A Tale of Two Shales
Marcellus and Utica Mudrocks

Geoscience Contributions to Well Architecture
Key Parameters to
Evaluate and Optimize Productivity

Timothy Carr, Guochang Wang and Taylor McClain

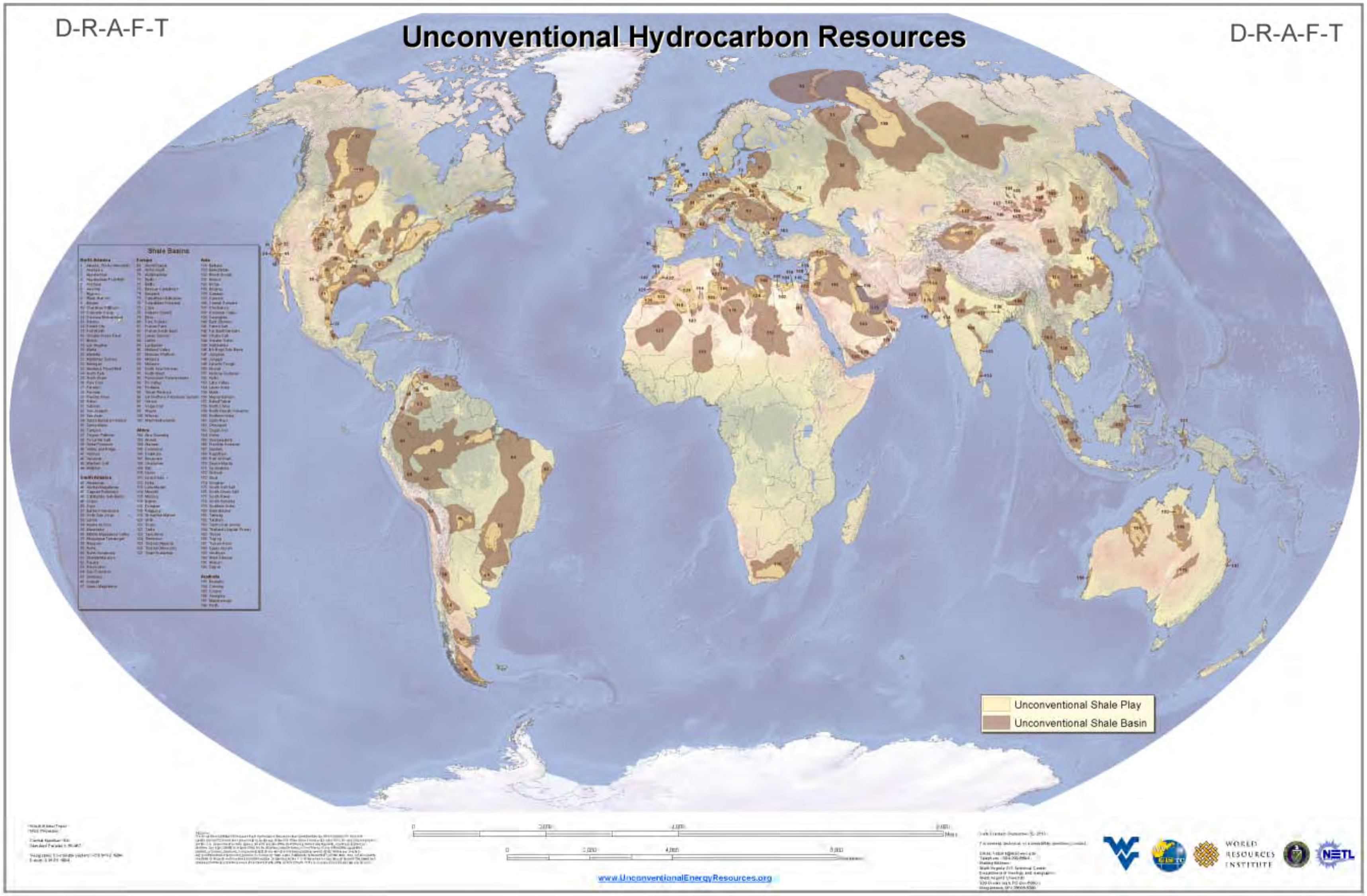
Successful Mudrock Plays

- Function of Drilling Intensity and Cost Reductions
- Technology can reduce cost and increase production
  - Steerable Rotary Bits
  - Length and Optimal Placement of Wellbores
    - Direction and Spacing
  - Number and Placement of Stages and Clusters
  - Better Definition of Most Productive Core Areas
    - Concentrate Drilling Effort Then Push Beyond
  - Better Definition of Target Zones
    - Ability to Stay in Zone
- Geoscience Contribution to Well Architecture

Successful Mudrock Plays
Key Geologic Parameters

- Understanding Resource, Reserves & Productivity
- Subtle Changes Mudrock Reservoir Properties
  - Distribution of Organic Content
  - "Fracability"
    - Mineralogy
    - Containment
  - Structural Discontinuities
    - Faulting and Geosteering
  - Present Stress Regime / Past Stress Regimes
    - Stimulated Reservoir Volume
  - Maturity
    - Fluid/Gas Type
    - Influence on Reservoir Porosity and Permeability

North America Mudrock Basins



http://www.unconventionalenergyresources.com/

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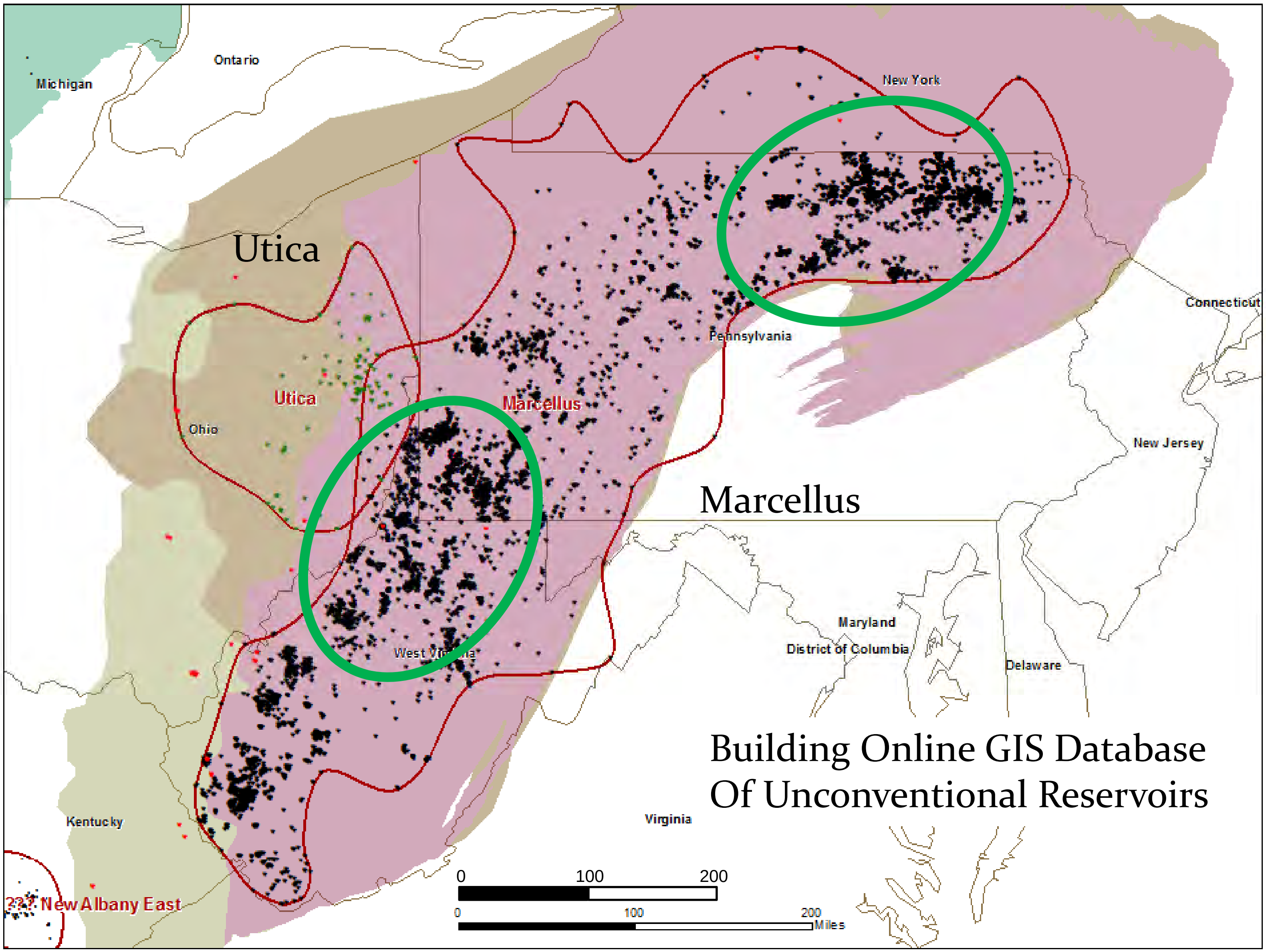
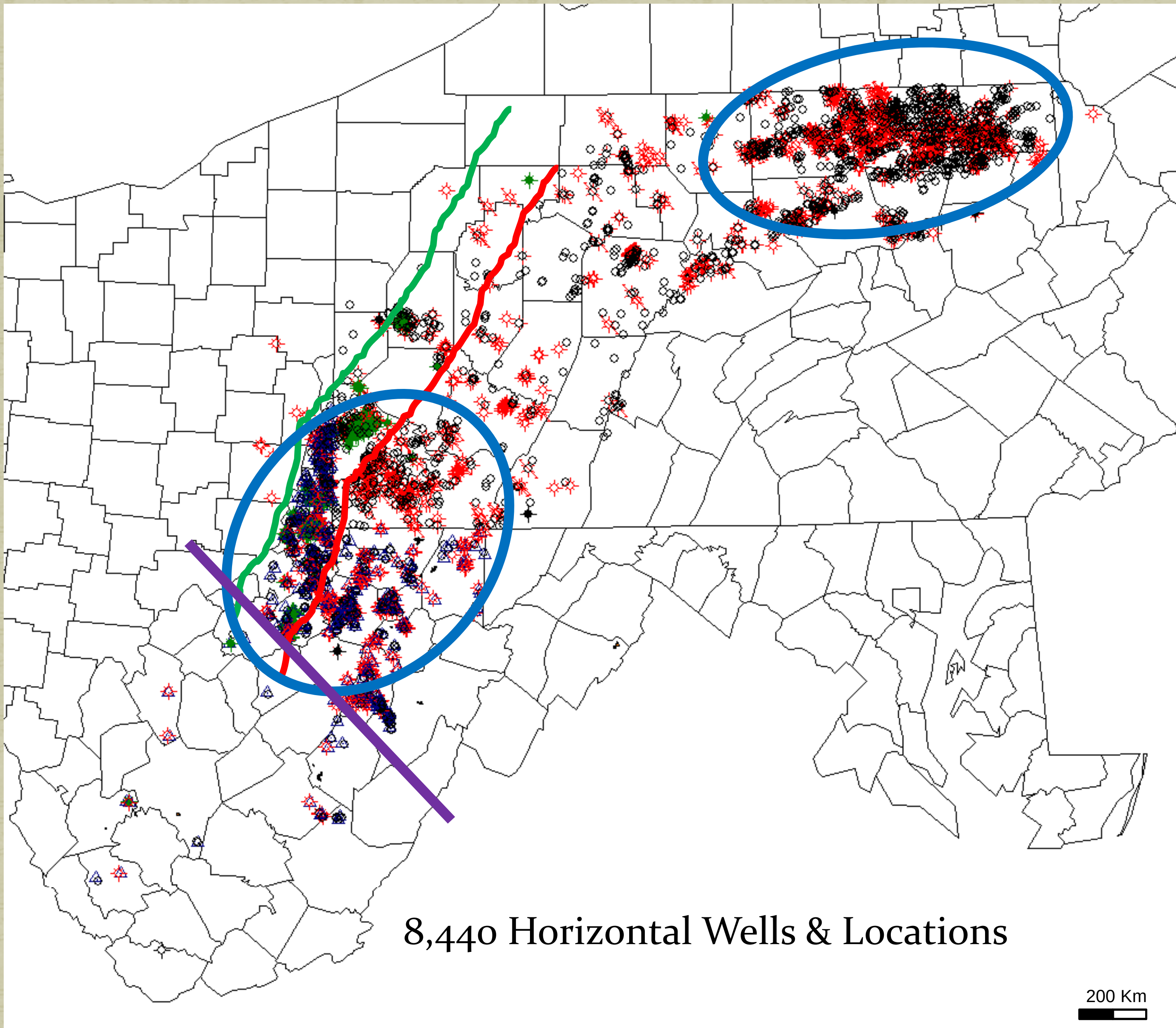
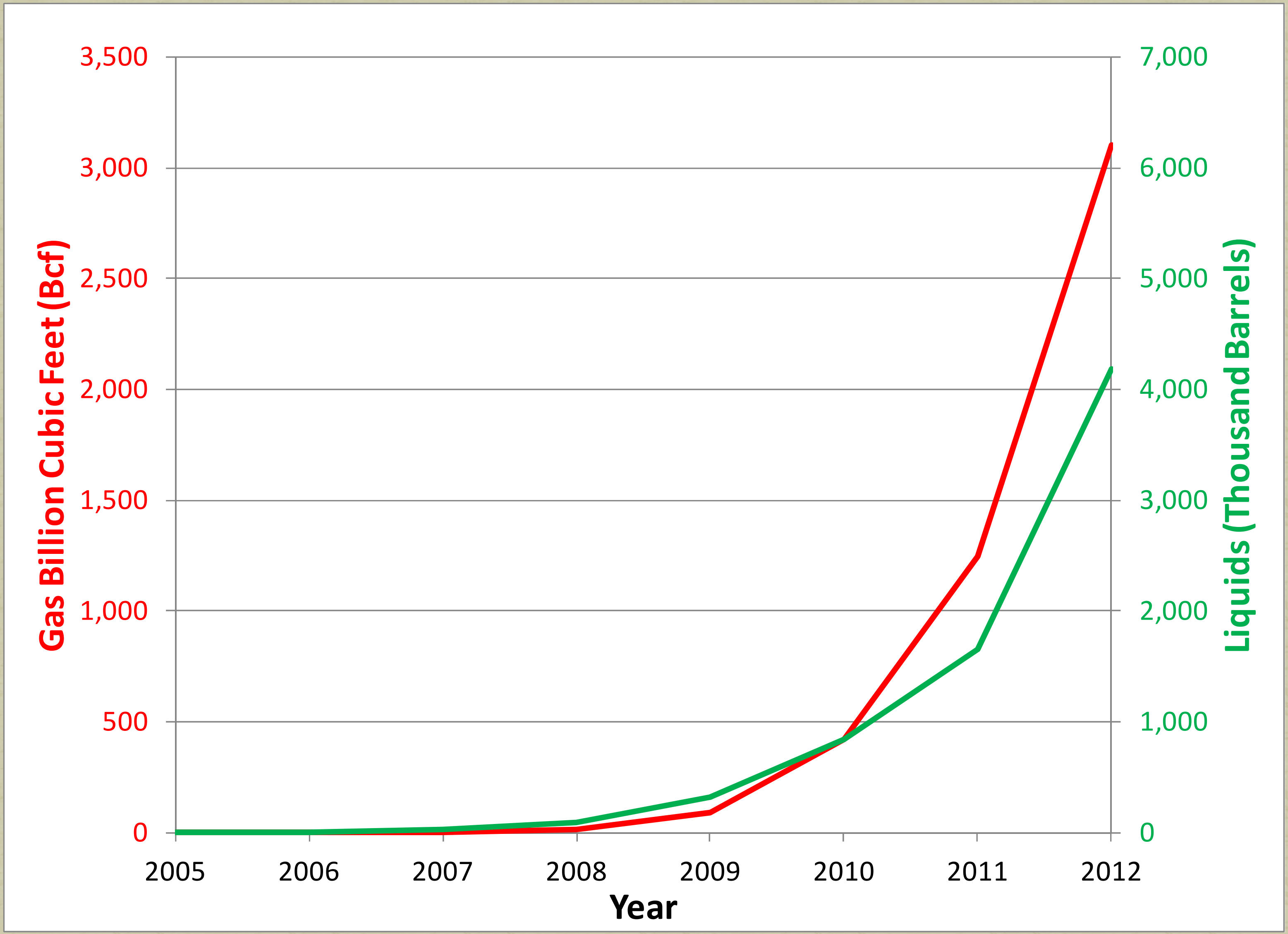


http://www.unconventionalenergyresources.com/

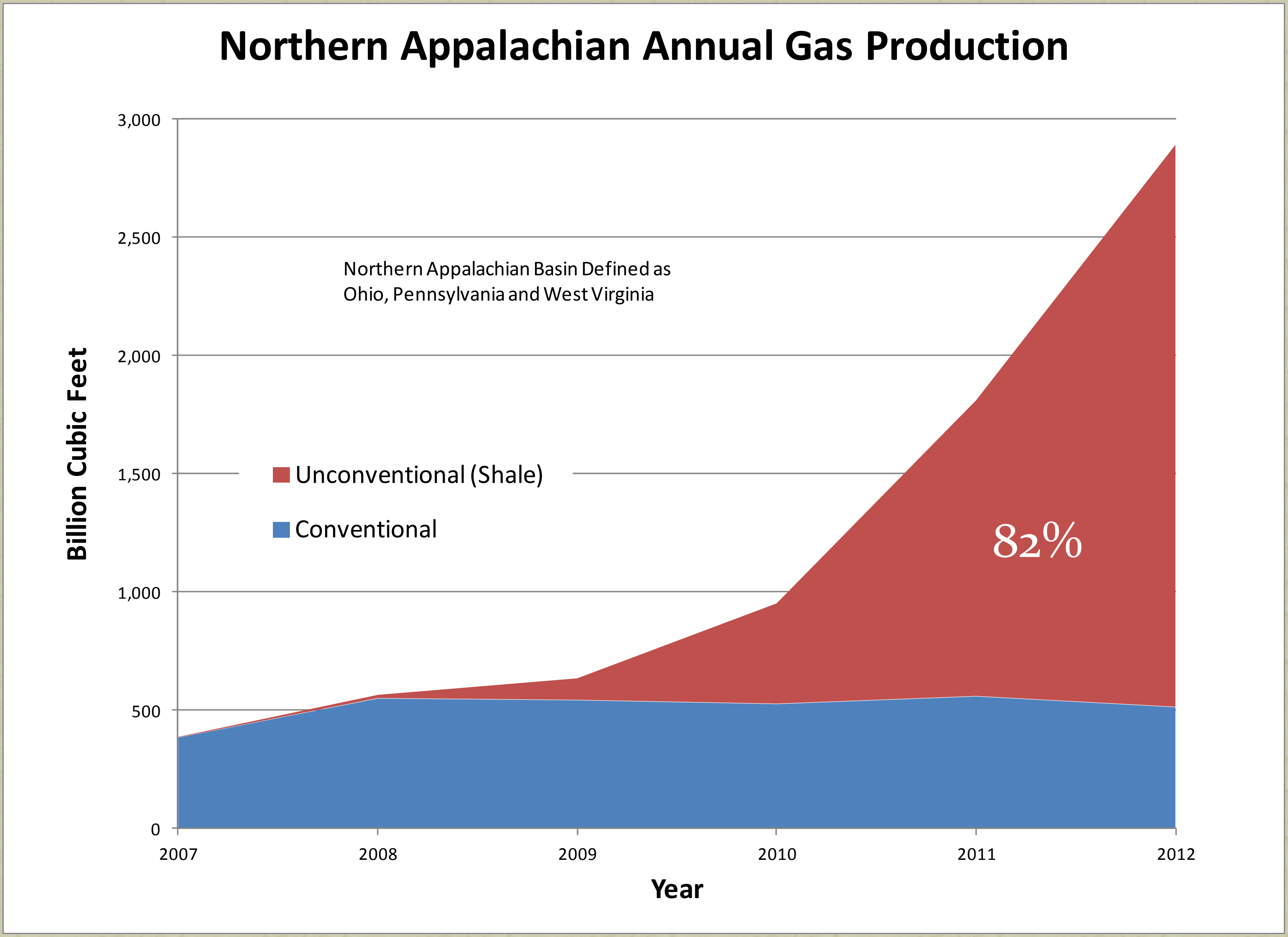
Marcellus Horizontal Wells Through 2012



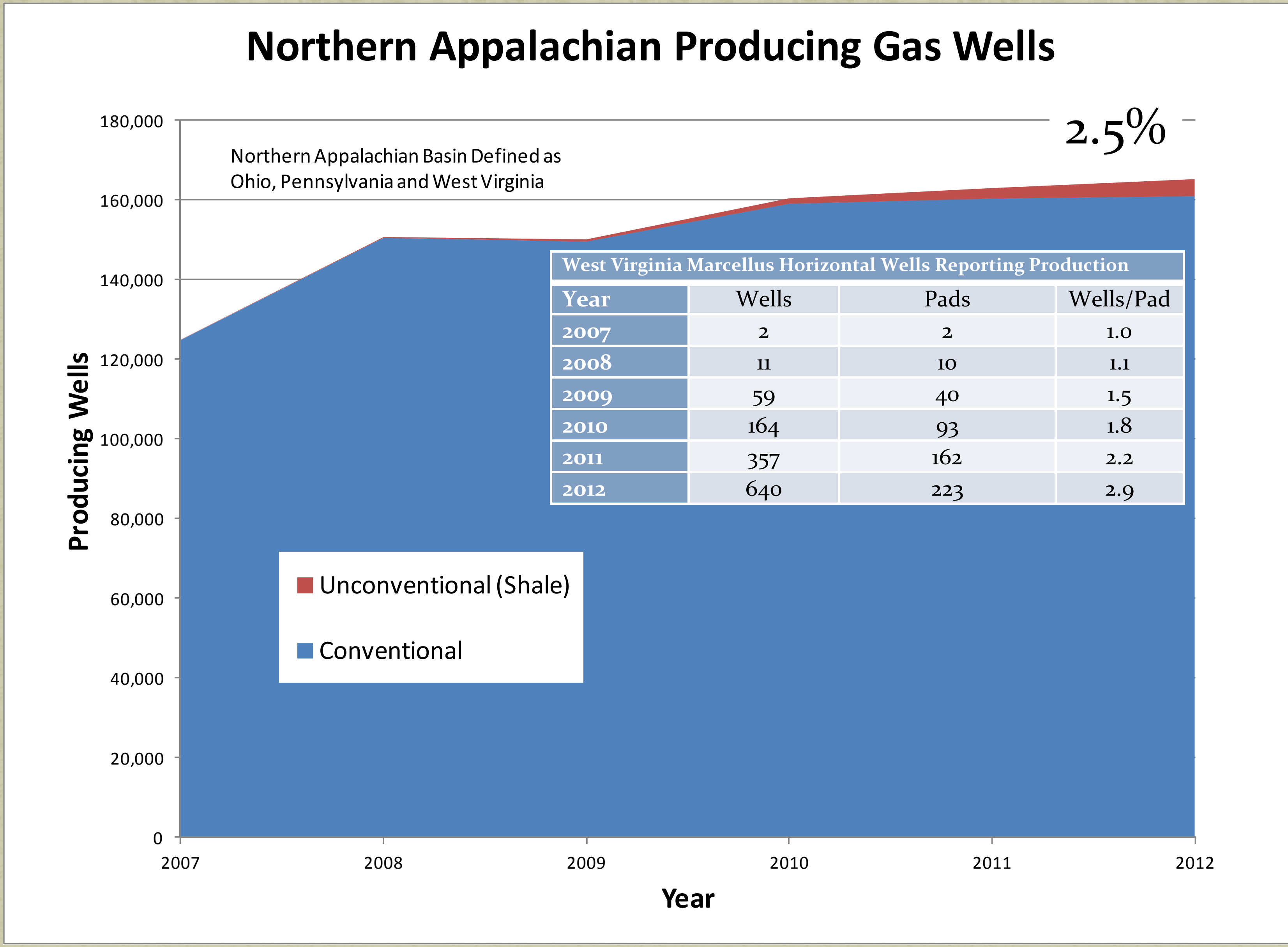
Marcellus and Utica Production



Marcellus and Utica Production



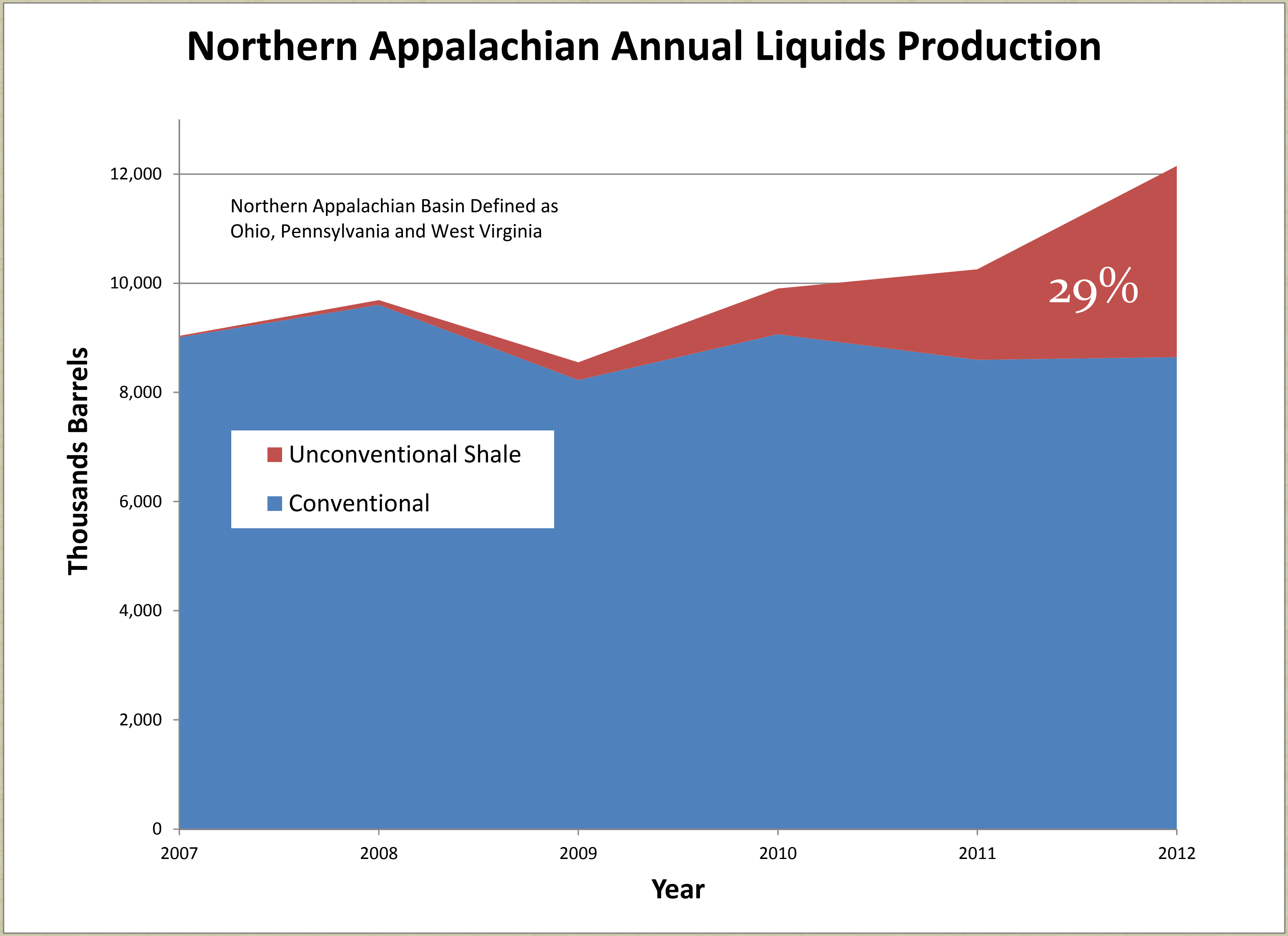
Marcellus and Utica Production



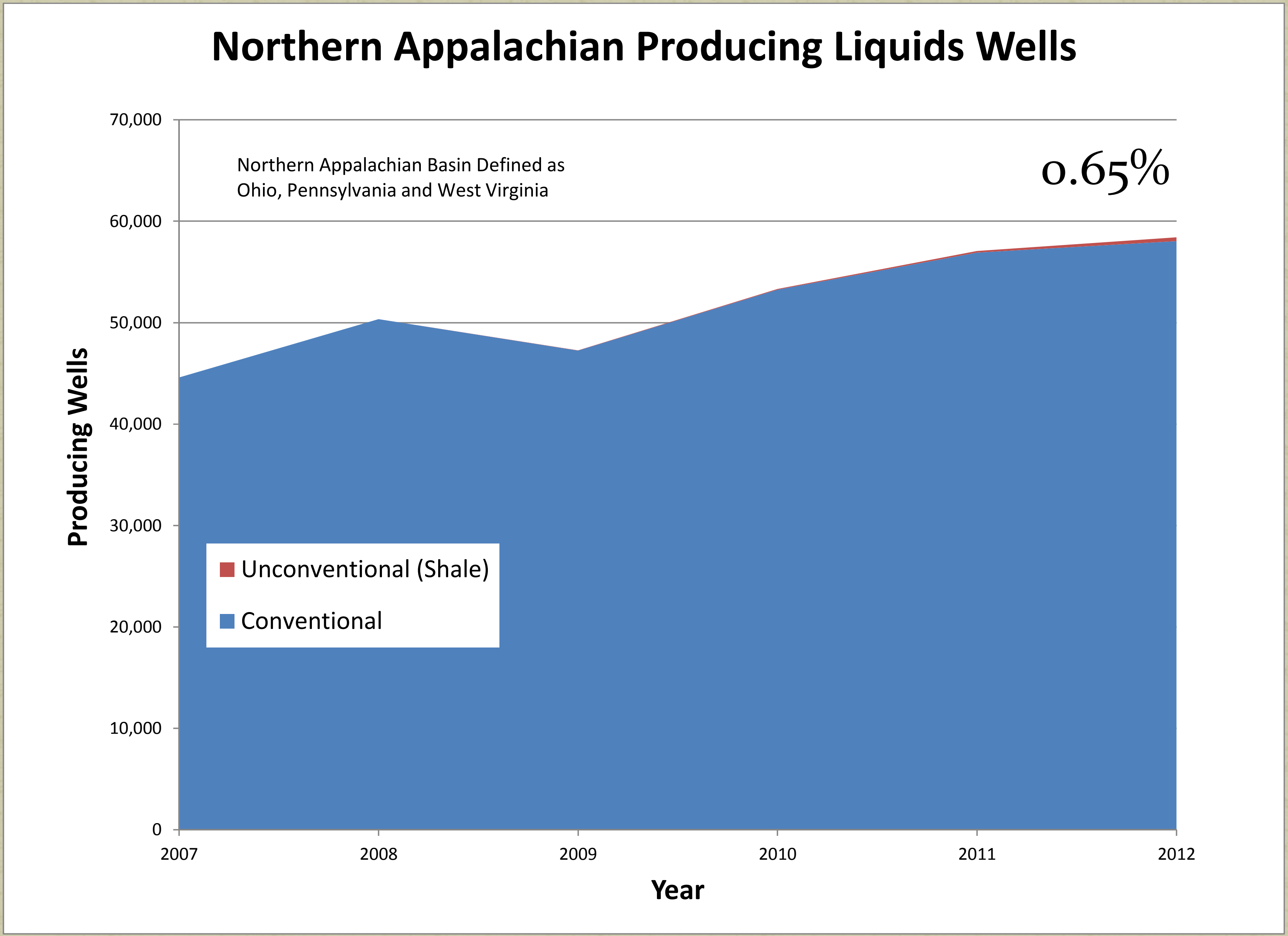
West Virginia Marcellus Horizontal Wells Reporting Production

Year	Wells	Pads	Wells/Pad
2007	2	2	1.0
2008	11	10	1.1
2009	59	40	1.5
2010	164	93	1.8
2011	357	162	2.2
2012	640	223	2.9

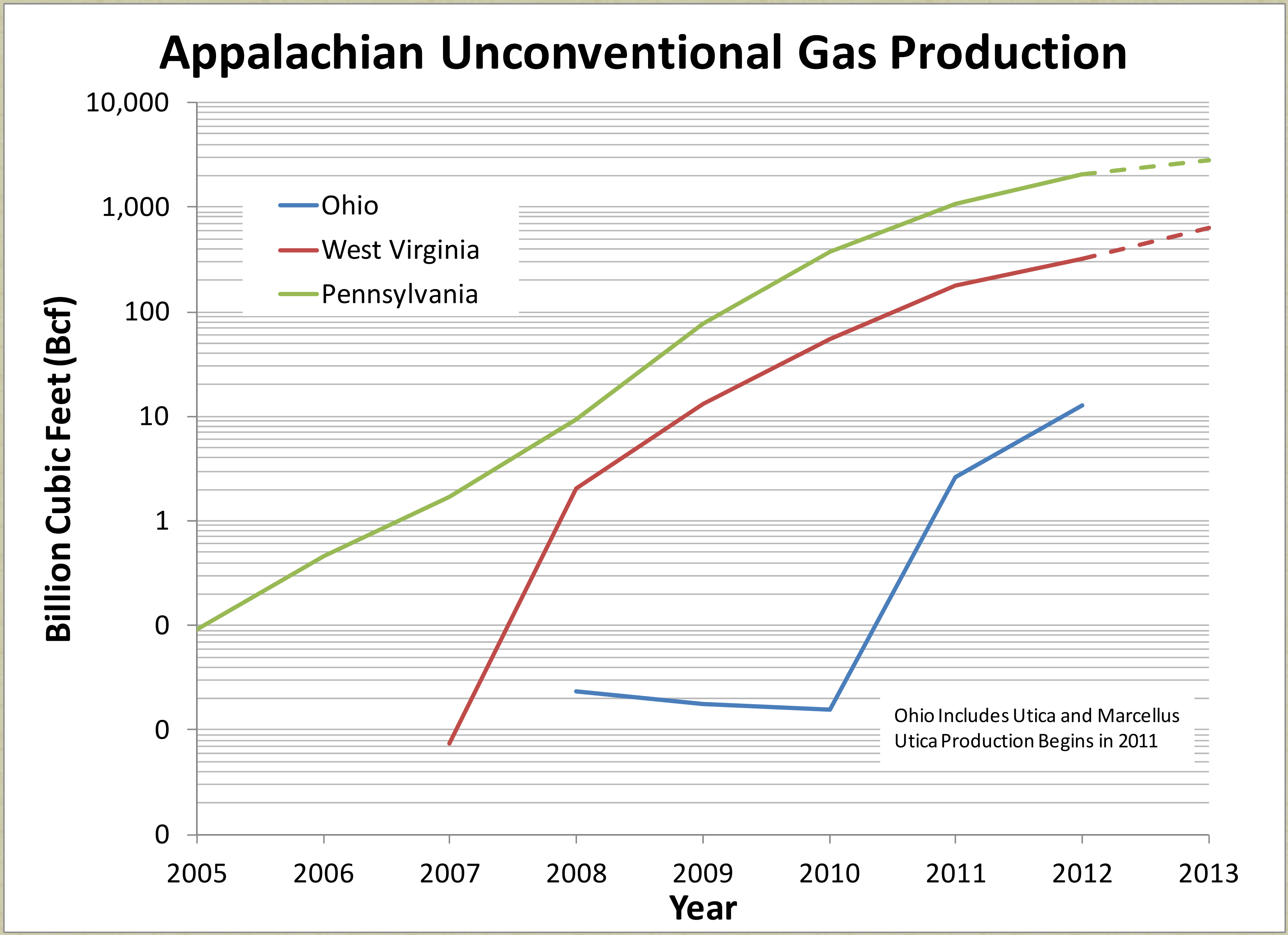
Marcellus and Utica Production



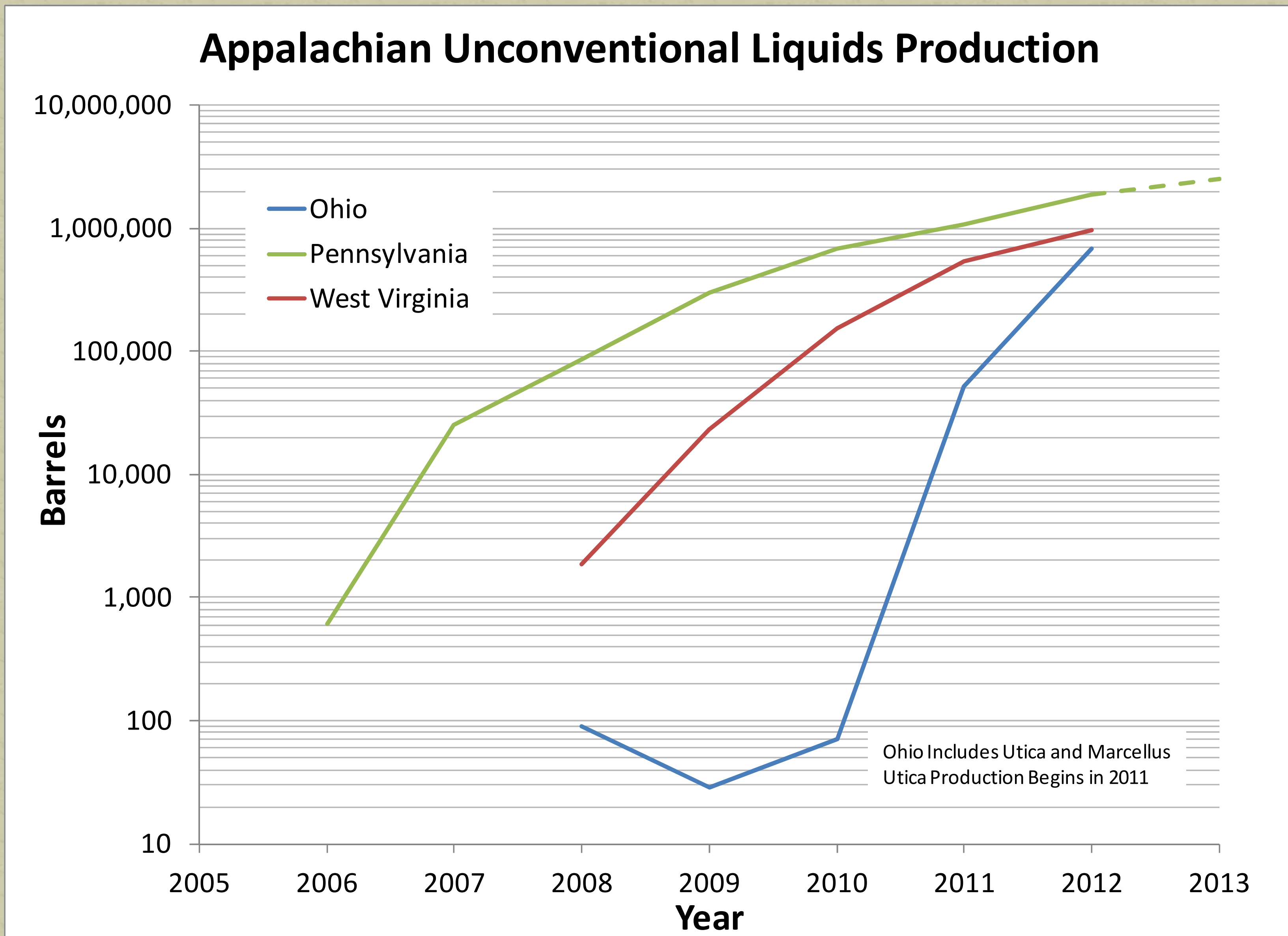
Marcellus and Utica Production



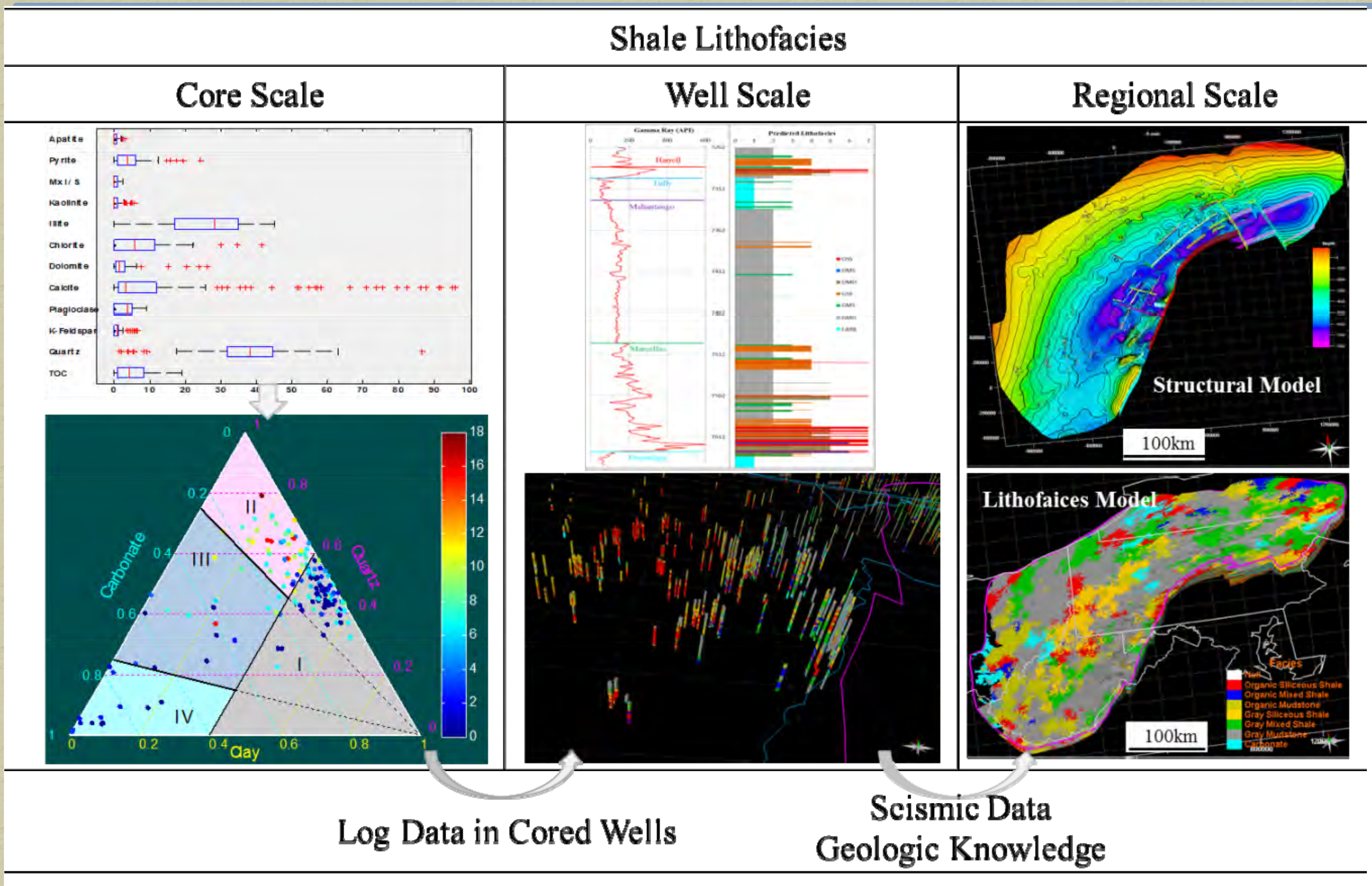
Marcellus and Utica Production



Marcellus and Utica Production

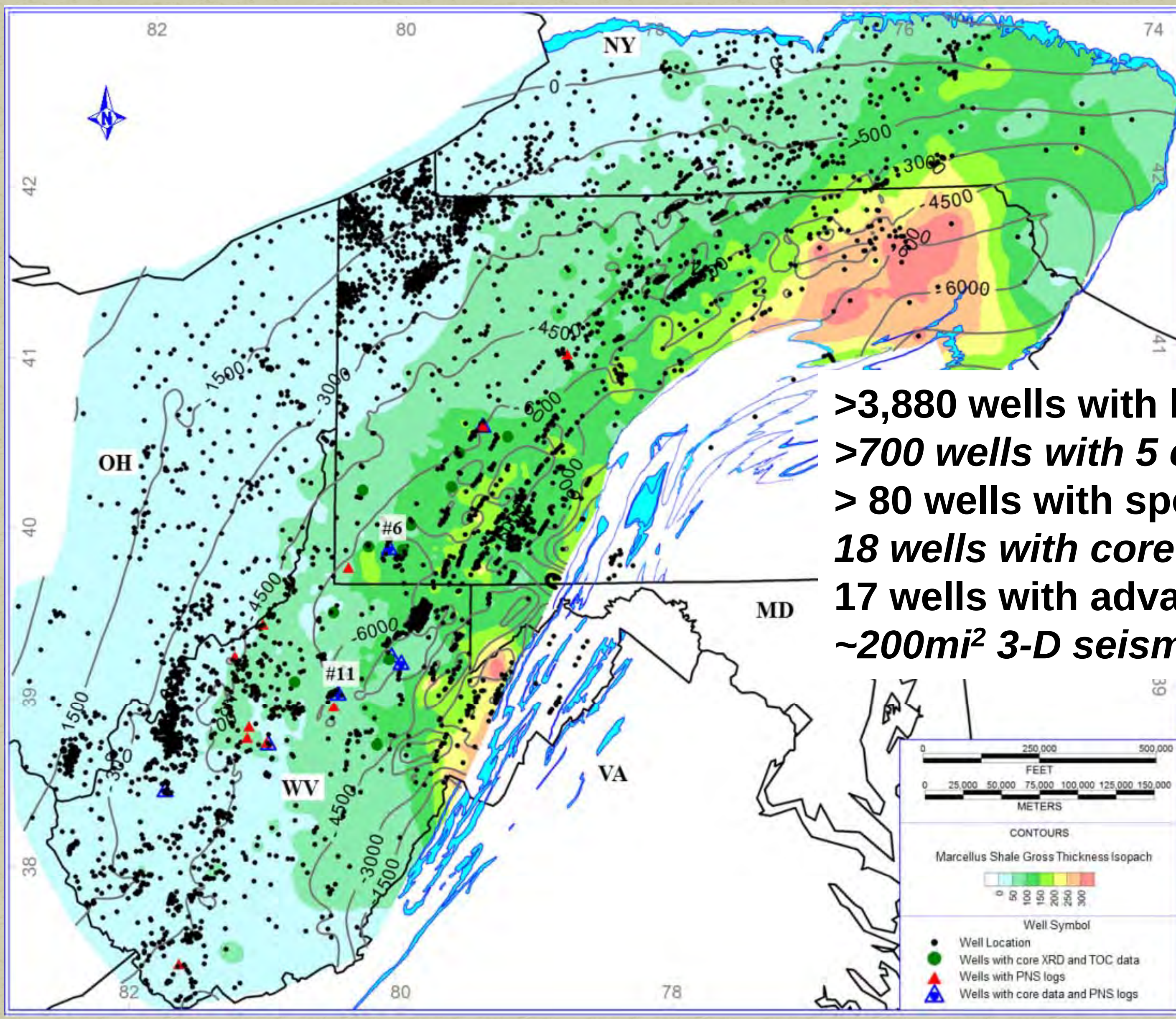


Predicting Mudrock Lithofacies



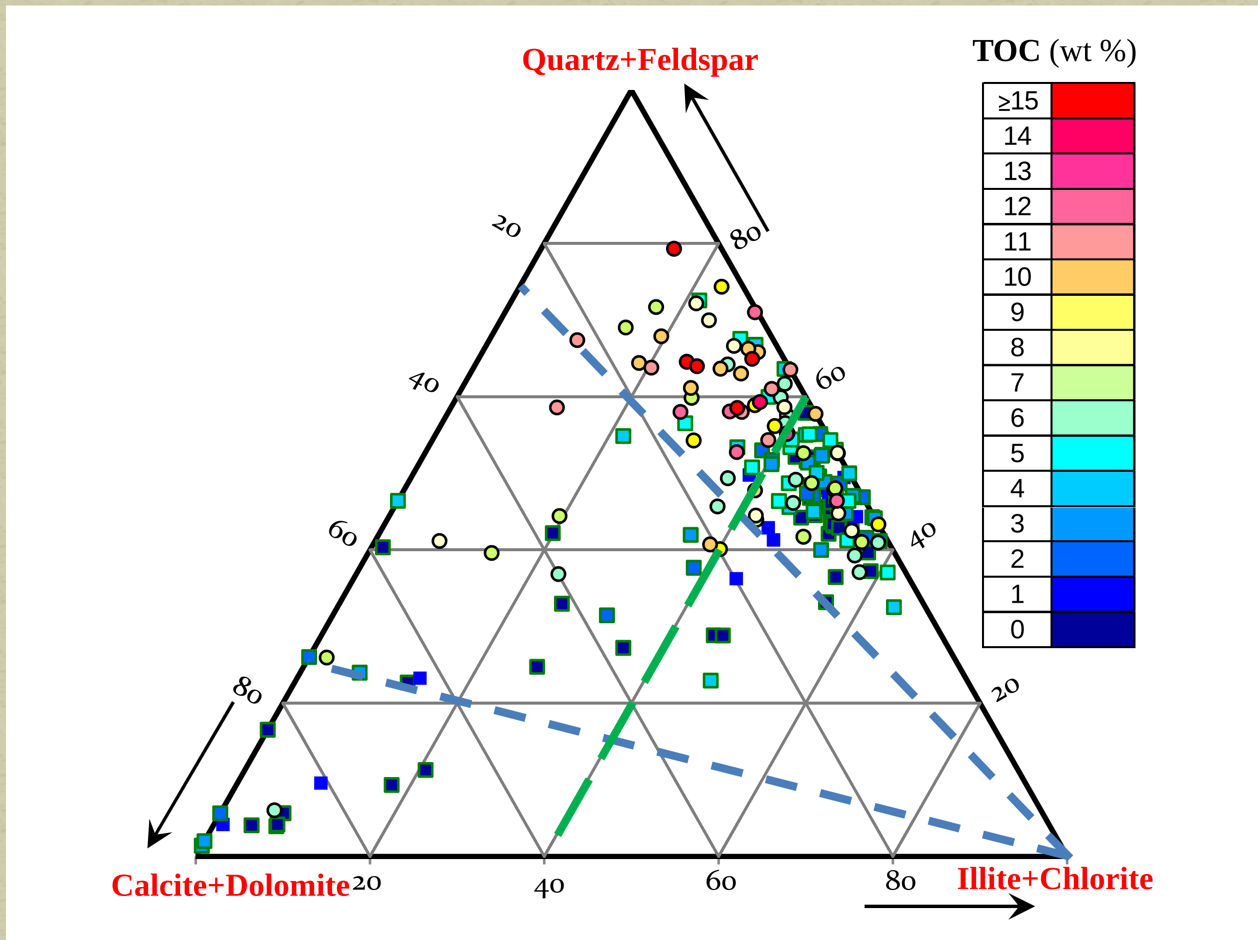
Wang, 2012

Geologic Setting and Database



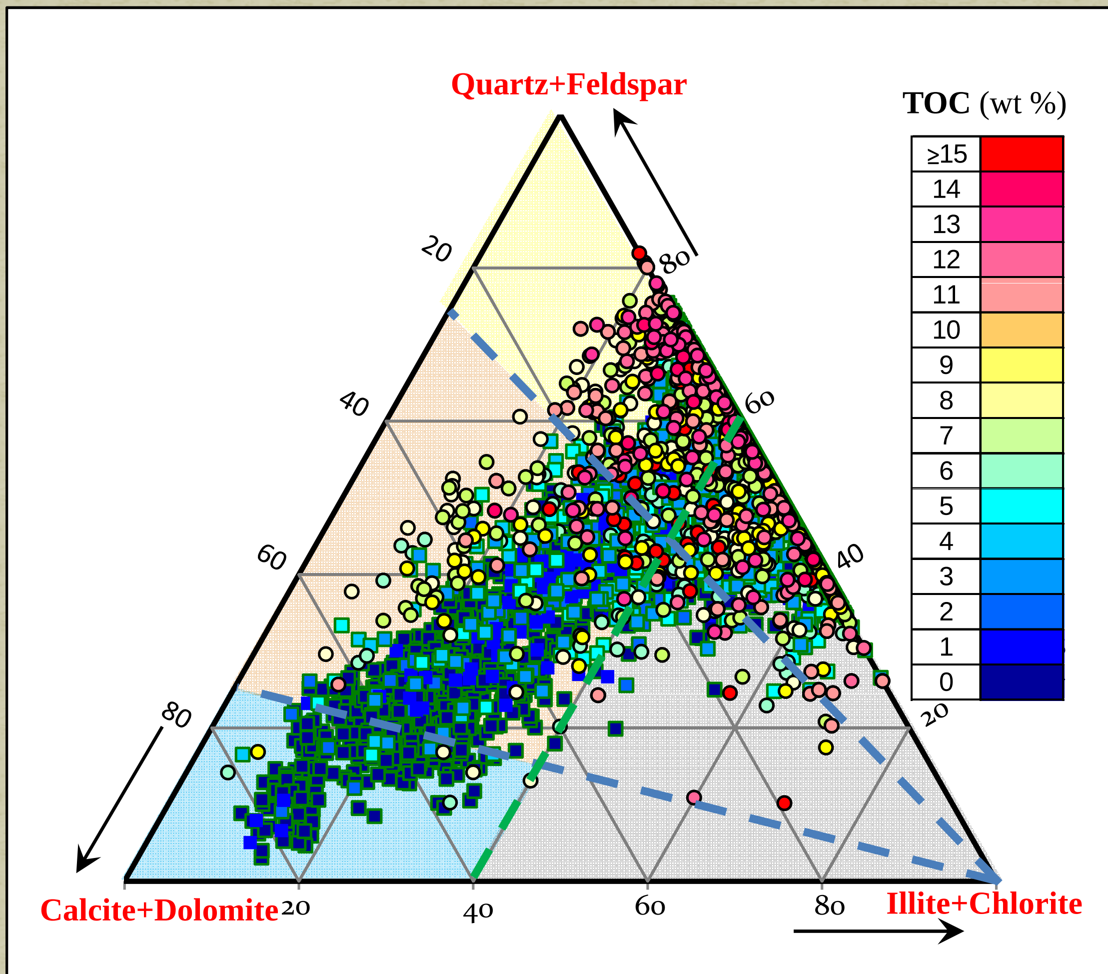
>3,880 wells with logs
>700 wells with 5 common logs
> 80 wells with spectral GR
18 wells with core data
17 wells with advanced logs
~200mi² 3-D seismic

Lithofacies Identification - Core



Lithofacies Identification - PNS

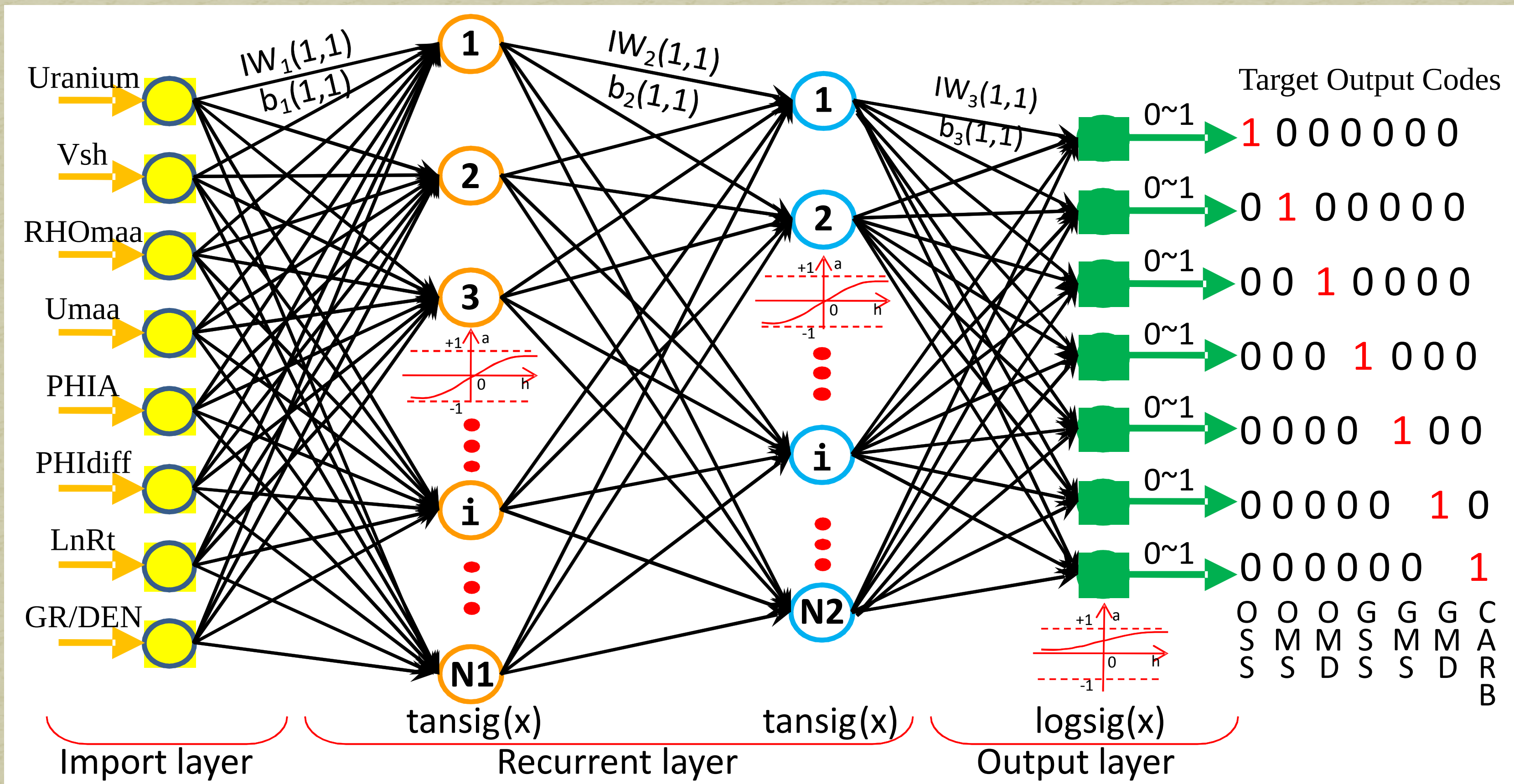
Pulsed Neutron Spectroscopy Log Suite (PNS Log)



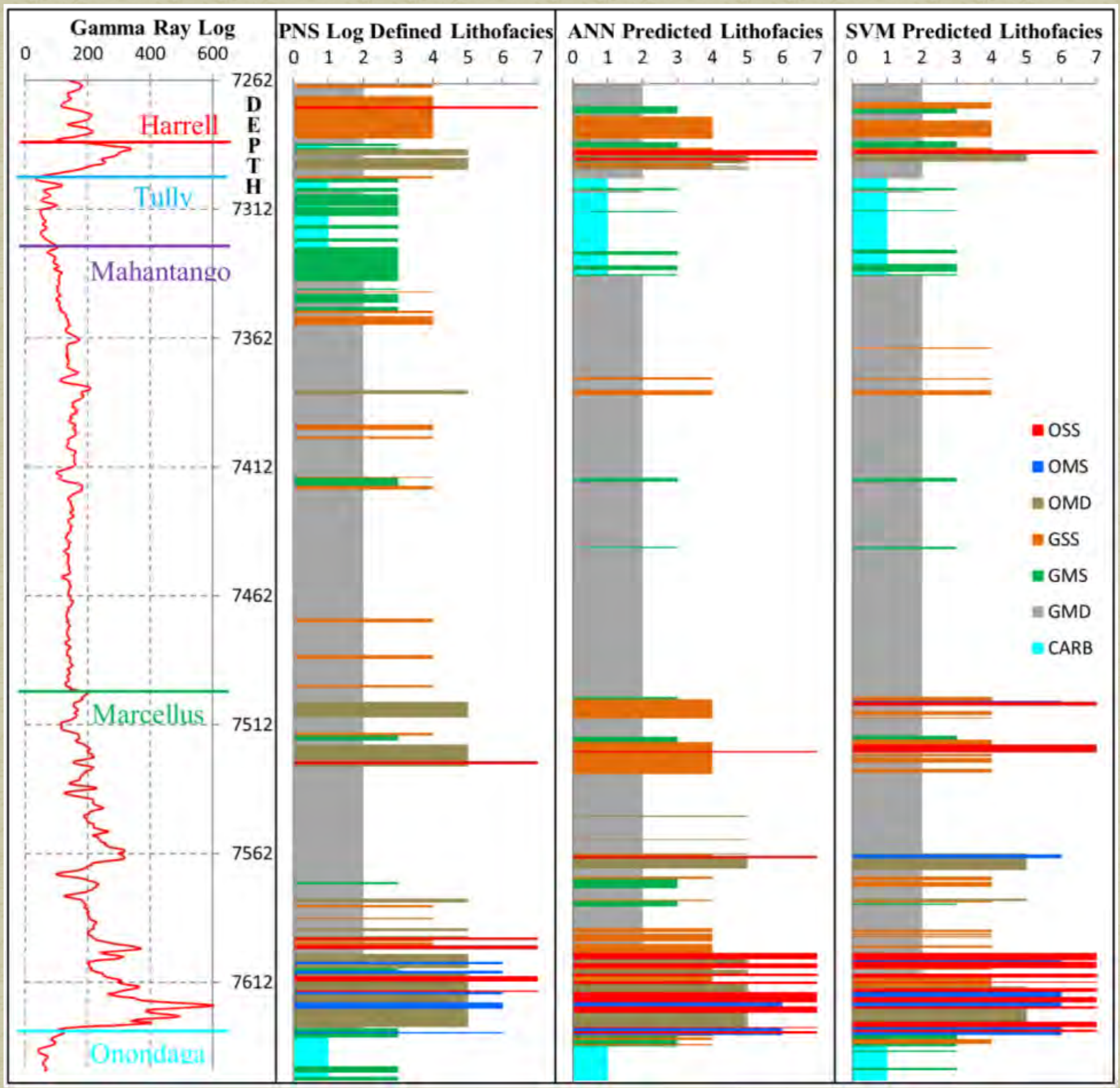
Lithofacies Identification Derived Input Log Parameters

- Uranium Concentration: Spectral Log
- Shale Volume: V_{sh}
- RHOmaa – (RhoB- Φ_t)/(1- Φ_t)
- Umaa: (PE * RhoB-0.5)/(1- Φ_t)
- Φ_t: Average of DPHI and NPHI
- PHIdiff: DPHI – NPHI
- LnRt: Natural Log of Deep Resistivity
- GR/RhoB

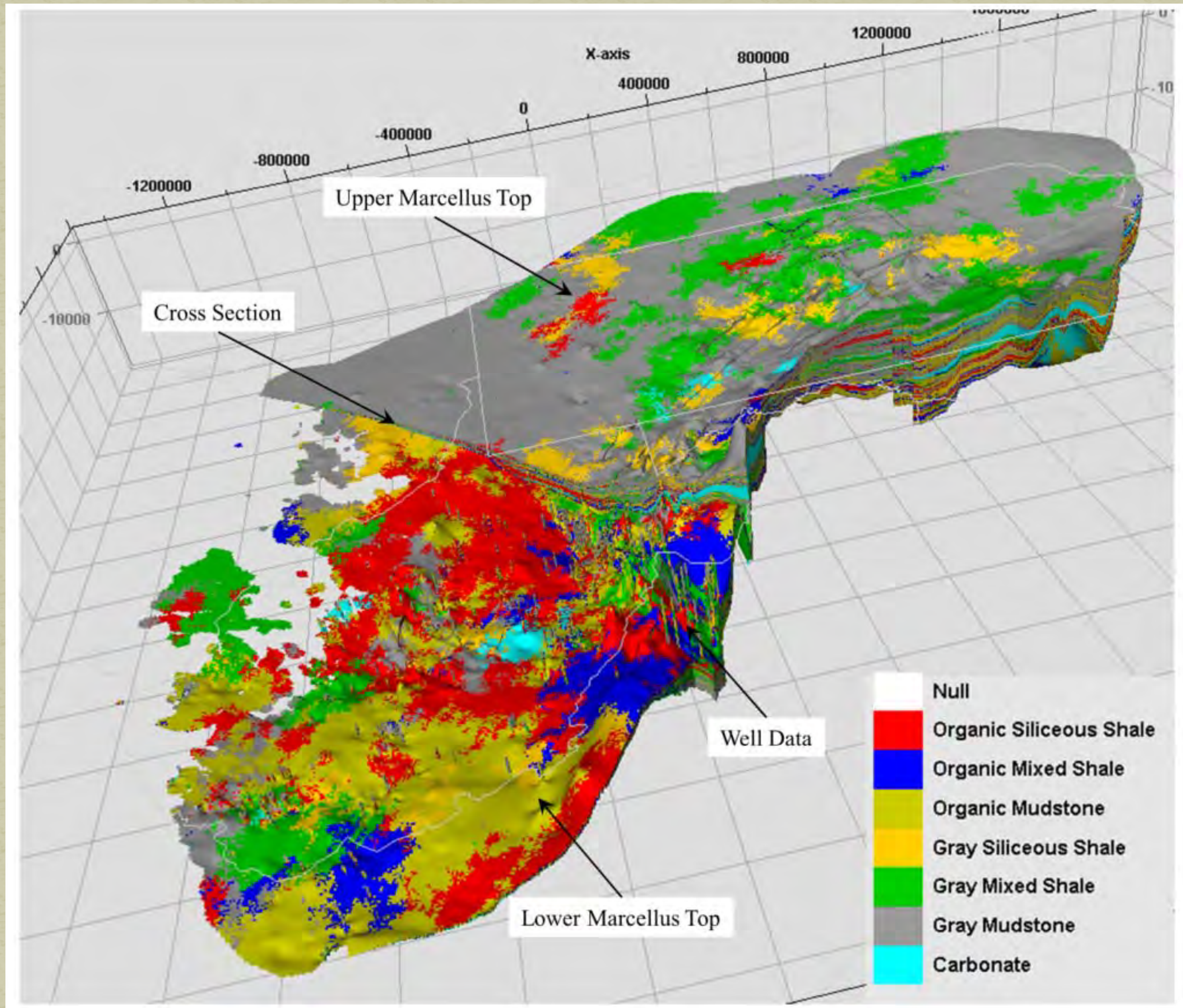
Lithofacies Identification Artificial Neural Network - ANN



Lithofacies Identification

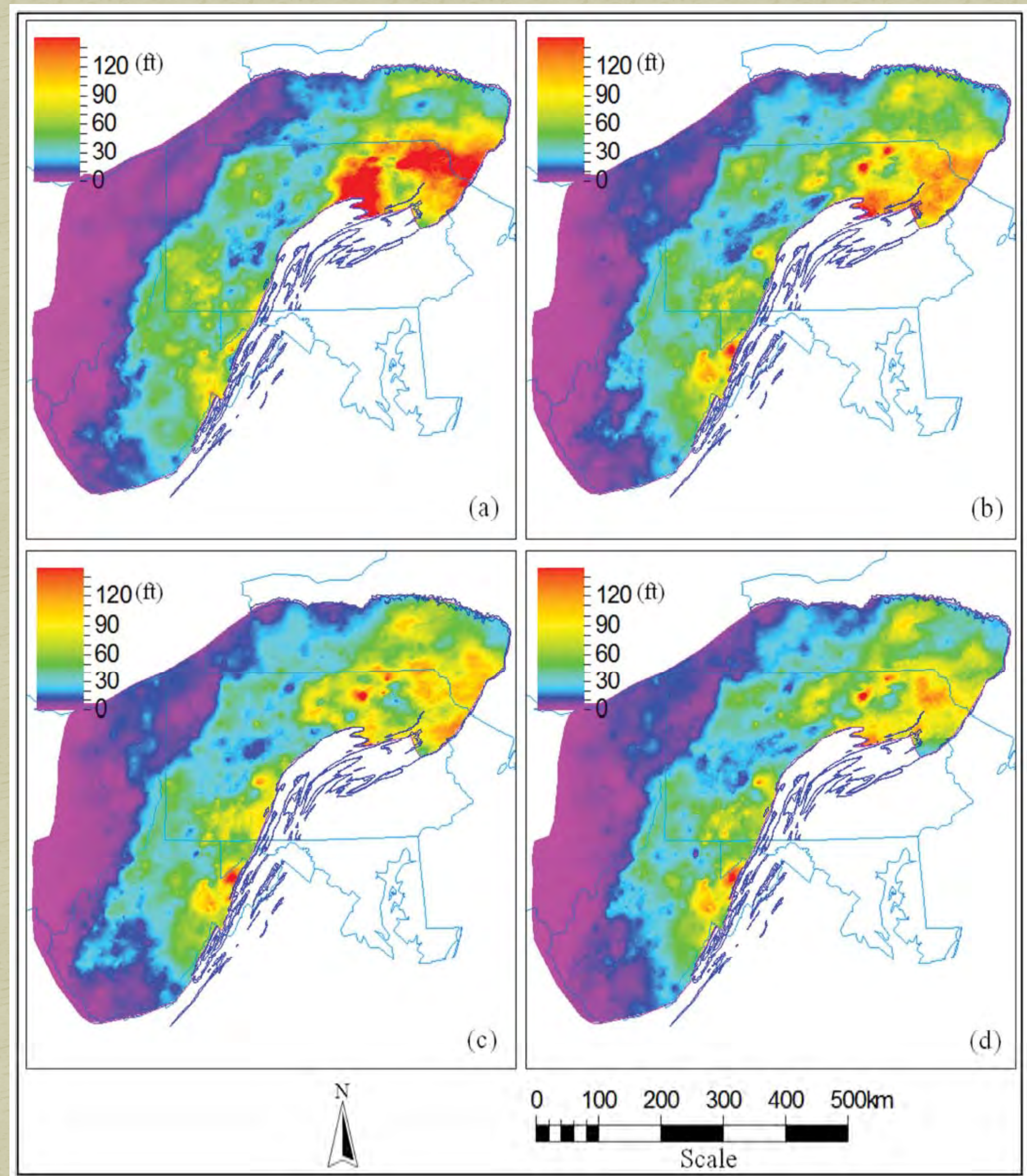


Lithofacies 3D Modeling



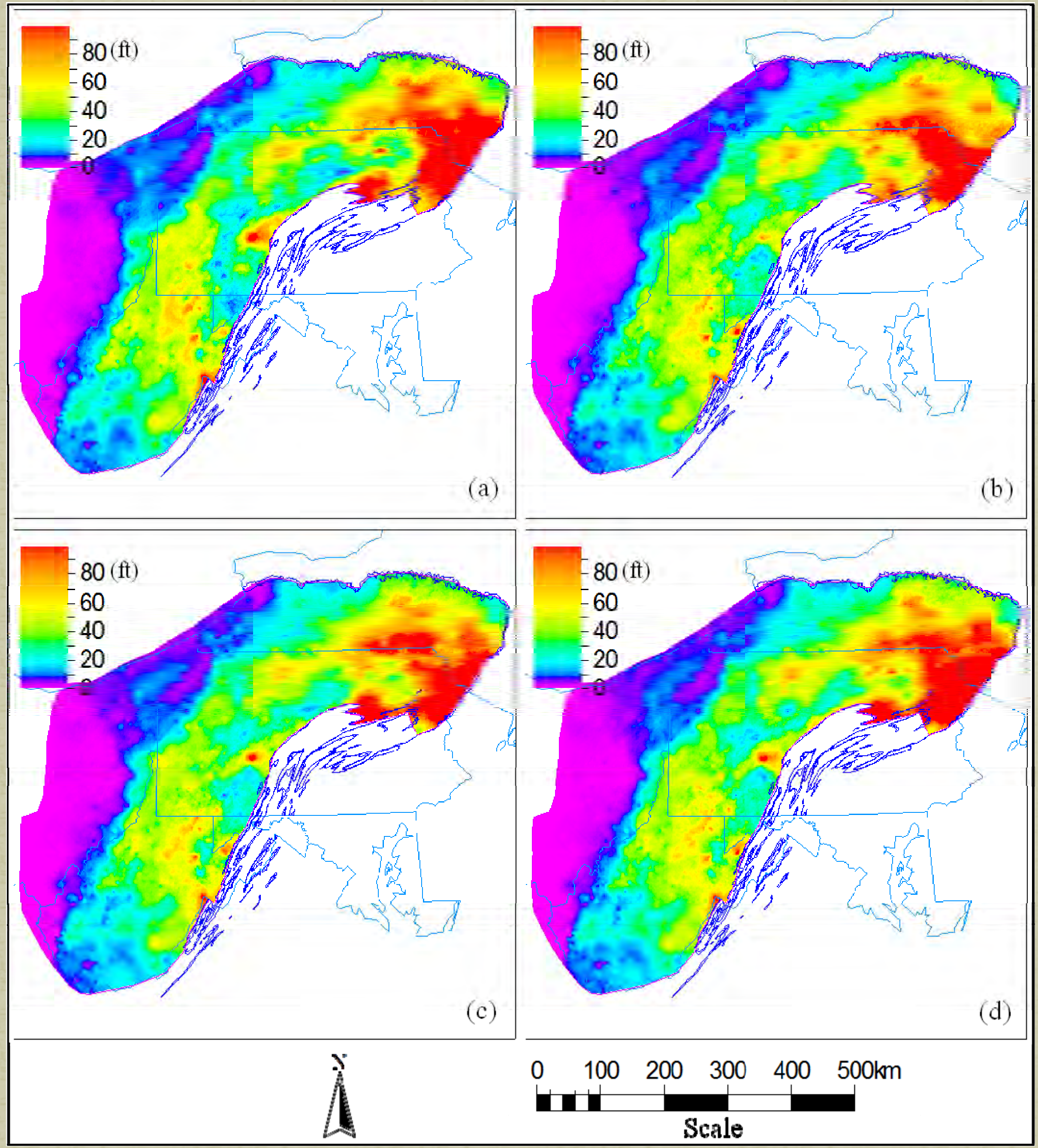
Wang and Carr, in press

Marcellus Brittle Lithofacies



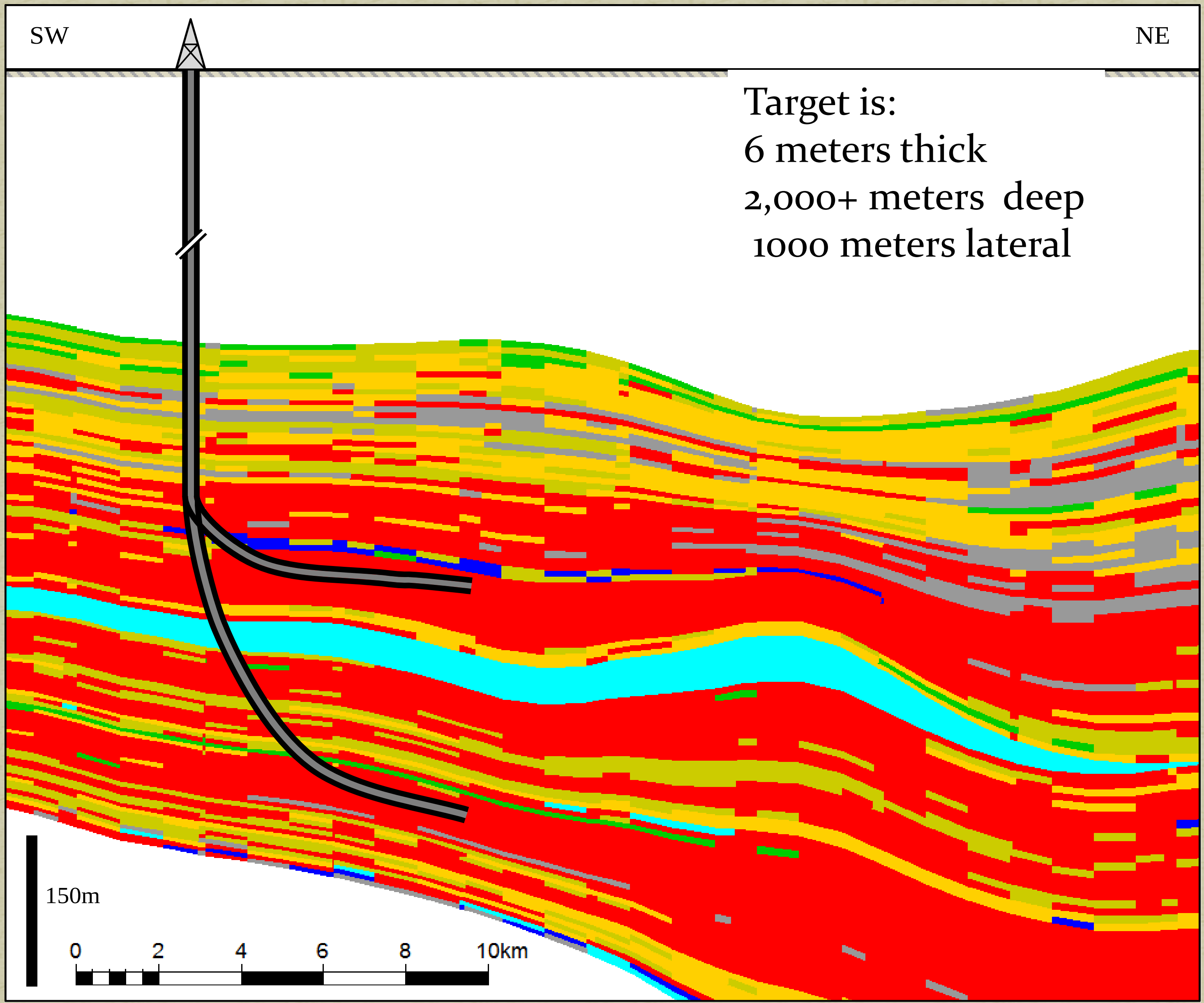
Wang, 2012

Marcellus Organic-Rich Lithofacies



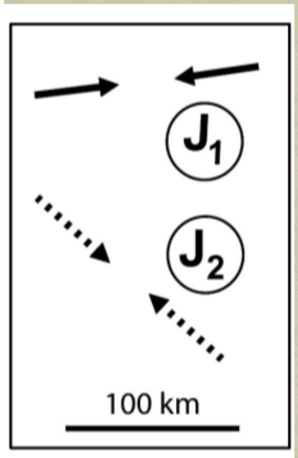
Wang and Carr, 2012

Productive Horizon Distribution

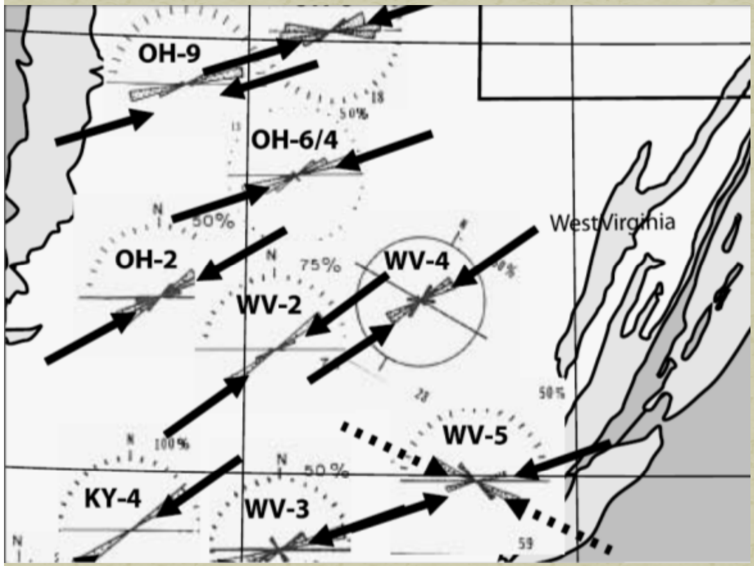


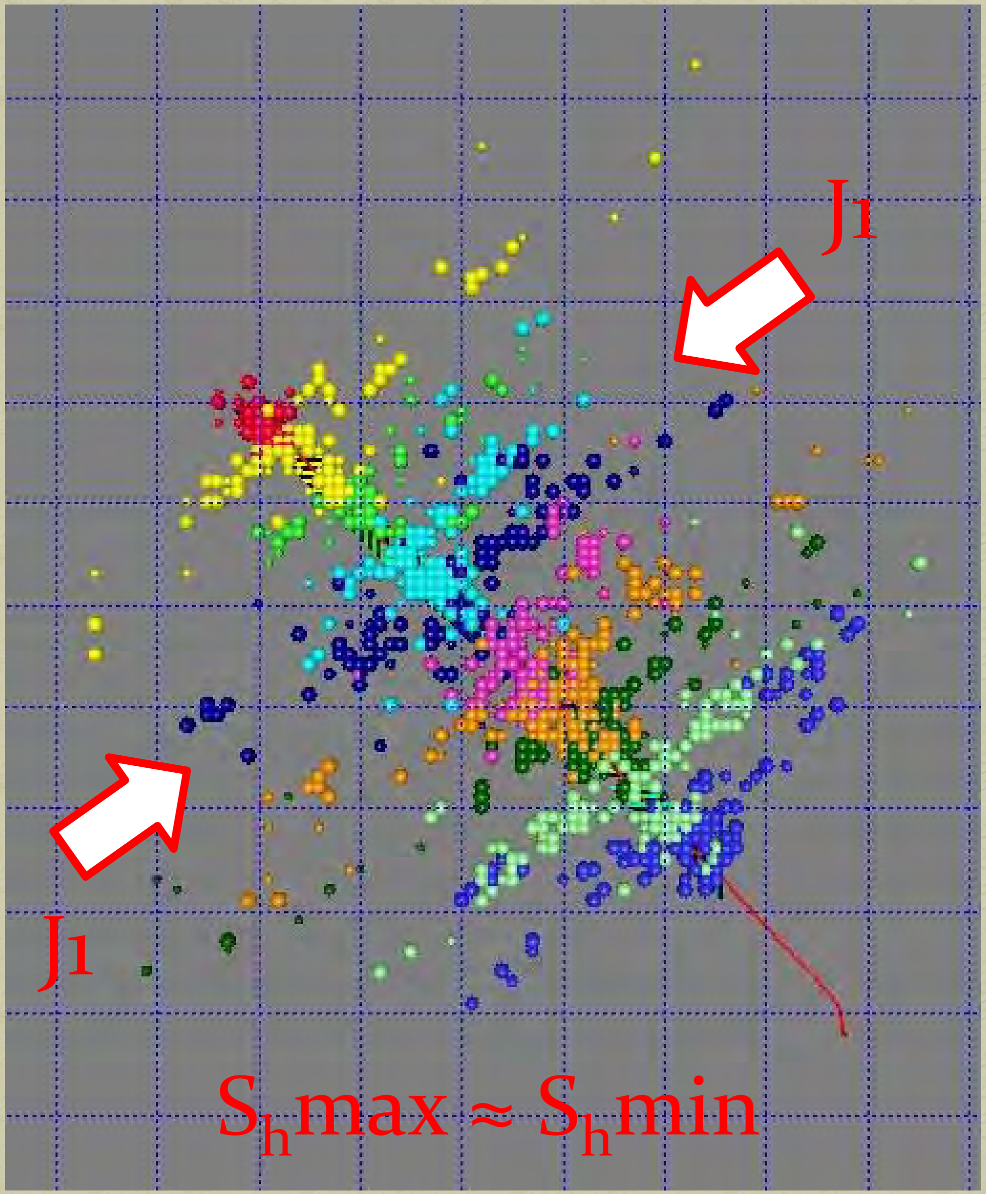
Wang, 2012

Treatment Efficiency



Engleder et al., 2009

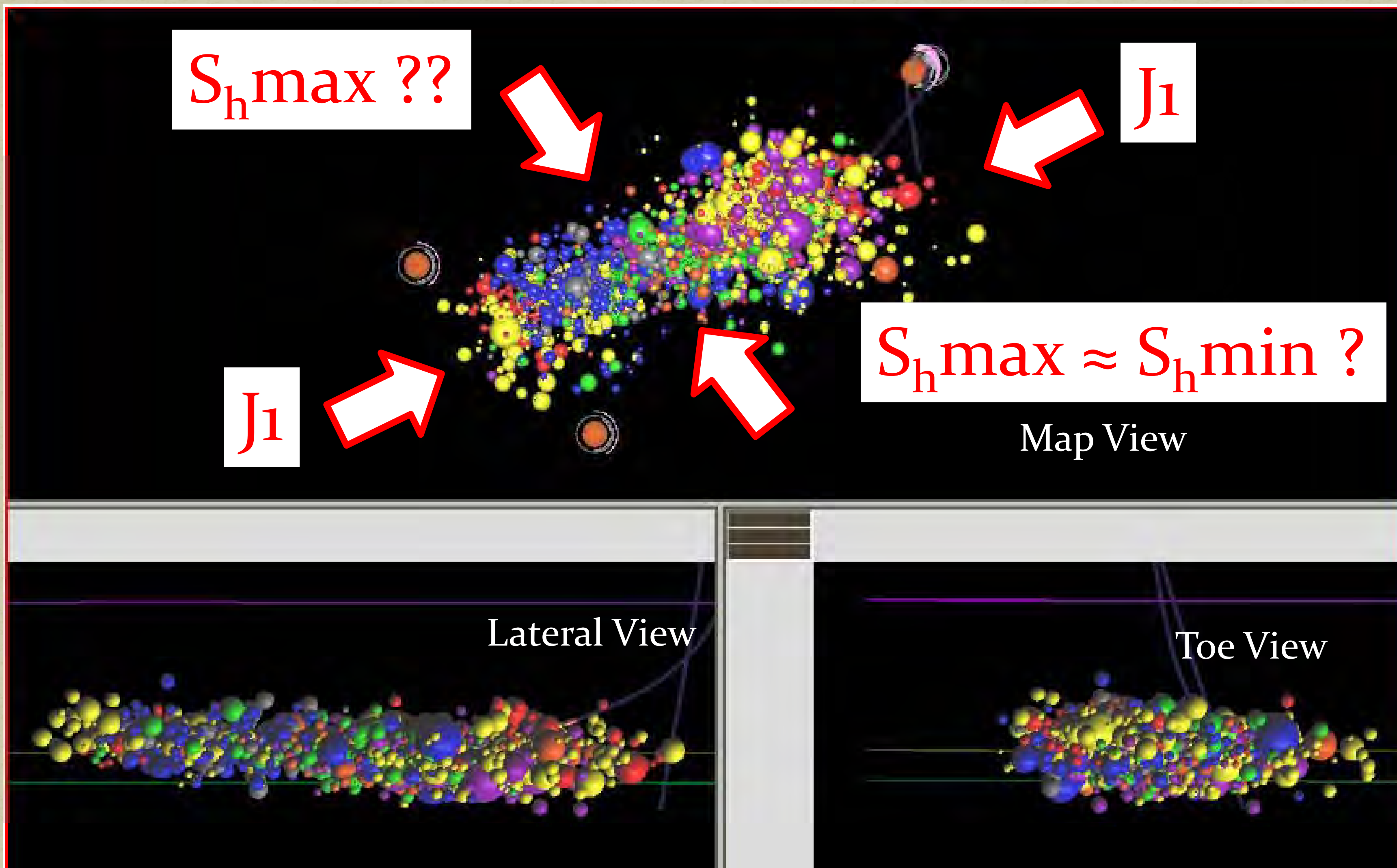




Each square 500 feet

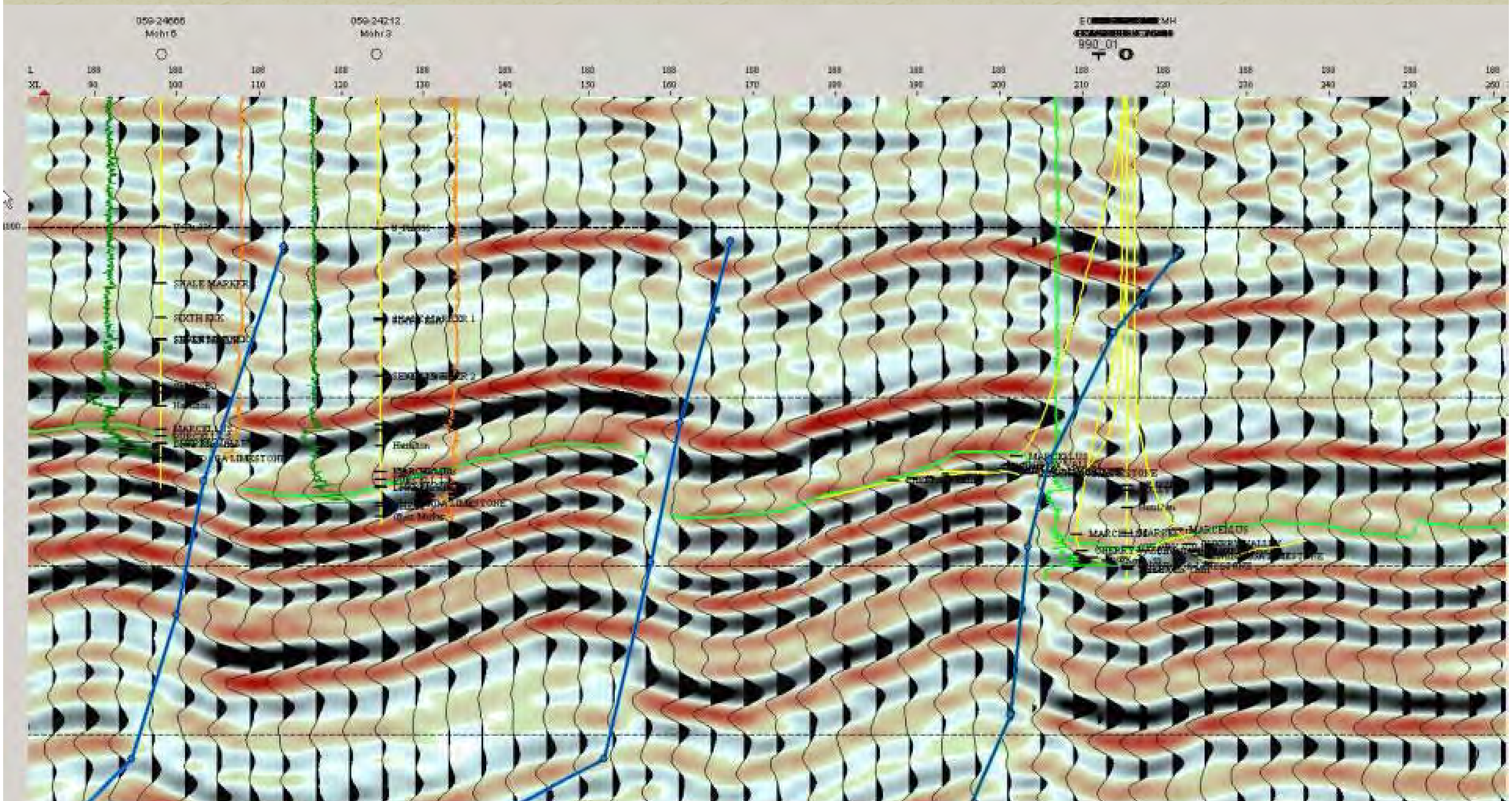
Microseismic, Inc.

Treatment Efficiency



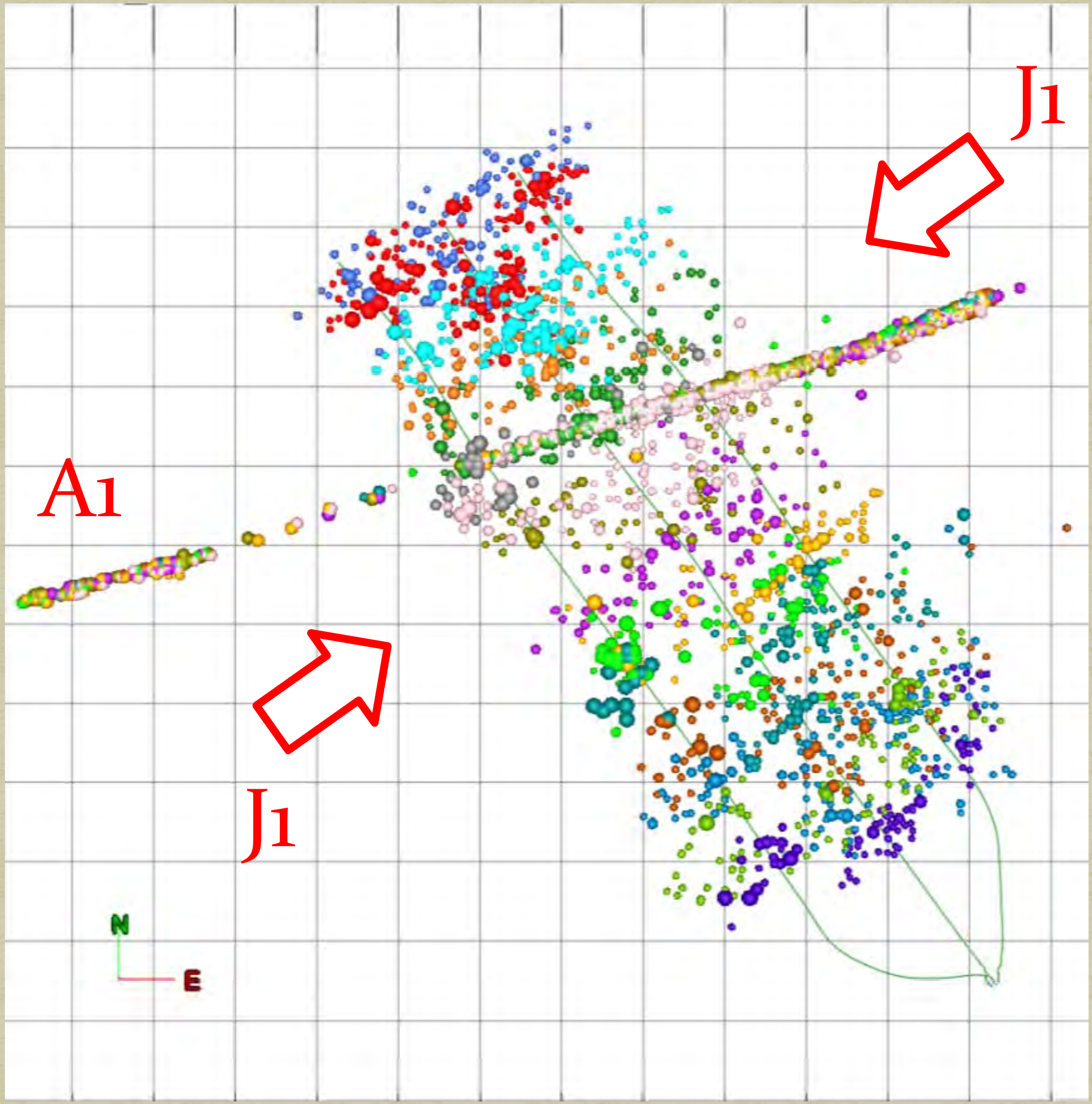
Fa Dwan et al., 2013, IPTC 16571

Marcellus Shale – Structural Discontinuities



Faults from Arcadian Orogeny

Geologic Failure

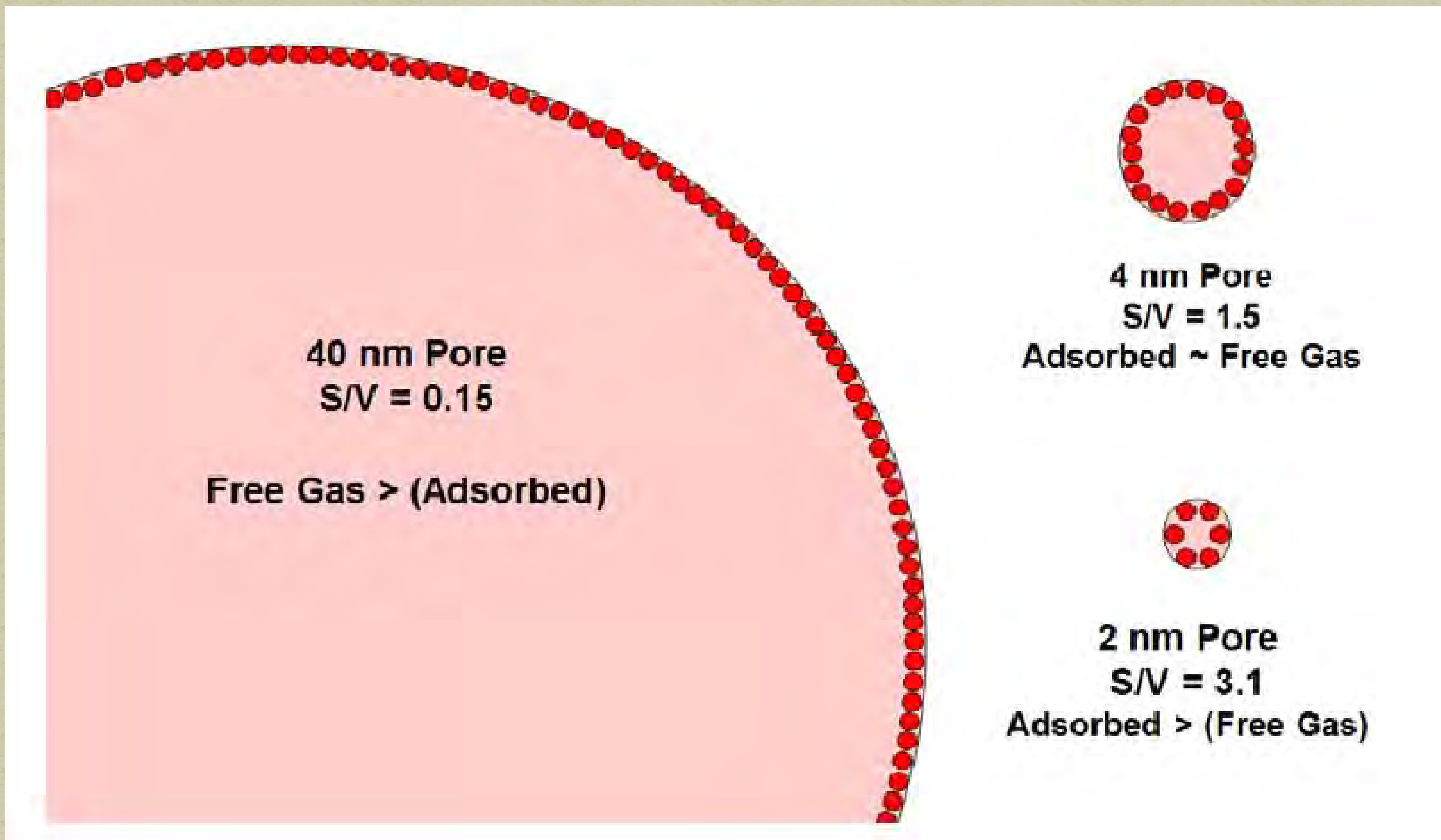


Each square 500 x 500 feet

Microseismic, Inc.

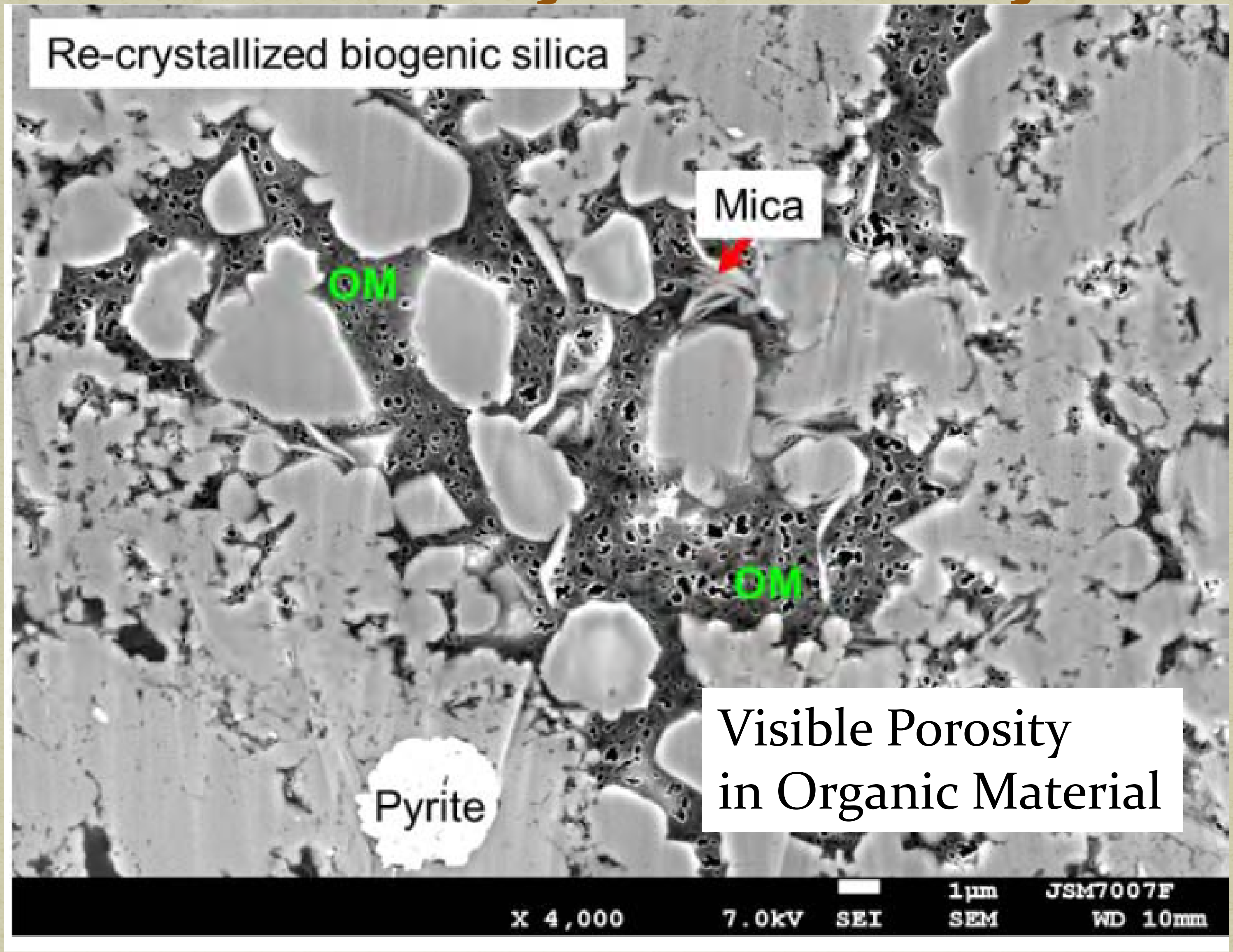
Maturity - Porosity

Nanometer Pores and Methane Molecules



Bohacs et al. 2013, IPTC 16676

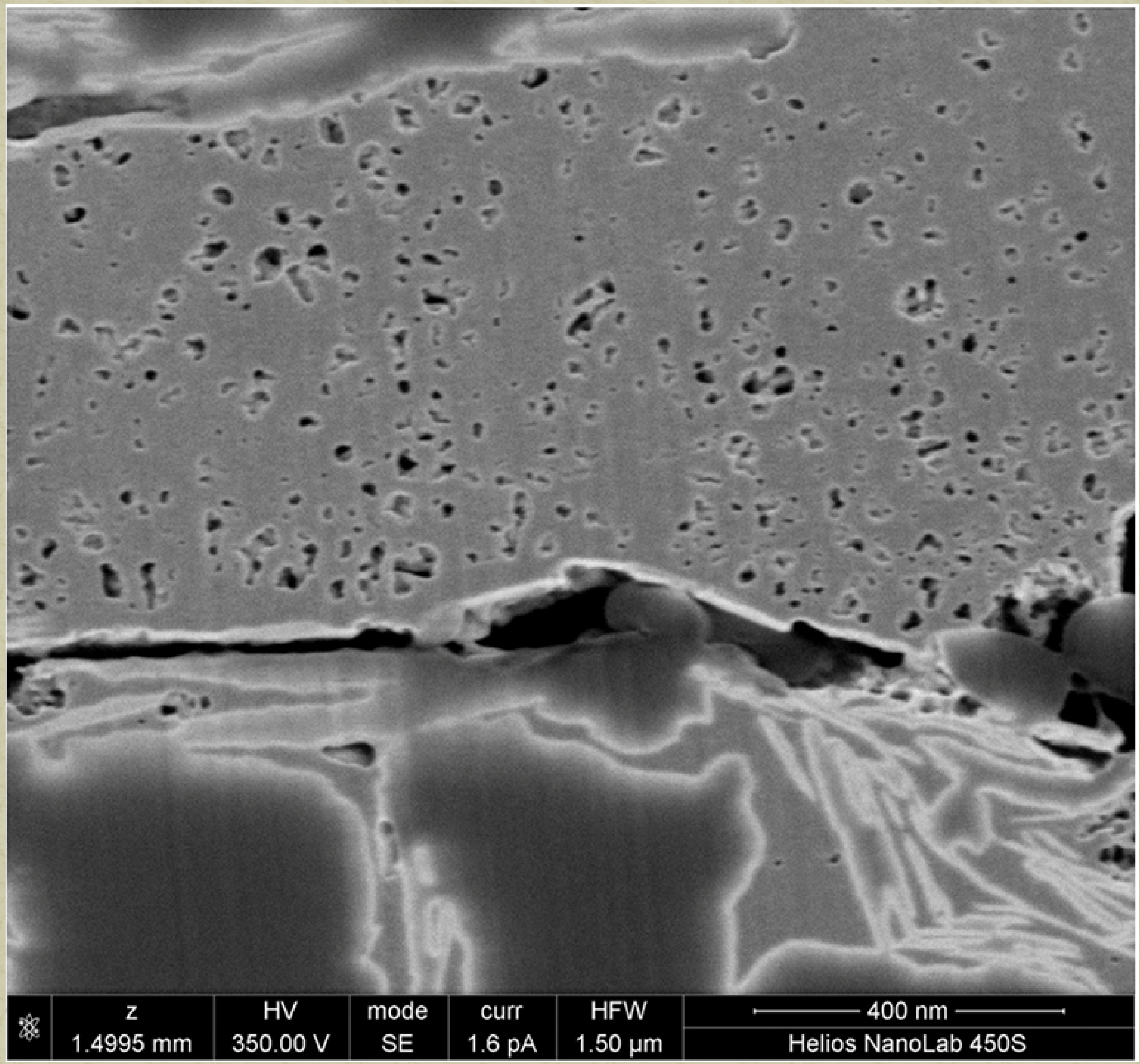
Maturity - Porosity



Barnett Shale from the Gas Window

Bohacs et al. 2013, IPTC 16676

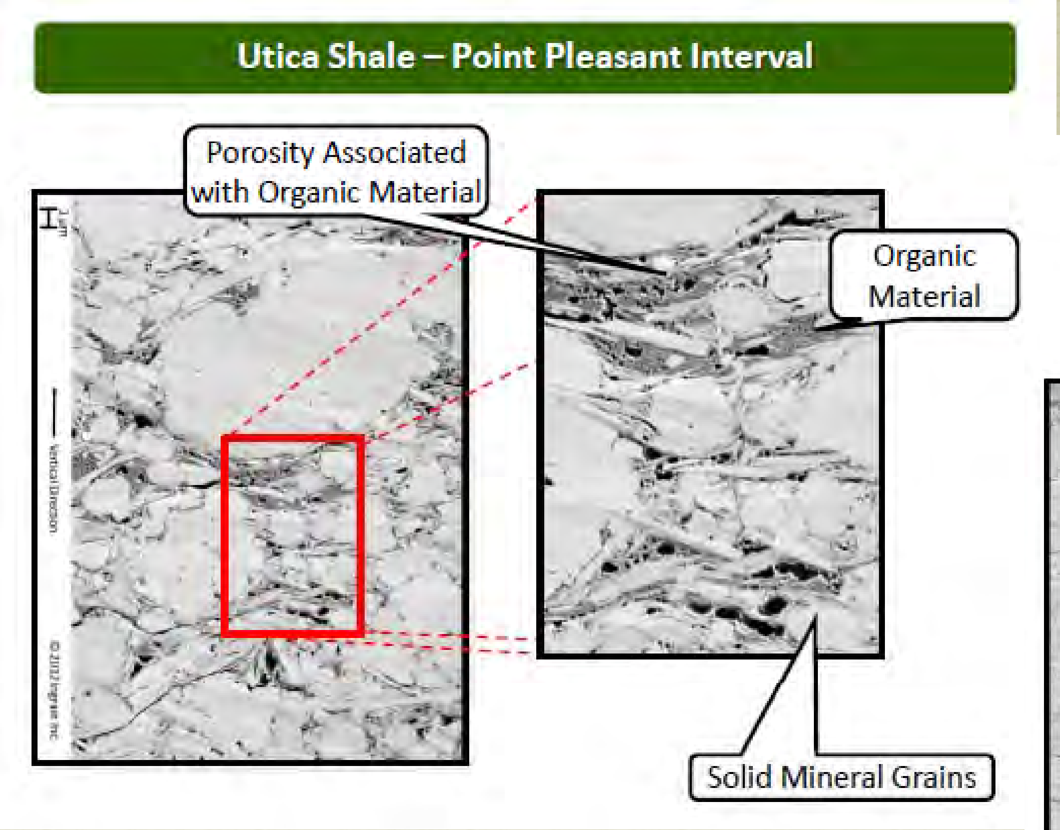
Marcellus Shale

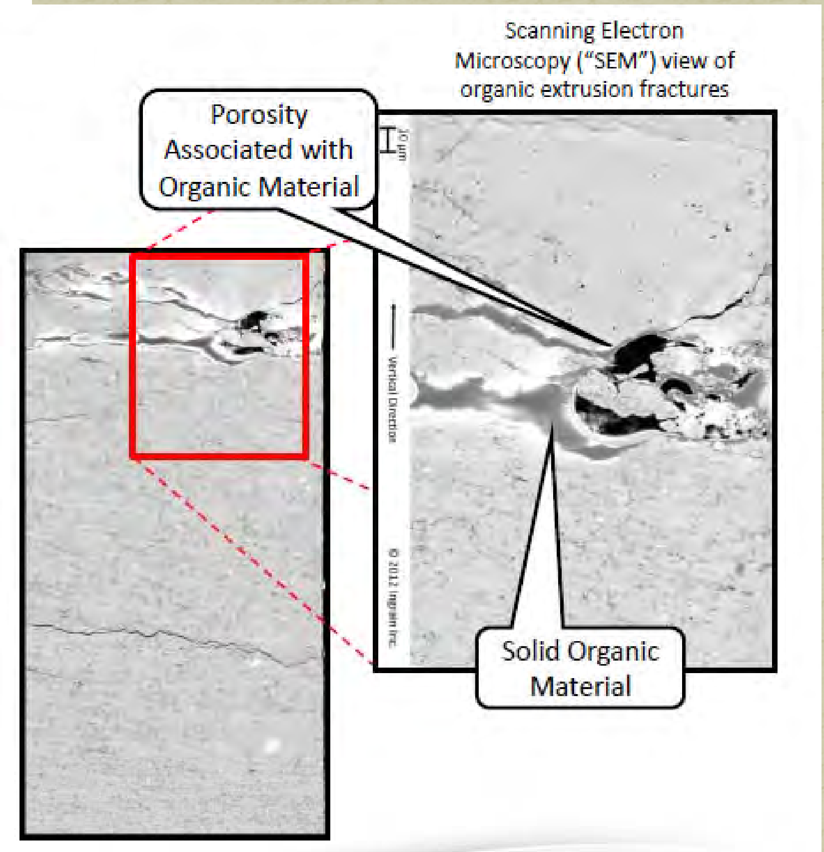


Marcellus Shale from the Gas Window

JPT, April, 2013

Utica – Point Pleasant Interval
Wet Gas Window

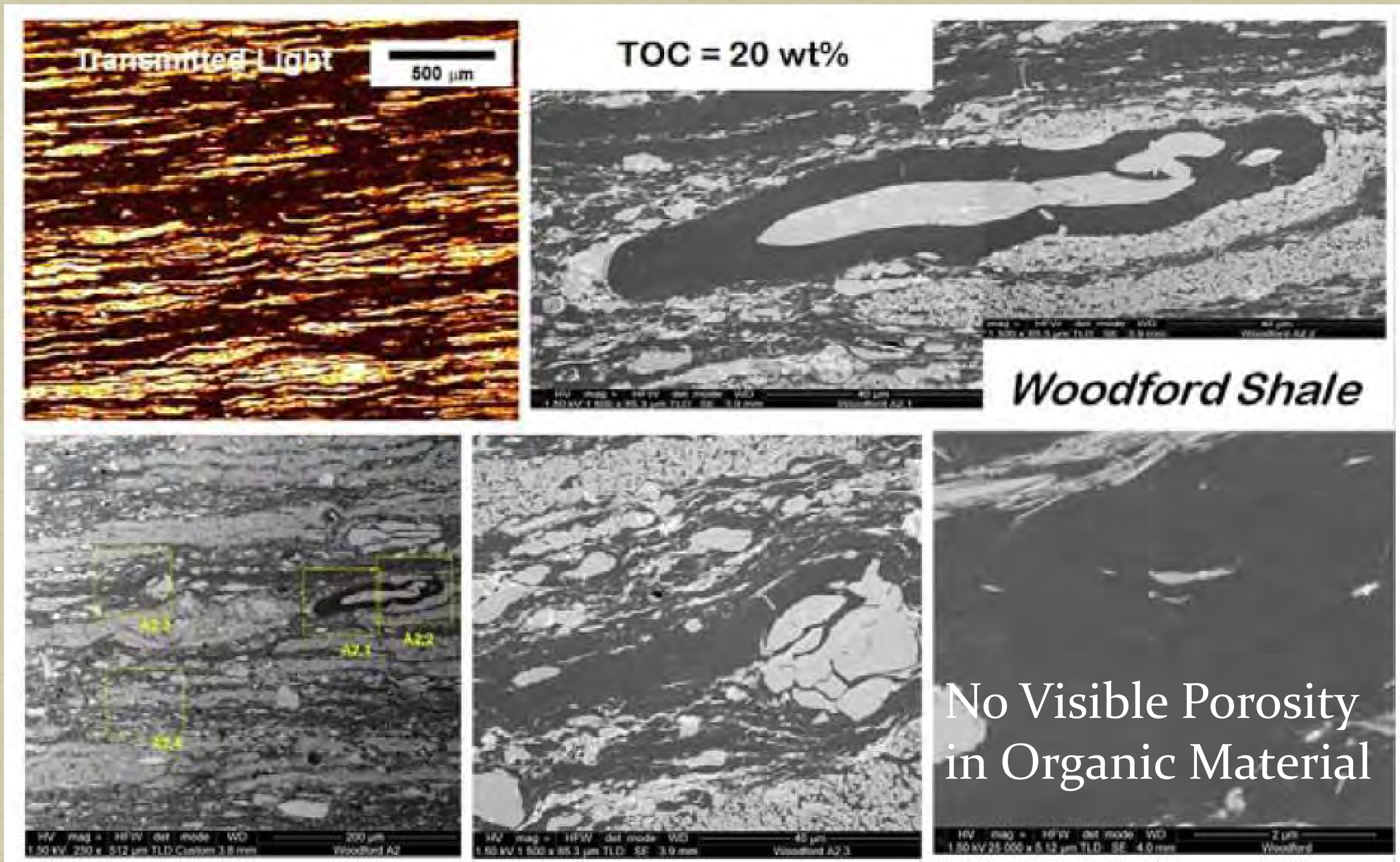




Utica from the Wet Gas Window

Source Ingrain Study for Gulfport – November 2012

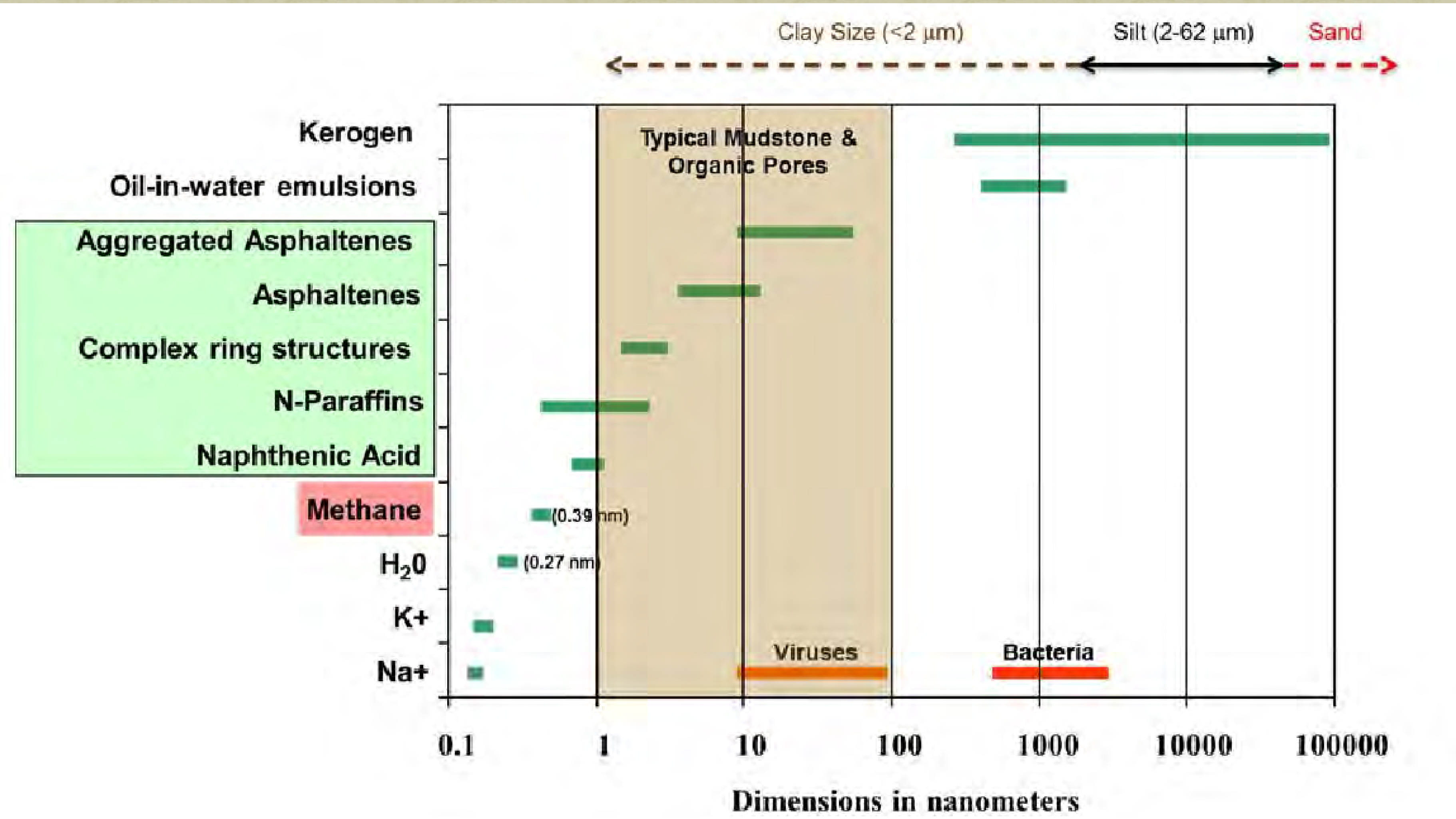
Maturity - Porosity



Woodford Shale from the Oil Window

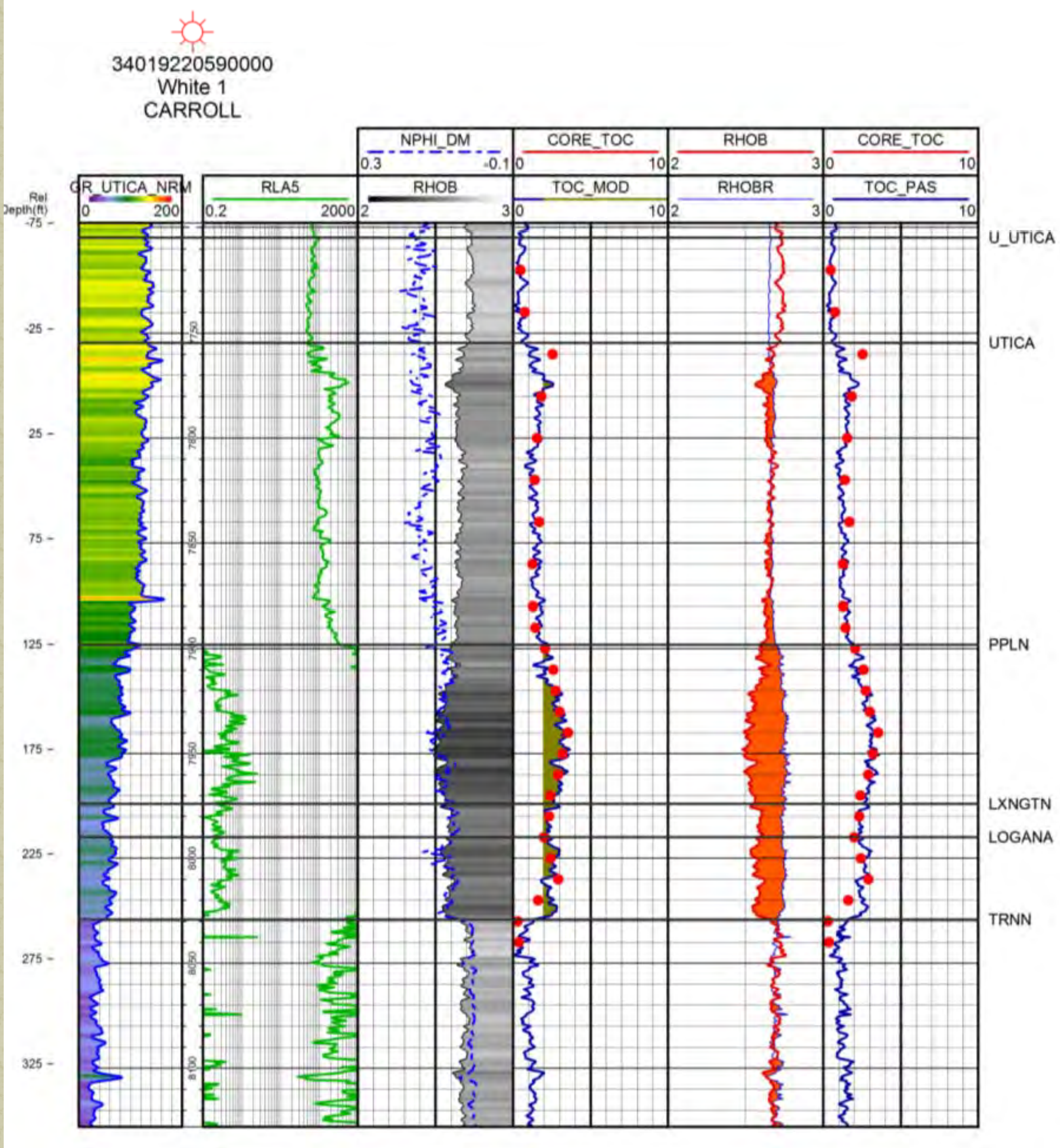
Bohacs et al. 2013, IPTC 16676

Size of Cations and Hydrocarbon Molecules



From Bohacs et al. 2012 and after Momper, 1978

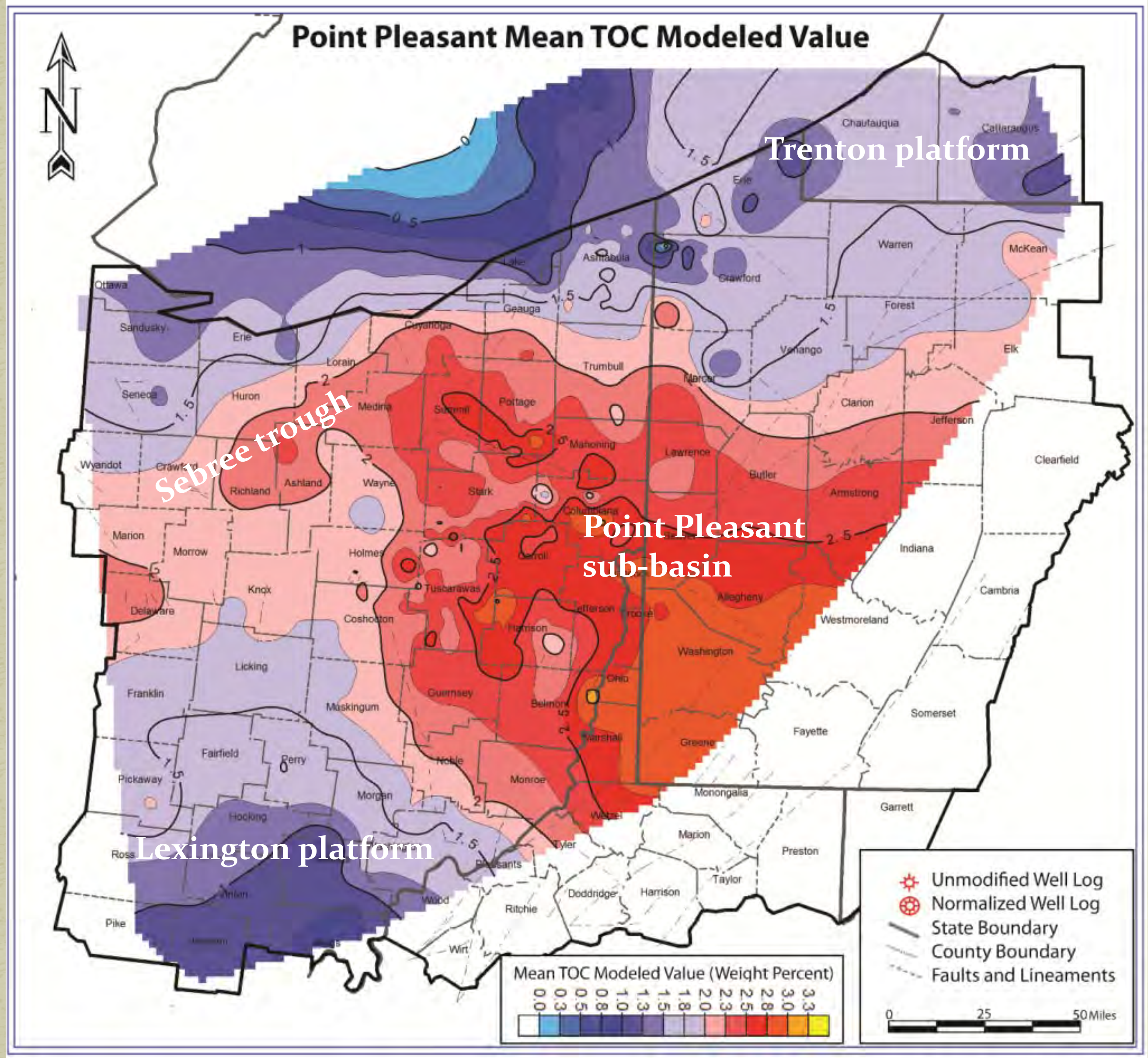
Utica-Point Pleasant Organic-Rich Interval



McClain, 2013

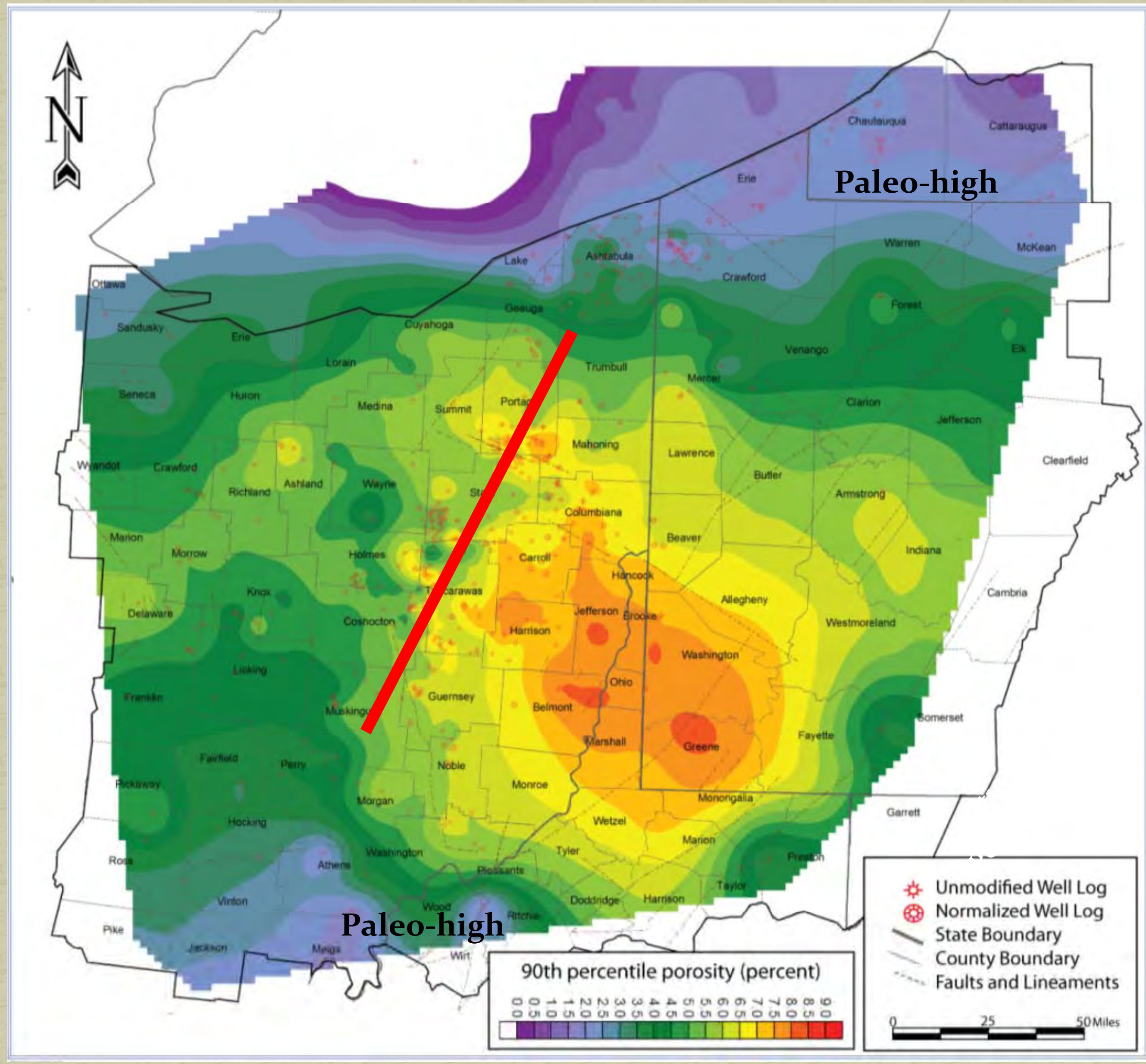
Utica-Point Pleasant Organic-Rich Interval

- Organic-rich strata focused in sub-basin
- Clean carbonates on platforms



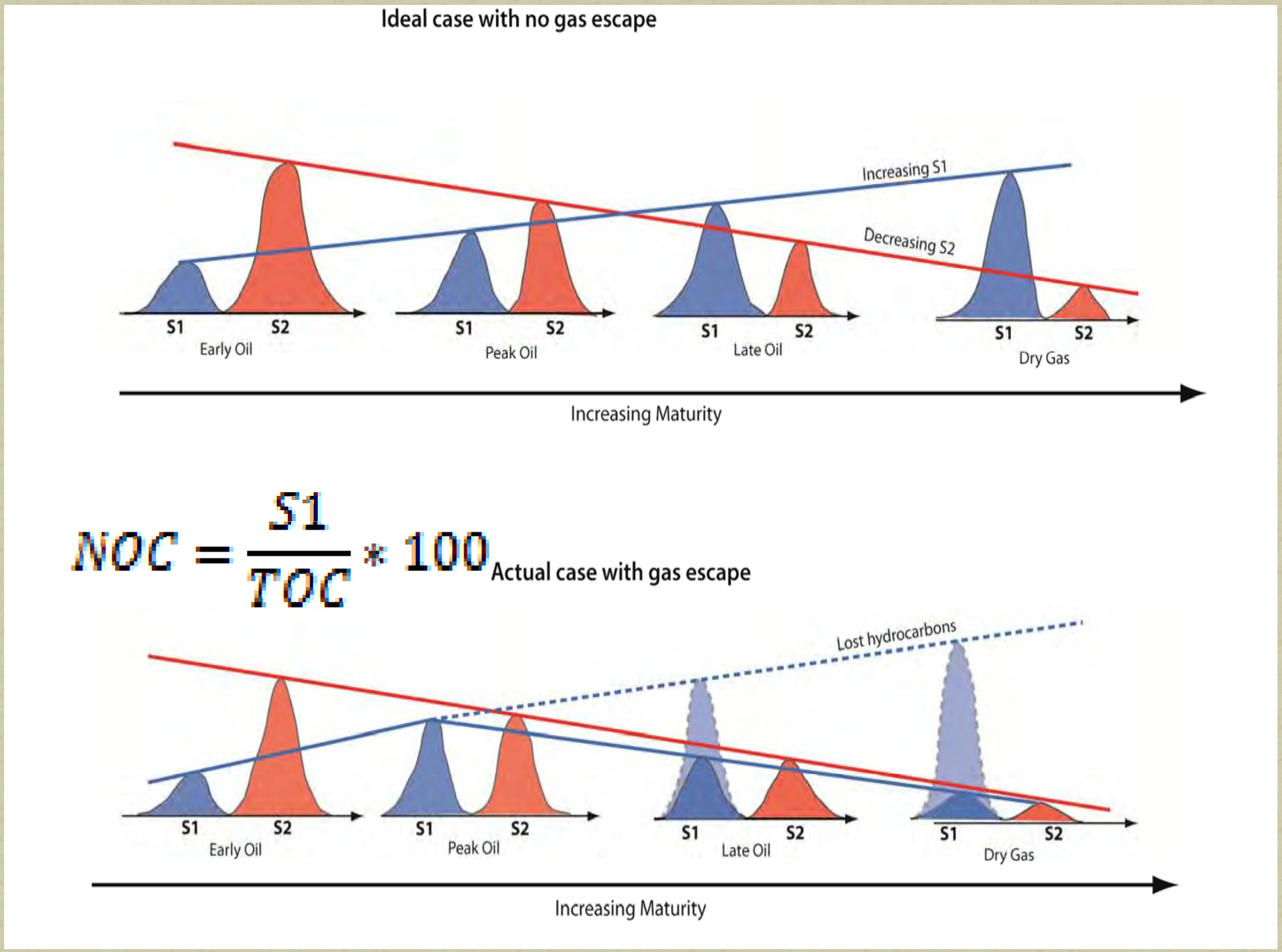
McClain, 2013

Utica Porosity and Maturity



Modified from McClain, 2013

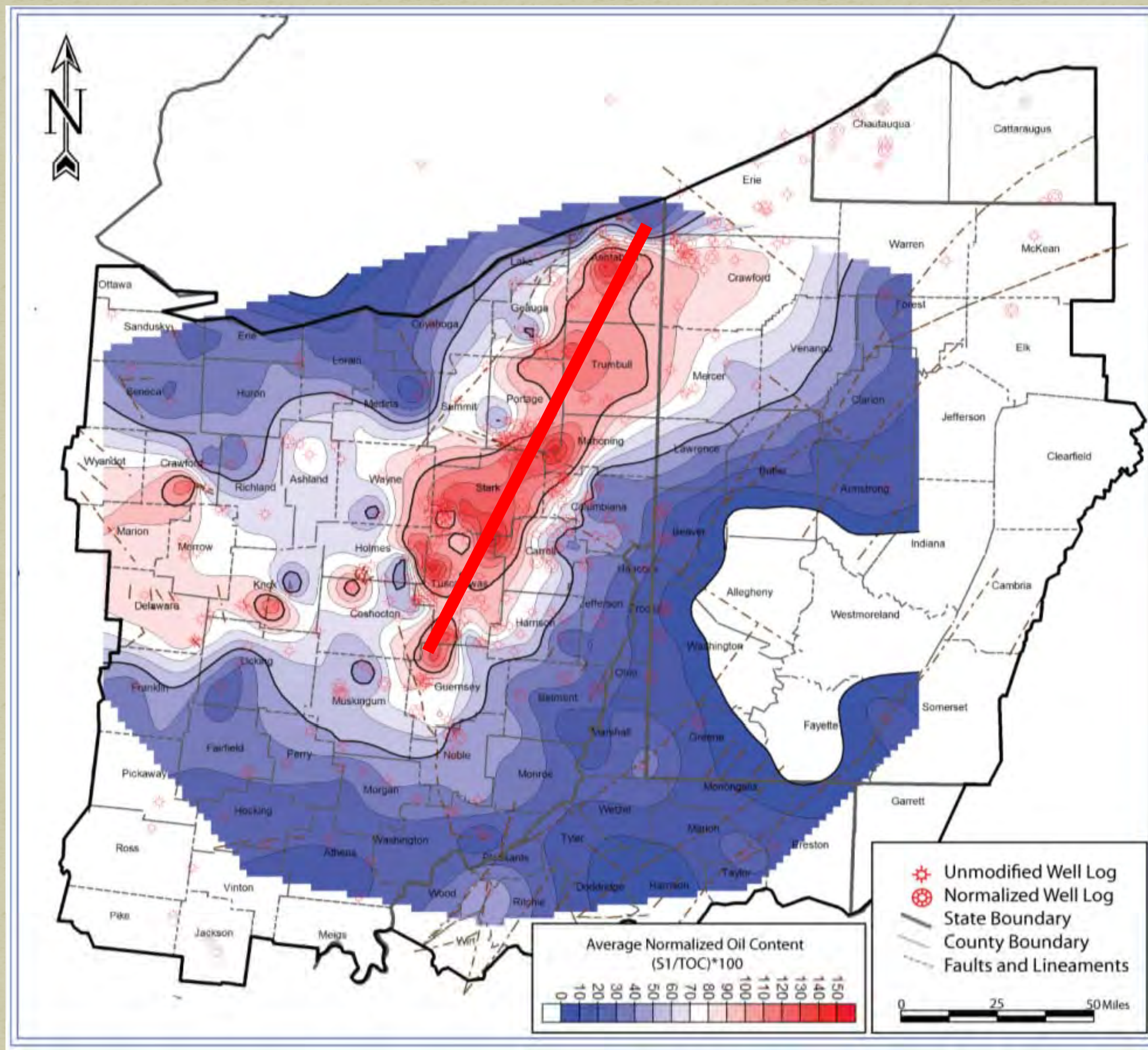
Maturity - Normalized Oil Content



$$NOC = \frac{S1}{TOC} * 100$$

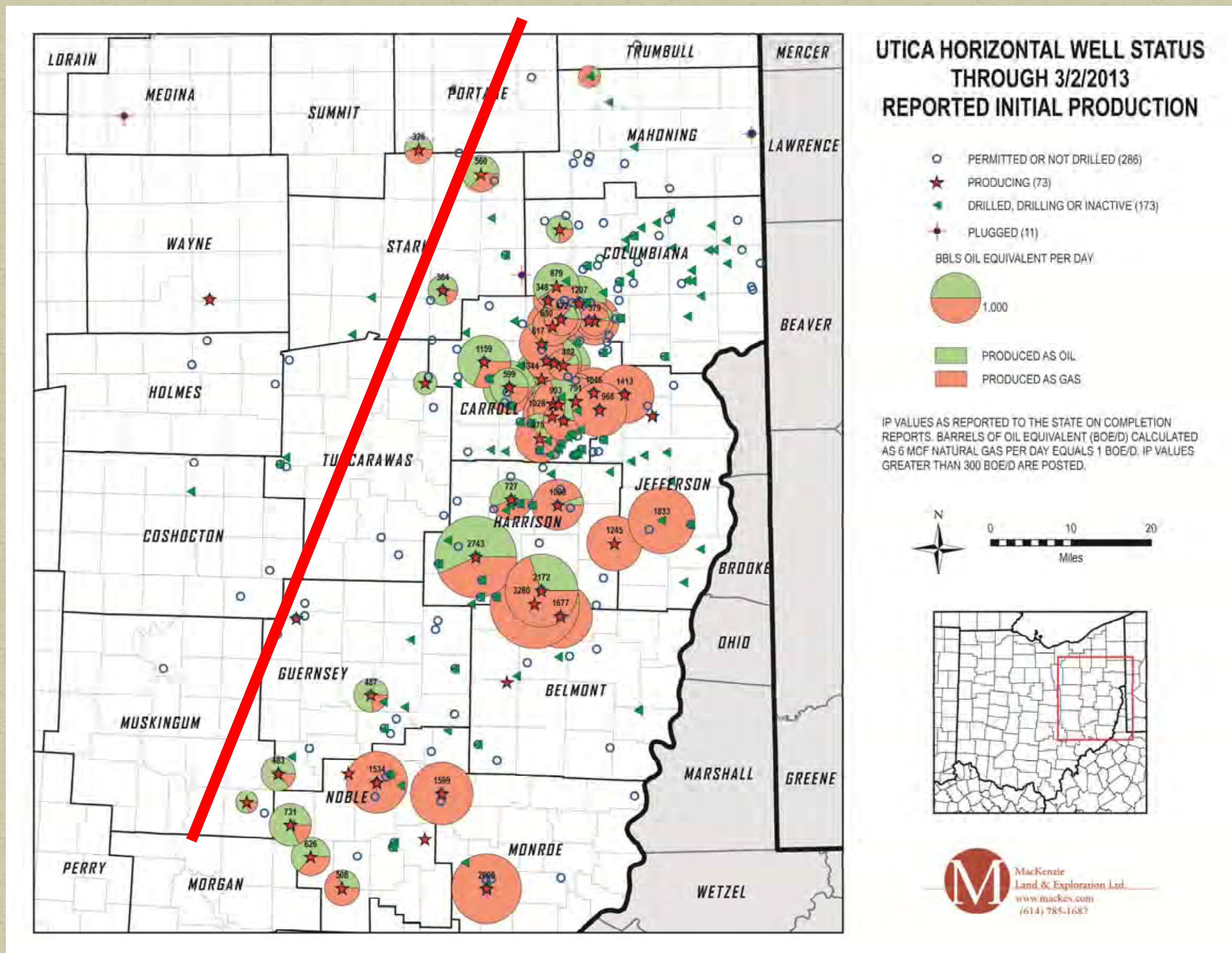
McClain, 2013

Utica Maturity
Normalized Oil Content



Modified from
McClain, 2013

Utica Activity and Production



Pete MacKenzie

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Thank You

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