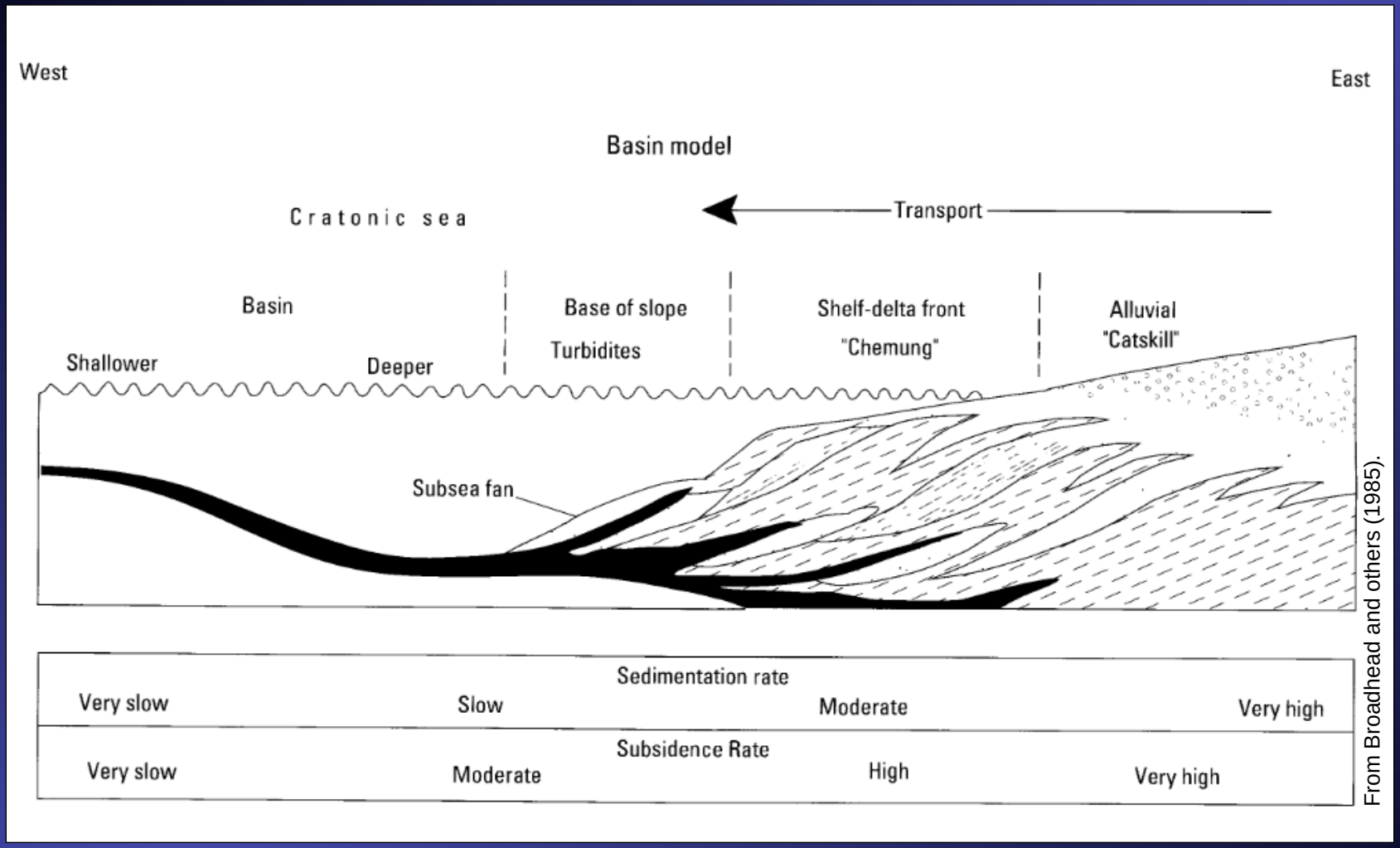
- Where and how much is present.
- How much organic matter it contains.
- Type of organic matter (gas vs. oil-rich shale).
- Clay and other minerals it contains.
- How deeply it was buried & “cooked.”
- Its brittleness vs. ductility (break or bend).
- How fractured it is (natural fractures).

All of these characteristics change in a shale formation across its areal extent.

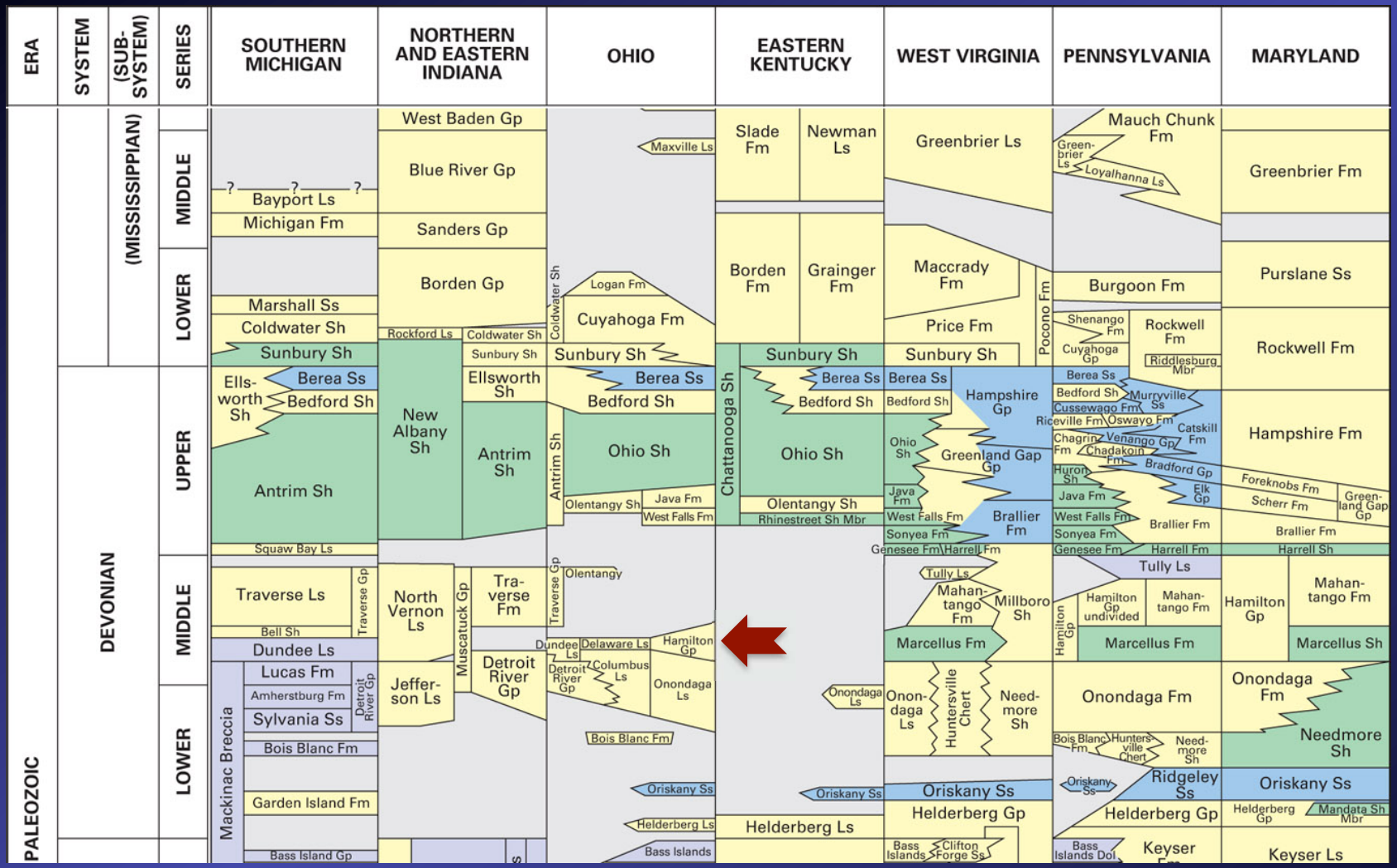



From Kostelnik (2010).

Highly magnified thin section of a piece of organic-rich shale showing extremely fine grain size and organic components (black in the matrix and yellow algal remains).

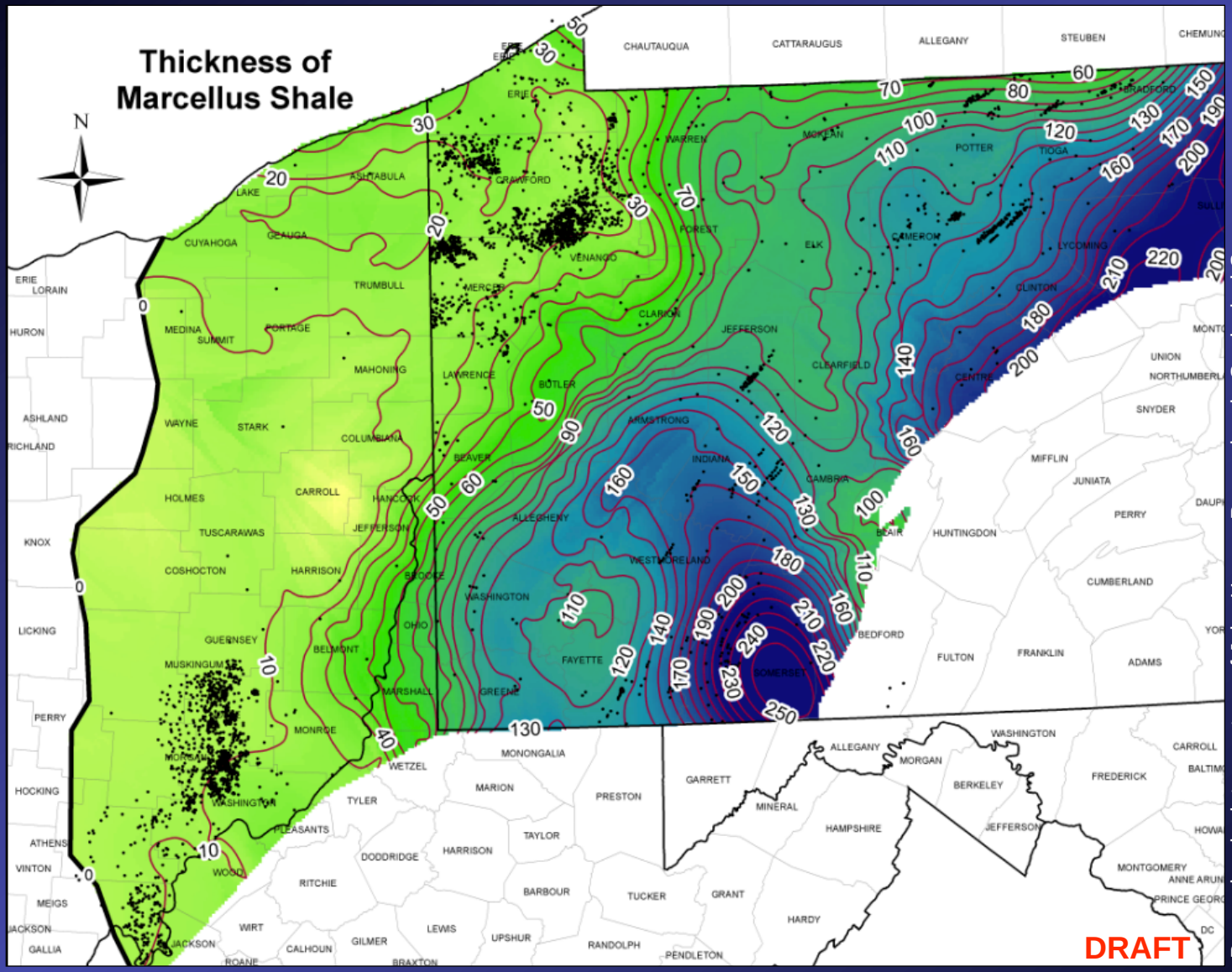



Devonian shale depositional model in cross-sectional view.



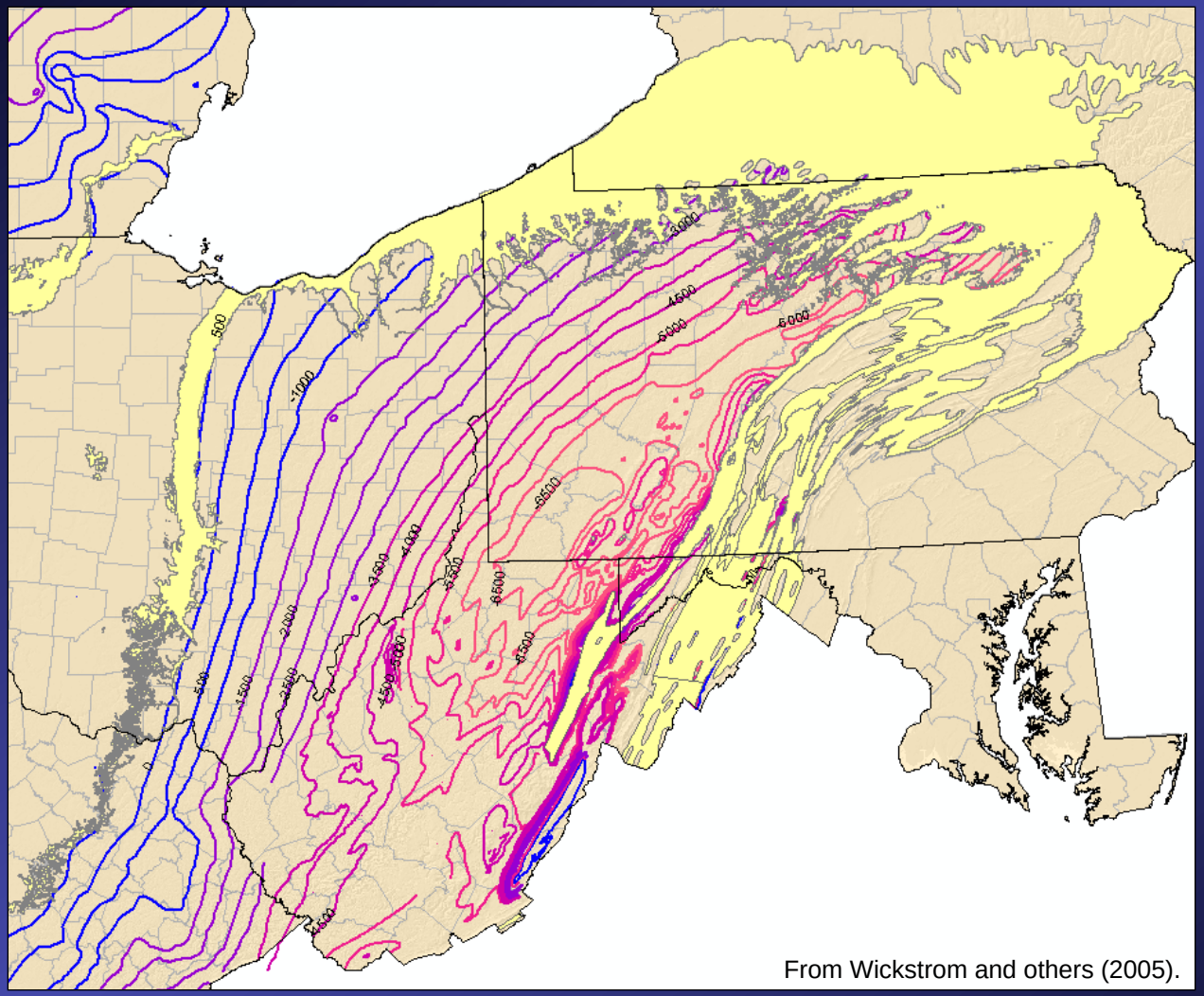

From Wickstrom and others (2005).

Multistate correlation chart showing the equivalent Devonian strata for the northern Appalachian basin, Cincinnati Arch, and Michigan Basin. The Marcellus thins as it enters Ohio—it is shown on this chart as part of the Hamilton Group (red arrow).



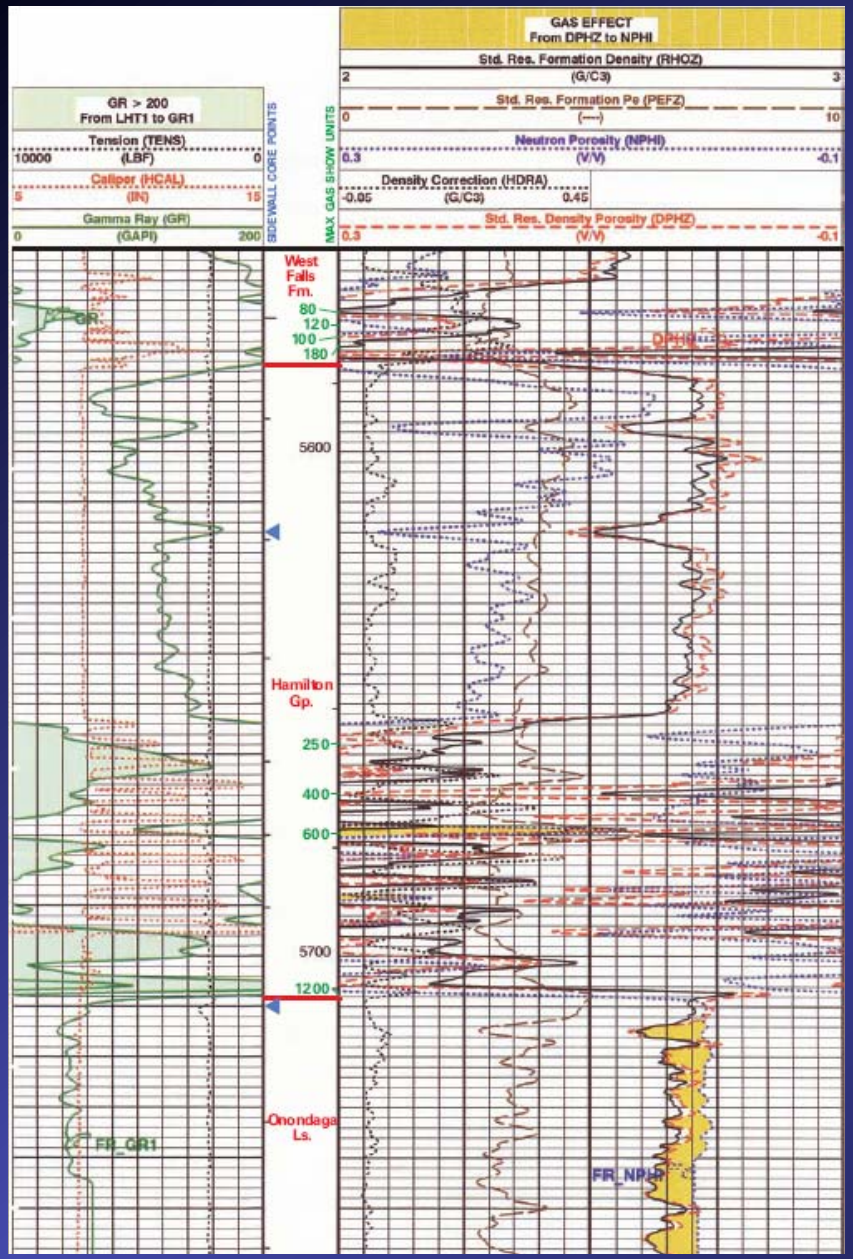

There is not a great deal of area in Ohio where the Marcellus is thick.

# Devonian Shale Outcrop and Structure on the Onondaga Limestone (Big Lime of Ohio)




From Wickstrom and others (2005).

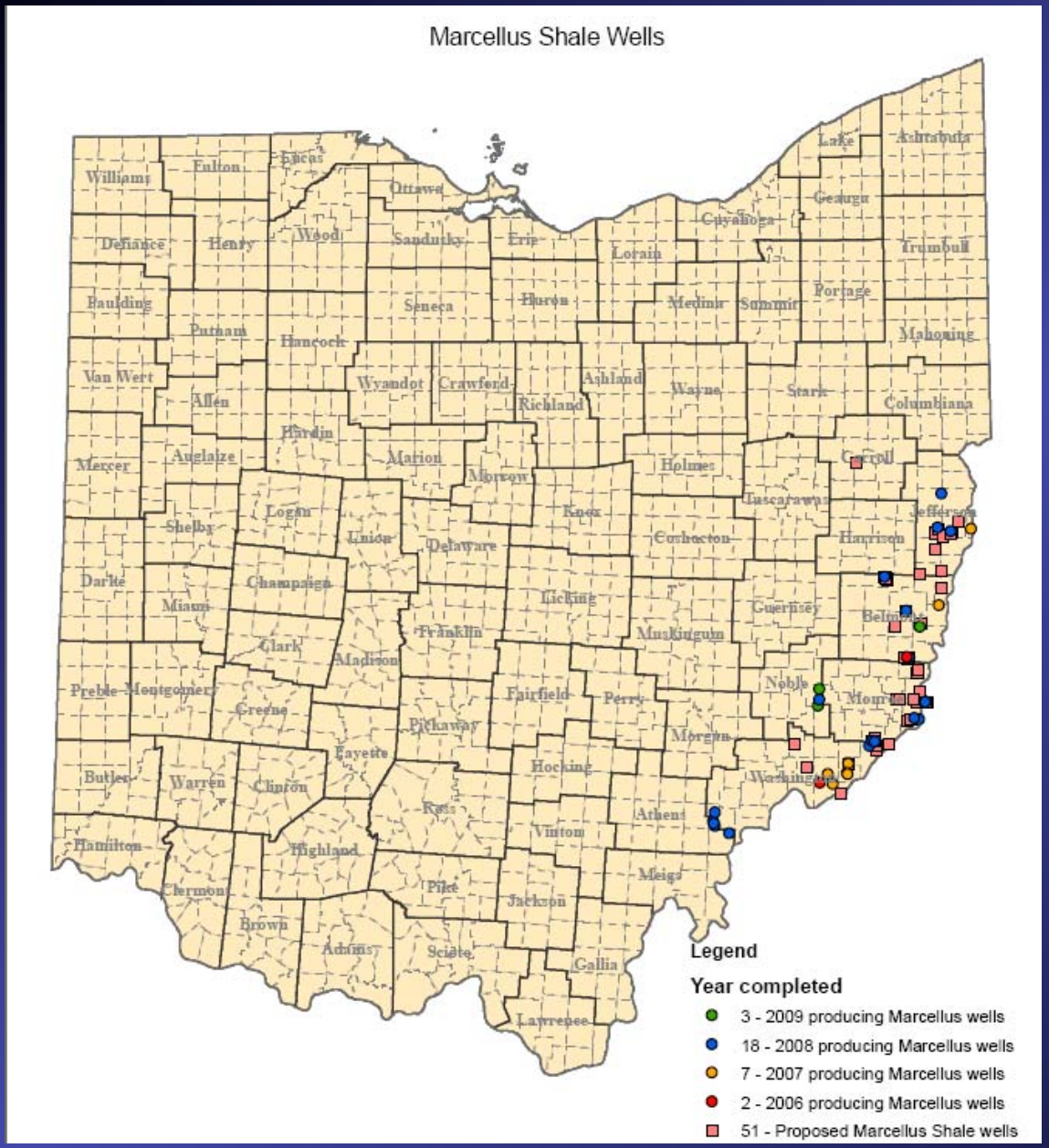
For approximate drilling depths to the base of the Marcellus, add your topographic elevation to these depths.



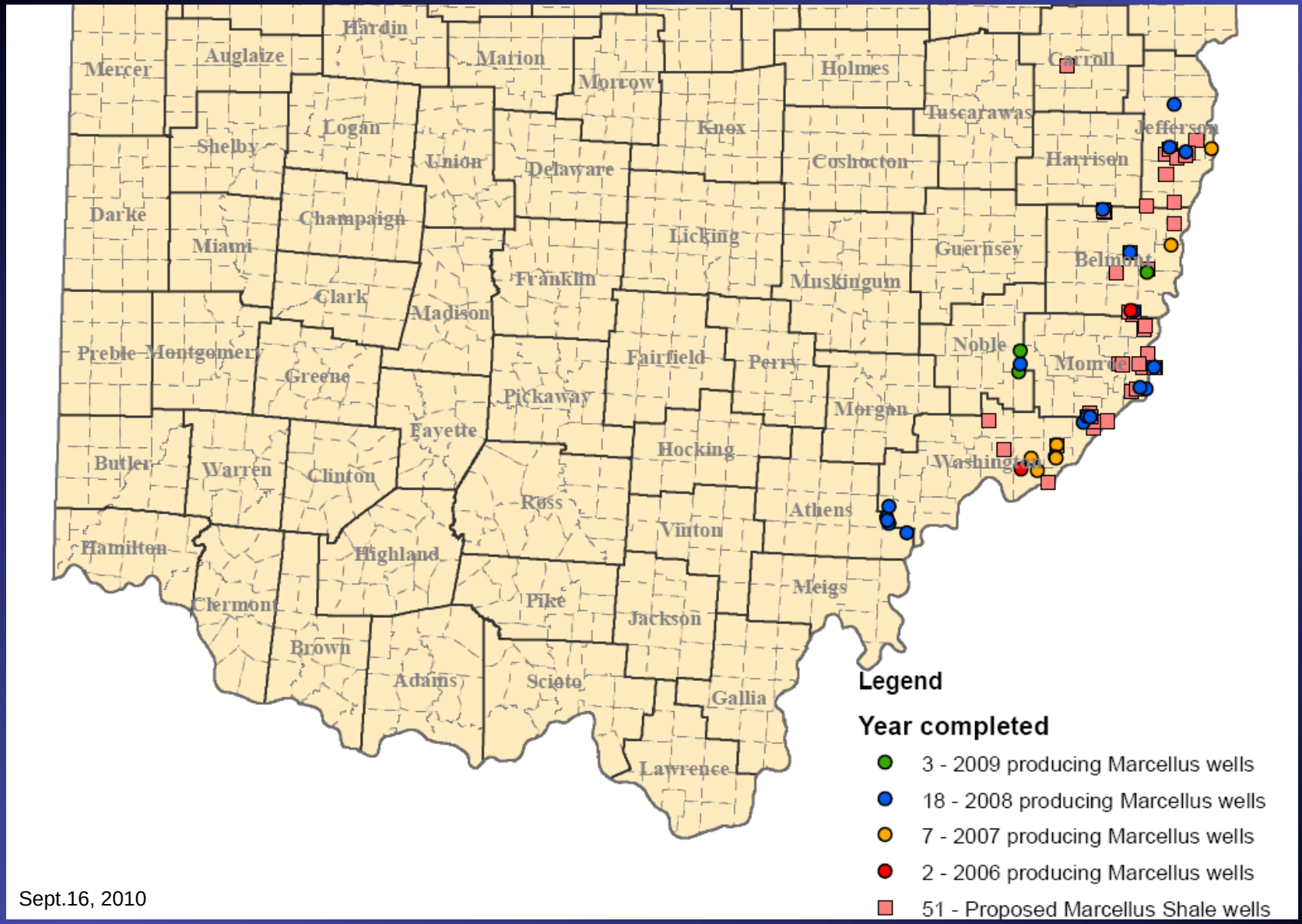

From Perry (2009).

Logs and gas shows from the First Energy, R.E. Burger well, Belmont County, Ohio.

Marcellus ~58′ thick
Max. gas show at base = 1,200 units




Map showing the locations of Marcellus Shale wells drilled or permitted in Ohio, 2006–Sept. 2010.




A zoomed-in view of the previous map.

# Acknowledgments


- USGS Open-File Reports
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  - John Harper & Jamie Kostelnik
- Ohio Geological Survey
  - Larry Wickstrom, Joe Wells, Ron Riley, Donovan Powers, Stephen Kelley

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