

# **AV Marcellus Shale – Geologic Considerations for an Evolving North American Liquids/Rich Play\***

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## **Key Points**

### **Regional Extent of Marcellus Liquids Rich Play**

- Play area is significantly west of major Appalachian Fold Belt; key structural features affecting area are basement faults systems related to Rome Trough rift system and strike-slip faults with later recurrent movement.
- Liquids rich portion of play in SW PA discovered in 2006 and 2007. Play is now in full development.
- Initial results and potential were not immediately evident.
- Proved/de-risked portion of play under development in SW PA, northern WV, and WV Panhandle.
- Northern PA is still unexplored and problematic thus far.
- NY political climate prohibited testing there.

### **SW PA Play Area**

- Very thin, condensed section; Tully to Marcellus interval condensed.
- SW PA sedimentation rate was lower.
- Key pay intervals are maximum flooding surfaces (MFS's) in Marcellus.
- High NTG ratio.
- Higher TOC%.
- Higher porosity and permeability.

- GIP- 40 BCF/mile to 150 BCF/mile.
- IPS – 1.0 Mmcfe/d to over 20 Mmcfe/d per lateral completion.
- EUR – 2 Bcfeq to over 20 Bcfeq per lateral.
- NGL's – Significant, up to 425,000 Bbls per lateral in NGL rich areas.
- NGL rich areas have superior economics over dry gas areas at current economics.

#### **NE PA Play Area**

- Very thick, expanded section.
- Lower Average. TOC.
- Low NTG Ratio.
- Tully to Marcellus interval is expanded.
- NE PA sedimentation rate was significantly higher.
- Key pay intervals are MFS's in Marcellus.

#### **Potential of Marcellus Play Area**

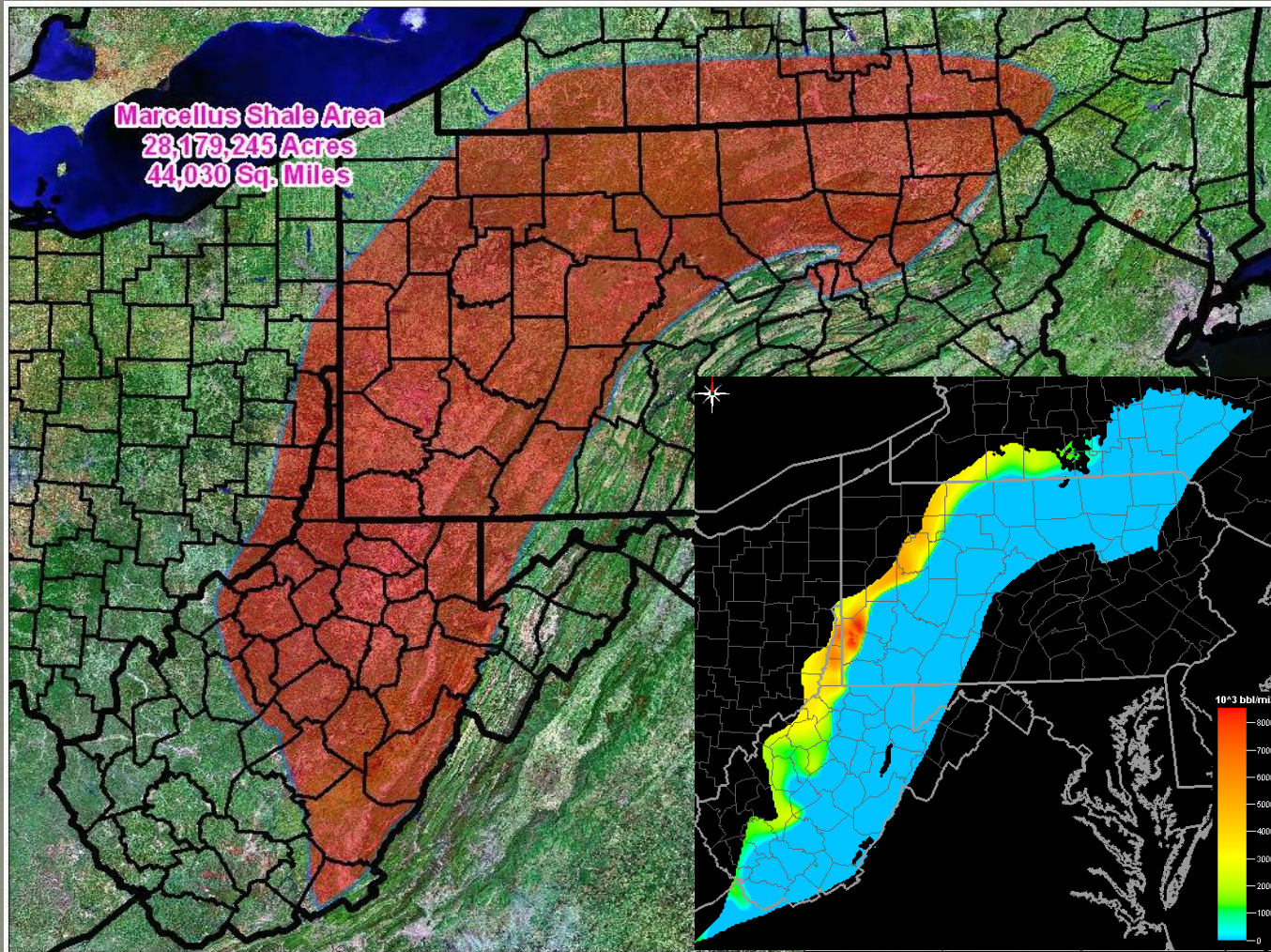
- Approximately 84 TCF/3.5 billion barrels liquids (Coleman et al., 2011) to 489 TCF (Engelder, 2009).
- Further, what about the resource potential of the Genesee Group and Utica/Point Pleasant intervals?

#### **References Cited**

Coleman, J.L., Milici, R.C., Cook, T.A., Charpentier, R.R., Kirschbaum, Mark, Klett, T.R., Pollastro, R.M., and Schenk, C.J., 2011, Assessment of undiscovered oil and gas resources of the Devonian Marcellus Shale of the Appalachian Basin Province, 2011: U.S. Geological Survey Fact Sheet 2011–3092, 2 p. Website accessed July 25, 2013. <http://pubs.usgs.gov/fs/2011/3092/>

Engelder, T., 2009, Marcellus: Fort Worth Basin Oil&Gas Magazine, August, 2009, 5p. Website accessed July 25, 2013. <http://www.marcellus.psu.edu/resources/PDFs/marcellusengelder.pdf>

# Marcellus Shale – Geologic Considerations for an Evolving North American Liquids!Rich Play



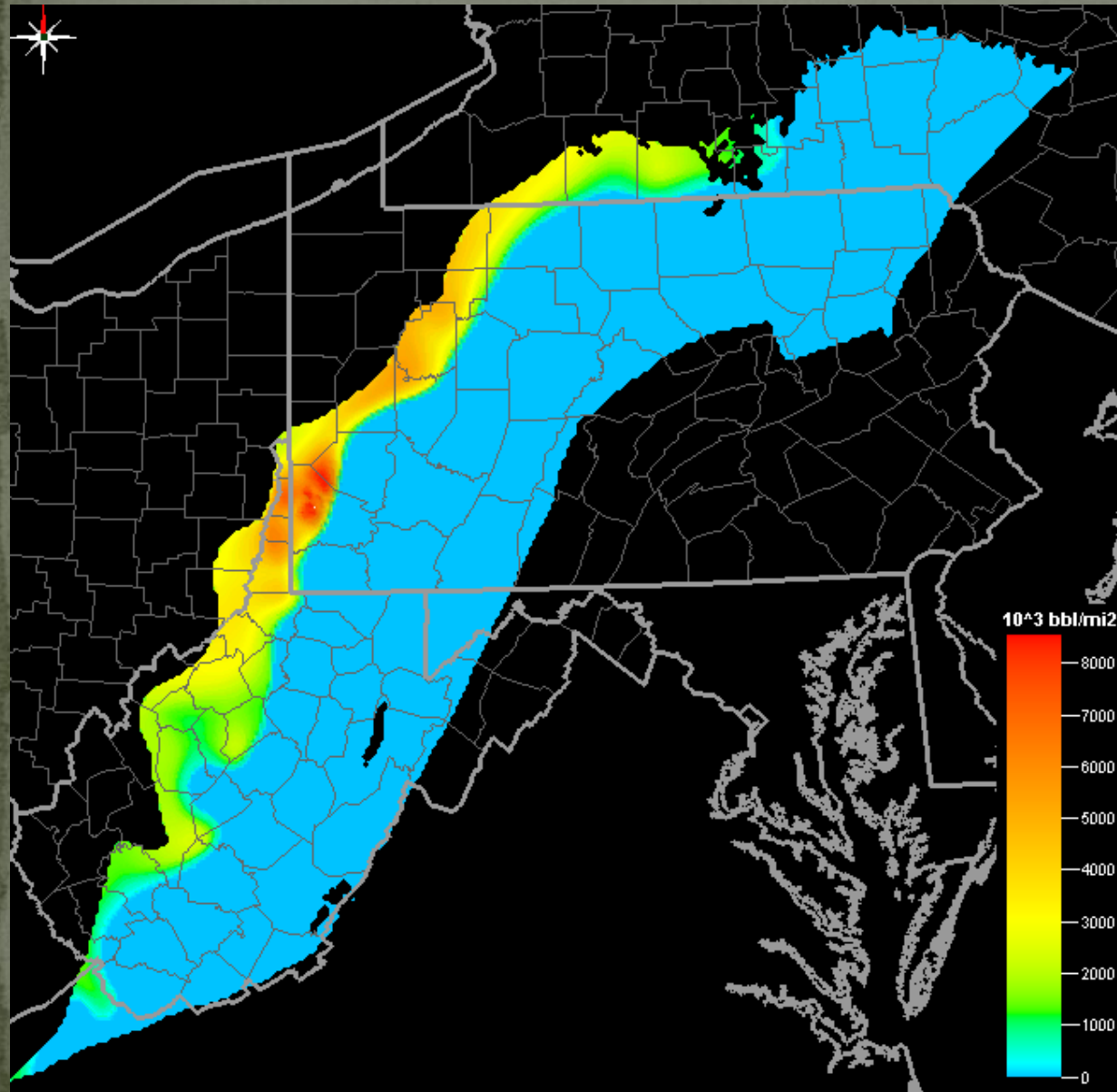
AAPG ACE 2013 – May 19, 2013  
W.A. Zagorski, D. Bowman, J. Morris & C. Yang  
Range Resources Corporation - SMSD

# Forward - Looking Statements

Statements concerning well drilling and completion costs assume a development mode of operation; additionally, estimates of future capital expenditures, production volumes, reserve volumes, reserve values, resource potential, resource potential including future ethane extraction, number of development and exploration projects, finding costs, operating costs, overhead costs, cash flow, NPV10, EUR and earnings are forward-looking statements. Our forward looking statements, including those listed in the previous sentence are based on our assumptions concerning a number of unknown future factors including commodity prices, recompletion and drilling results, lease operating expenses, administrative expenses, interest expense, financing costs, and other costs and estimates we believe are reasonable based on information currently available to us; however, our assumptions and the Company's future performance are both subject to a wide range of risks including, the volatility of oil and gas prices, the results of our hedging transactions, the costs and results of drilling and operations, the timing of production, mechanical and other inherent risks associated with oil and gas production, weather, the availability of drilling equipment, changes in interest rates, litigation, uncertainties about reserve estimates, environmental risks and regulatory changes, and there is no assurance that our projected results, goals and financial projections can or will be met. This presentation includes certain non-GAAP financial measures. Reconciliation and calculation schedules for the non-GAAP financial measures can be found on our website at [www.rangeresources.com](http://www.rangeresources.com).

The SEC permits oil and gas companies, in filings made with the SEC, to disclose proved reserves, which are estimates that geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions as well as the option to disclose probable and possible reserves. Range has elected not to disclose the Company's probable and possible reserves in its filings with the SEC. Range uses certain broader terms such as "resource potential," or "unproved resource potential," "upside" and "EURs per well" or other descriptions of volumes of resources potentially recoverable through additional drilling or recovery techniques that may include probable and possible reserves as defined by the SEC's guidelines. Range has not attempted to distinguish probable and possible reserves from these broader classifications. The SEC's rules prohibit us from including in filings with the SEC these broader classifications of reserves. These estimates are by their nature more speculative than estimates of proved, probable and possible reserves and accordingly are subject to substantially greater risk of being actually realized. Unproved resource potential refers to Range's internal estimates of hydrocarbon quantities that may be potentially discovered through exploratory drilling or recovered with additional drilling or recovery techniques and have not been reviewed by independent engineers. Unproved resource potential does not constitute reserves within the meaning of the Society of Petroleum Engineer's Petroleum Resource Management System and does not include proved reserves. Area wide unproven, unrisks resource potential has not been fully risked by Range's management. "EUR," or estimated ultimate recovery, refers to our management's internal estimates of per well hydrocarbon quantities that may be potentially recovered from a hypothetical future well completed as a producer in the area. These quantities do not necessarily constitute or represent reserves within the meaning of the Society of Petroleum Engineer's Petroleum Resource Management System or the SEC's oil and natural gas disclosure rules. Our management estimated these EURs based on our previous operating experience in the given area and publicly available information relating to the operations of producers who are conducting operating in these areas. Actual quantities that may be ultimately recovered from Range's interests will differ substantially. Factors affecting ultimate recovery include the scope of Range's drilling program, which will be directly affected by the availability of capital, drilling and production costs, commodity prices, availability of drilling services and equipment, drilling results, lease expirations, transportation constraints, regulatory approvals, field spacing rules, recoveries of gas in place, length of horizontal laterals, actual drilling results, including geological and mechanical factors affecting recovery rates and other factors. Estimates of resource potential may change significantly as development of our resource plays provides additional data. In addition, our production forecasts and expectations for future periods are dependent upon many assumptions, including estimates of production decline rates from existing wells and the undertaking and outcome of future drilling activity, which may be affected by significant commodity price declines or drilling cost increases. Investors are urged to consider closely the disclosure in our most recent Annual Report on Form 10-K, available from our website at [www.rangeresources.com](http://www.rangeresources.com) or by written request to 100 Throckmorton Street, Suite 1200, Fort Worth, Texas 76102. You can also obtain this Form 10-K by calling the SEC at 1-800-SEC-0330.

# Regional Extent Marcellus Liquids Rich Play



Liquids rich portion of play in SW PA discovered in 2006 and 2007. Play in full development now.

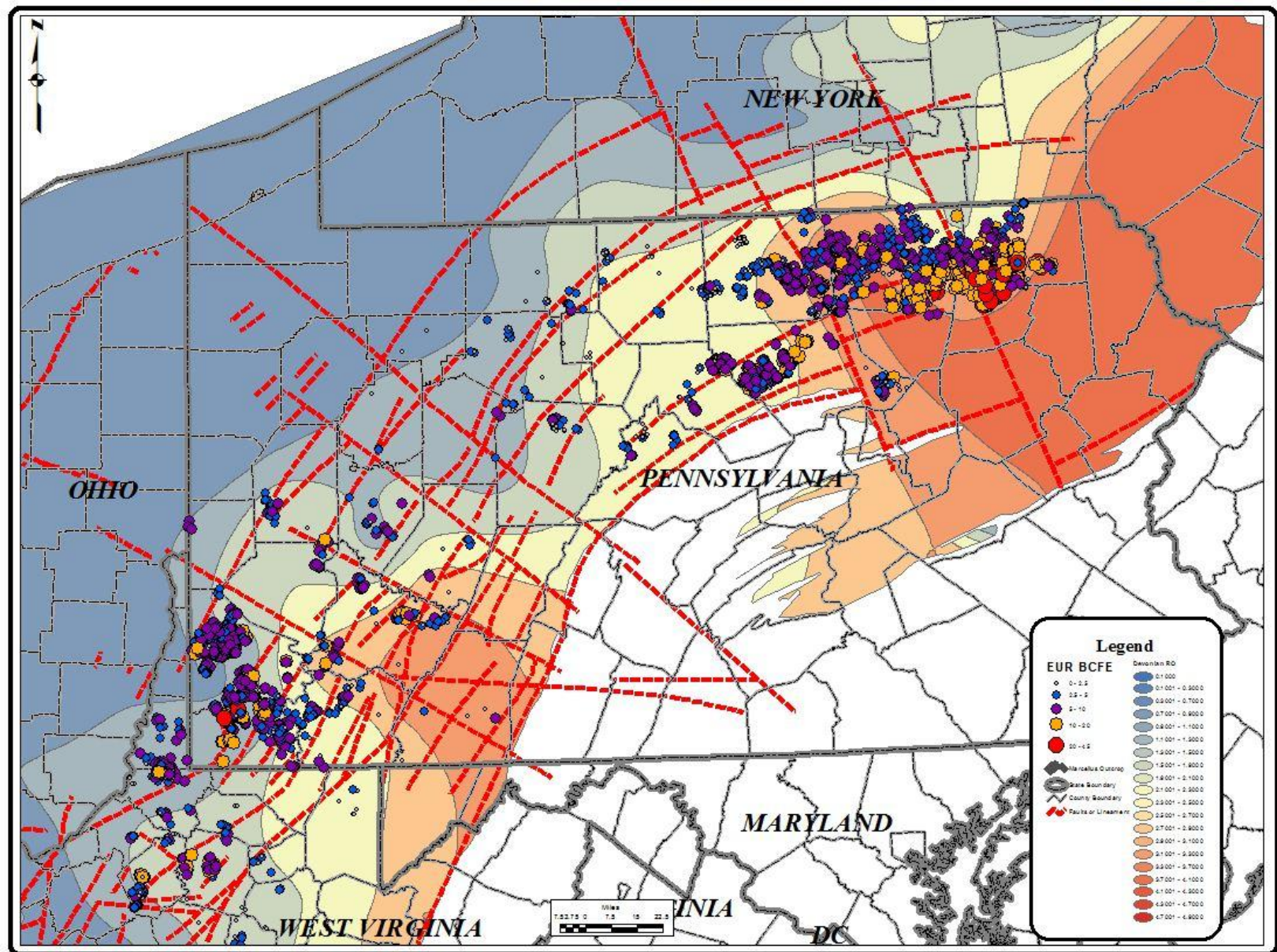
Initial results and potential not immediately evident.

Proved/de-risked portion of play under development in SW PA, northern WV and WV Panhandle.

Northern PA still unexplored and problematic thus far.

NY political climate prohibited testing there.

# Marcellus Shale Play Thermal Maturity

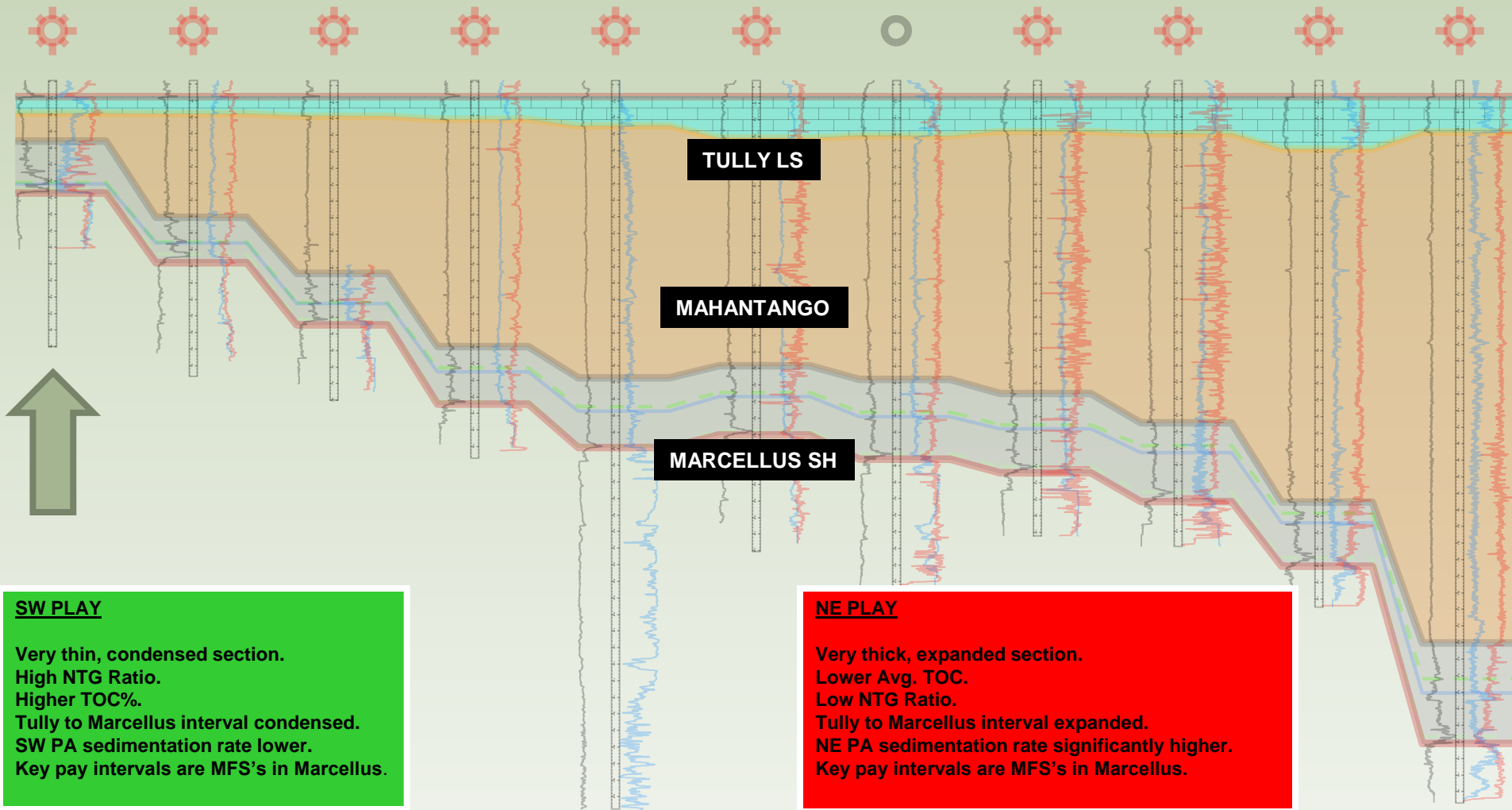


# Regional Stratigraphic Cross-Section

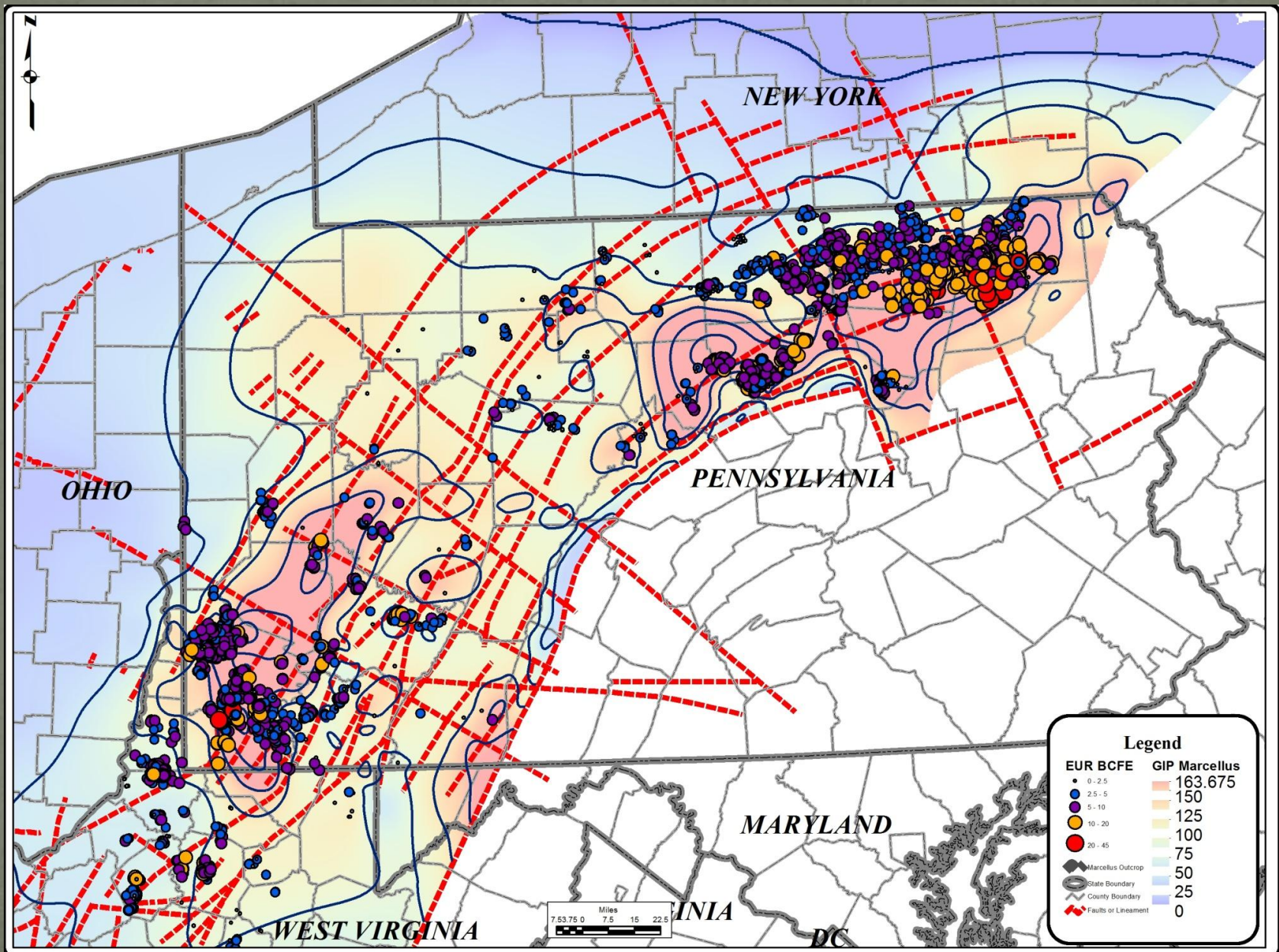
MARCELLUS SHALE

SW

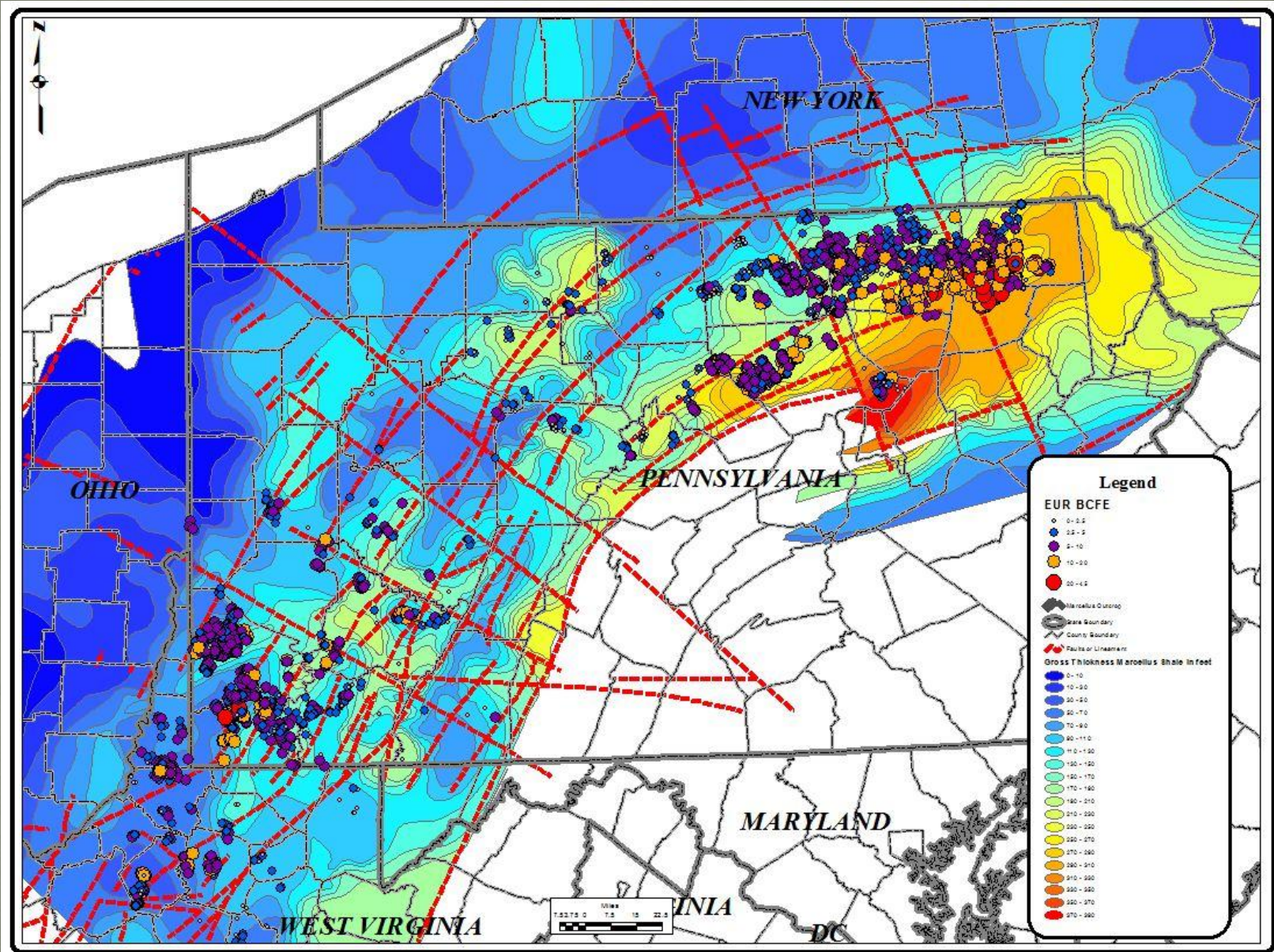
NE



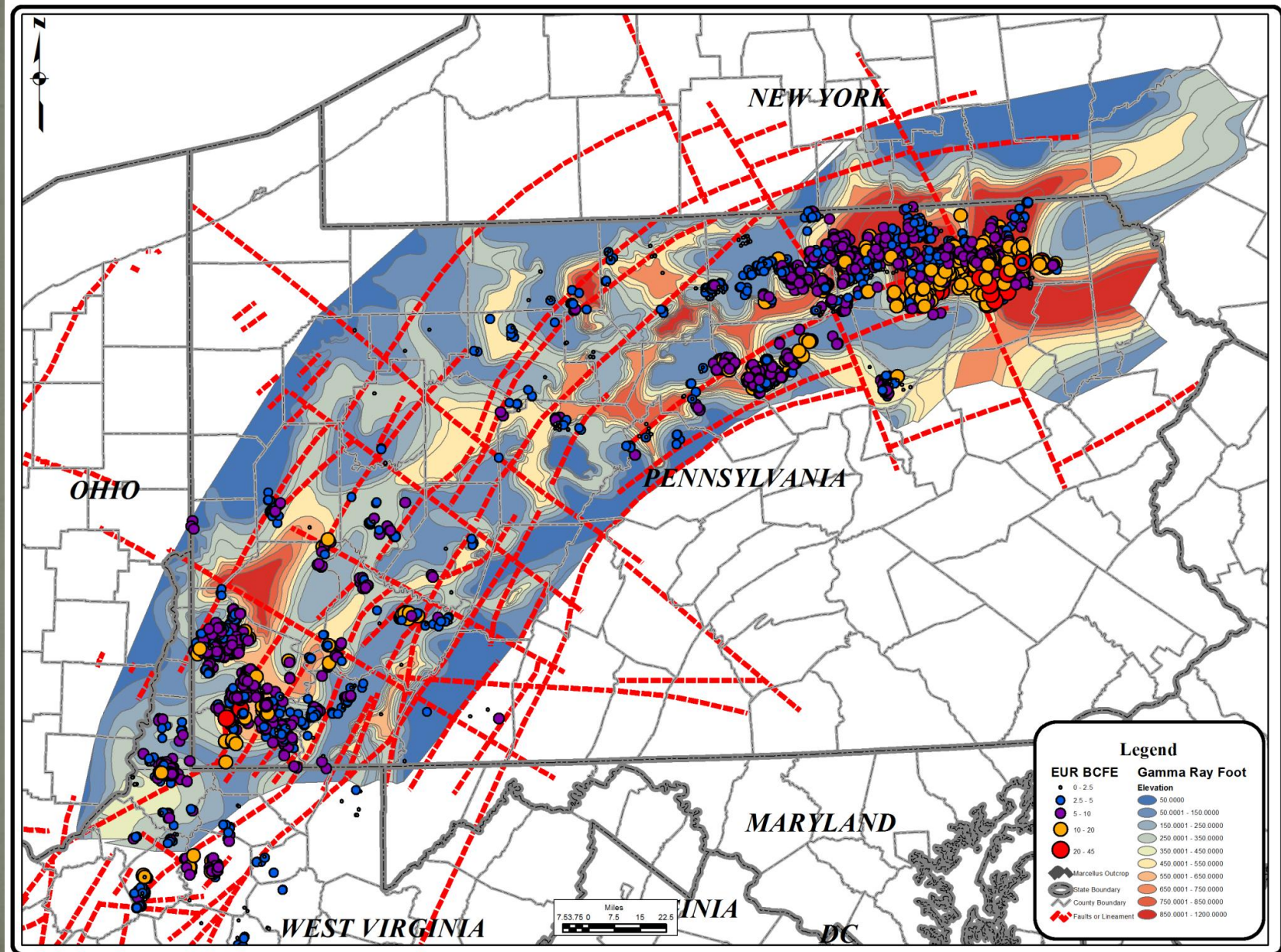
# Marcellus Shale Play GIP



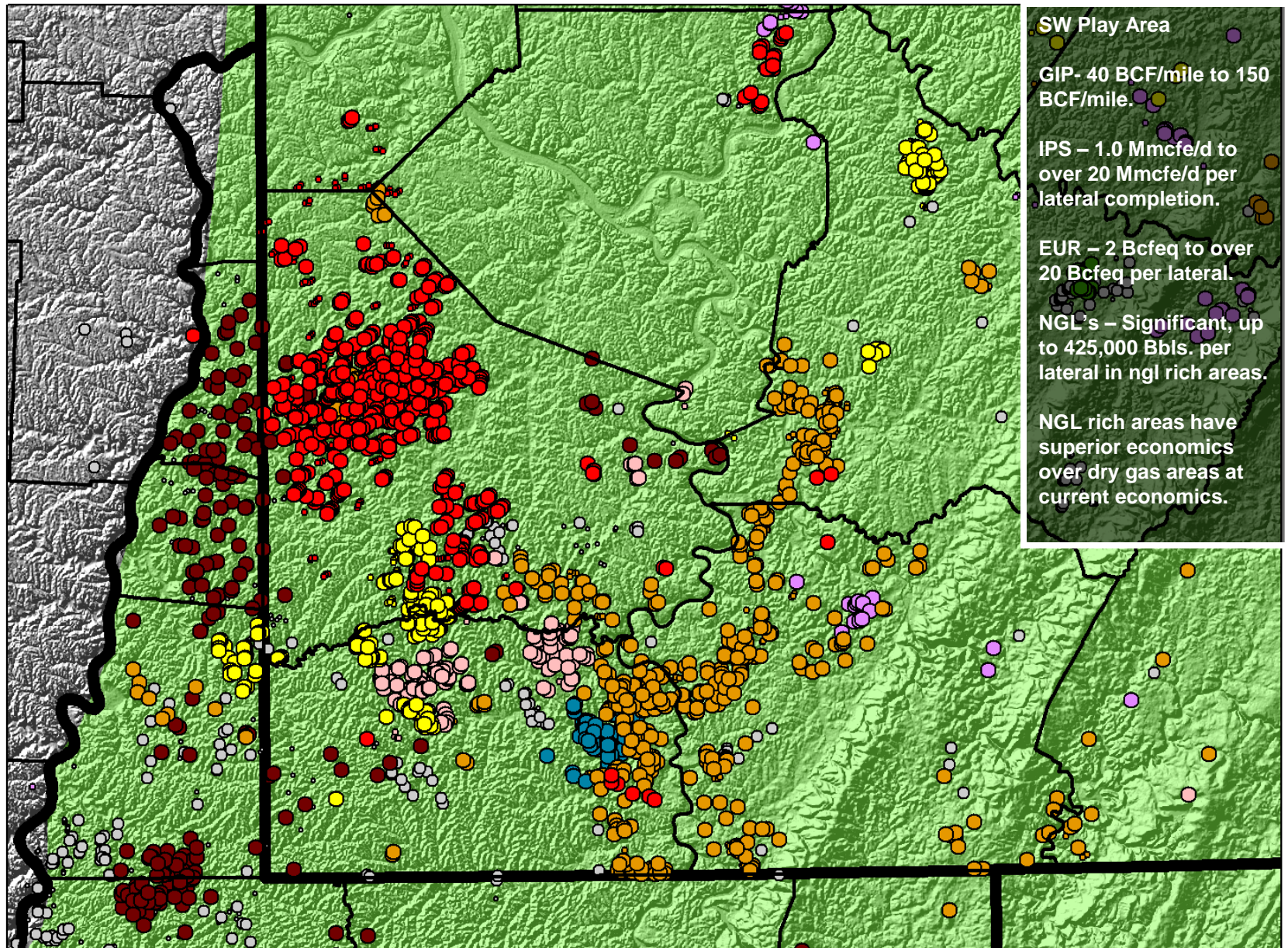
# Marcellus Shale Play Marcellus Gross Thickness



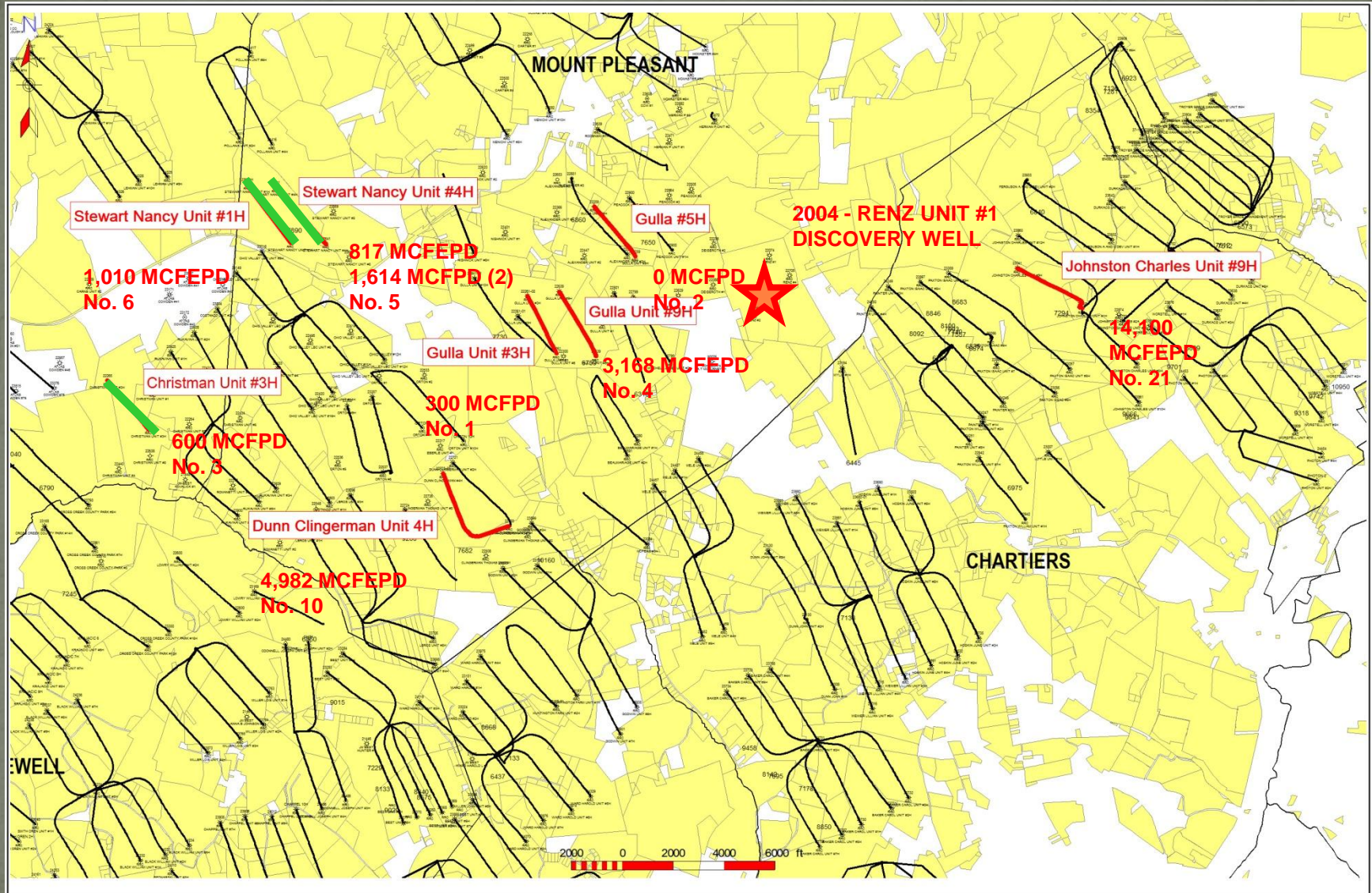
# Marcellus Shale Play GRFT Map – Net Organics



# SW PA Marcellus Core Area – 2004 to Present

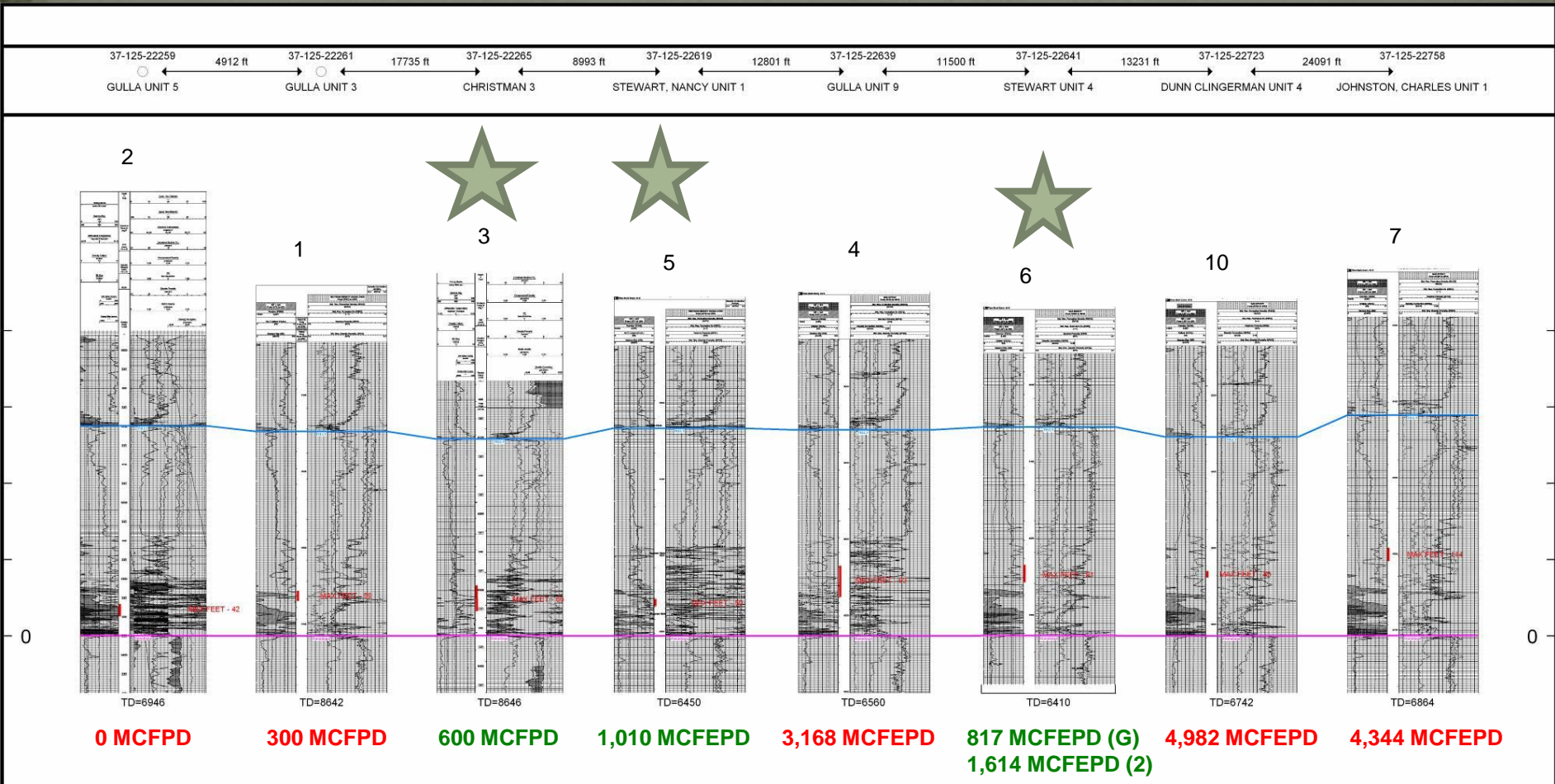


# Initial Discovery Well and Key Horizontal Tests to 2008



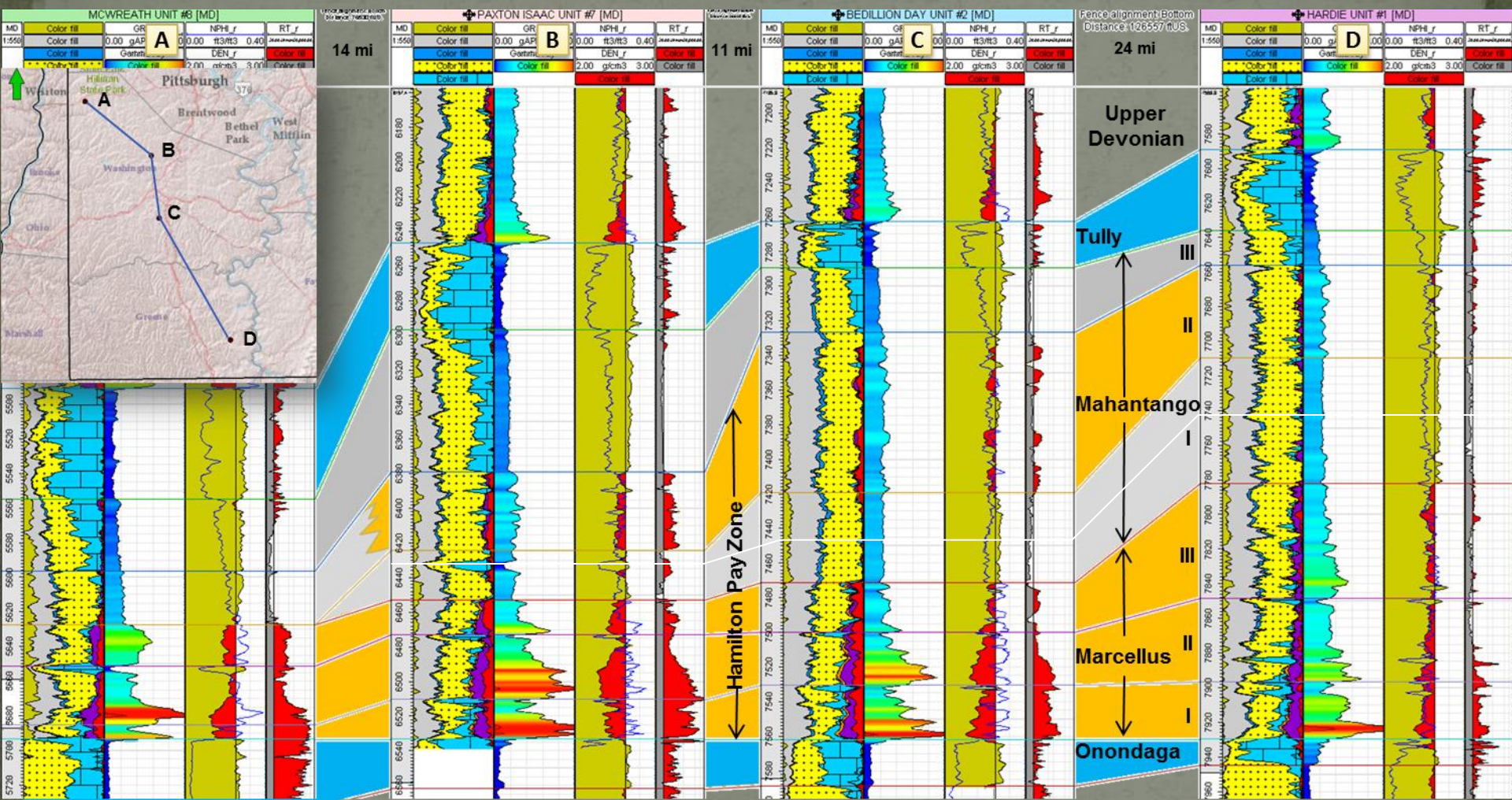
First three lateral wells tested 0 MCFPD to 600 MCFPD. Fourth and afterwards tested 1614 MCFPD to 14,100 MCFPD...What was the driver? All have similar azimuths and length. Initial laterals in liquids rich portion of play highlighted in green and were among the first laterals in the play.

# 2006 – 2008 Early Horizontal Well Target Intervals



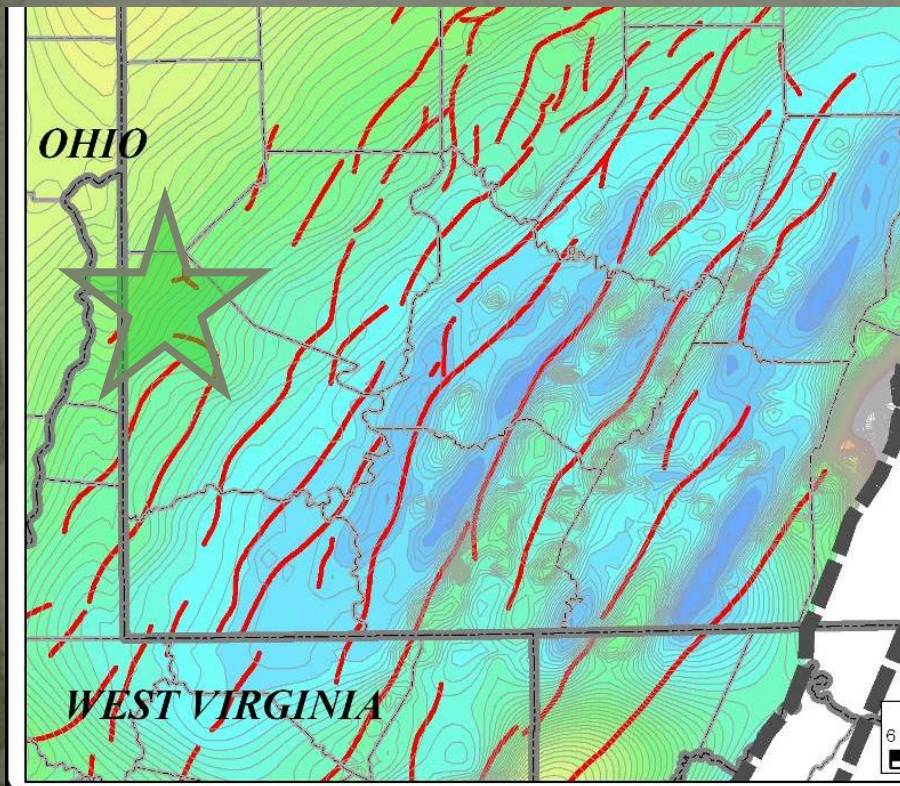
**Initial four wells on left landed lower in Marcellus section: all low IP's. Four laterals on the right landed higher in section with major changes in results. Landing point/target = Major driver! Note the sequence and IP's of the liquids rich laterals. IP test rate strong driver in focus of field development but not the entire story.**

# Marcellus Stratigraphic Packages SW PA

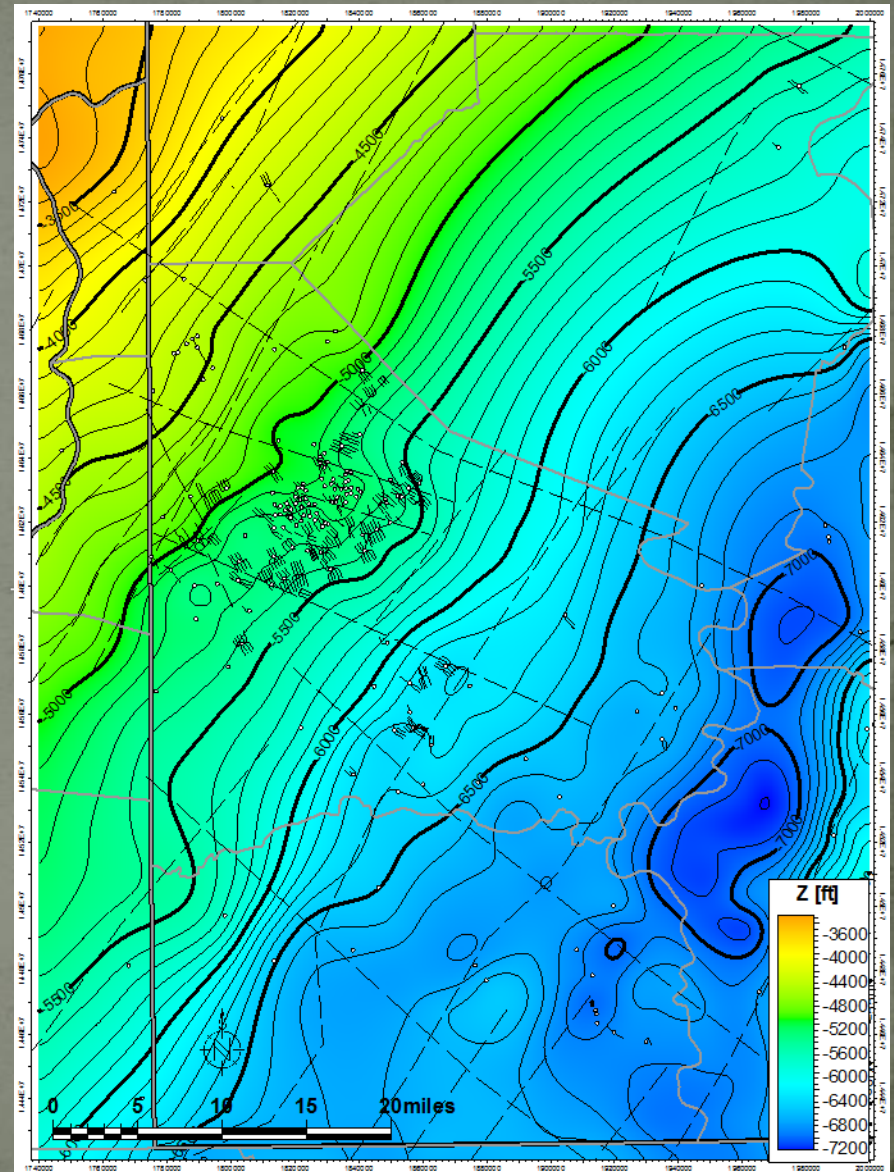


Cross section shows significant differences between western liquids rich area and eastern dry gas trends. Note the rapid thinning from east to west but see hints of increasing porosity and permeability.

# Structure: Onondaga Top



Play area is significantly west of major Appalachian Fold Belt. Key structural features affecting area are basement faults systems related to Rome Trough rift system and later day recurrent strike-slip movement.

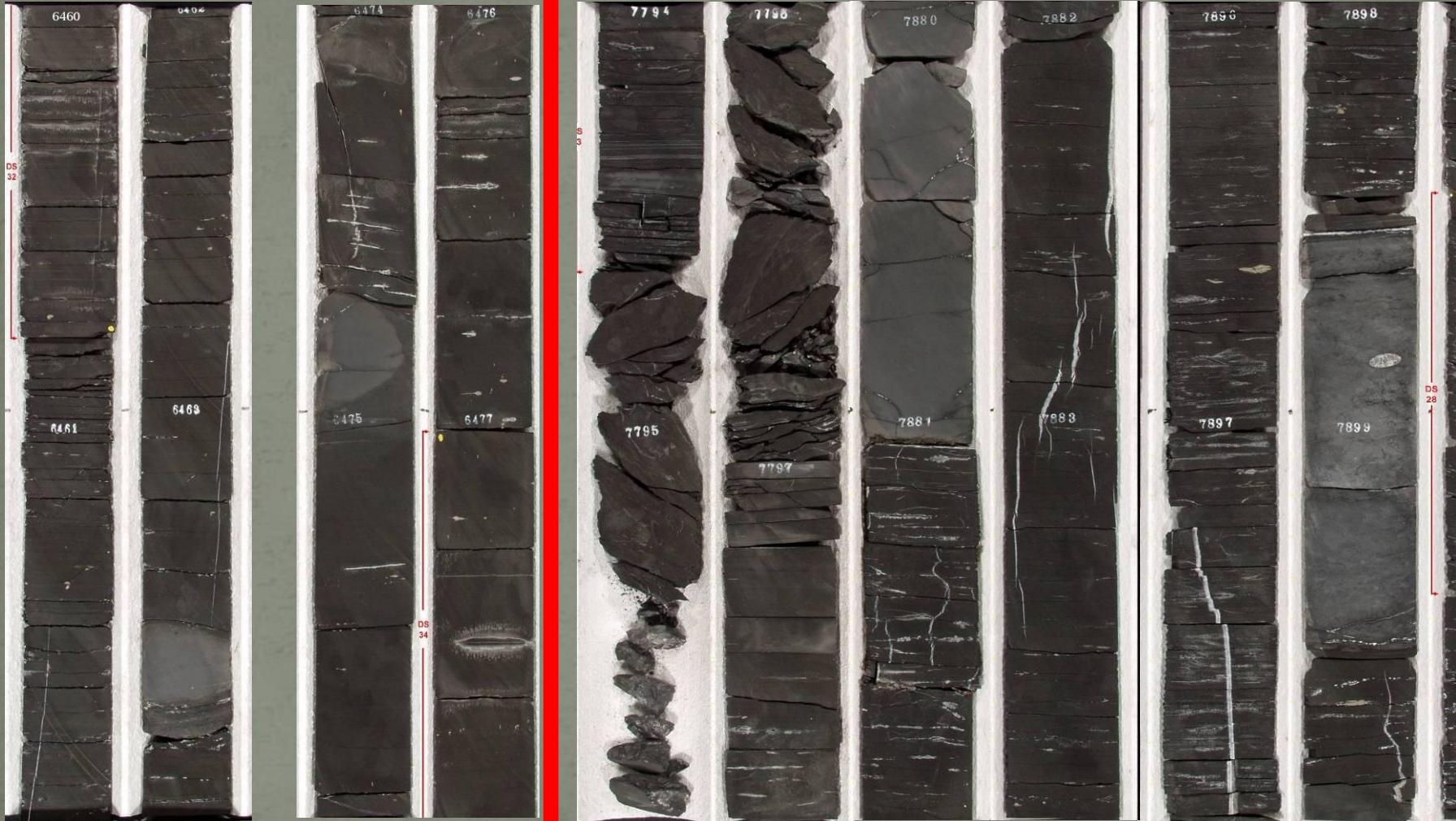


# SW PA Core Studies – Natural Fractures Increase to East

Western Washington County  
Well

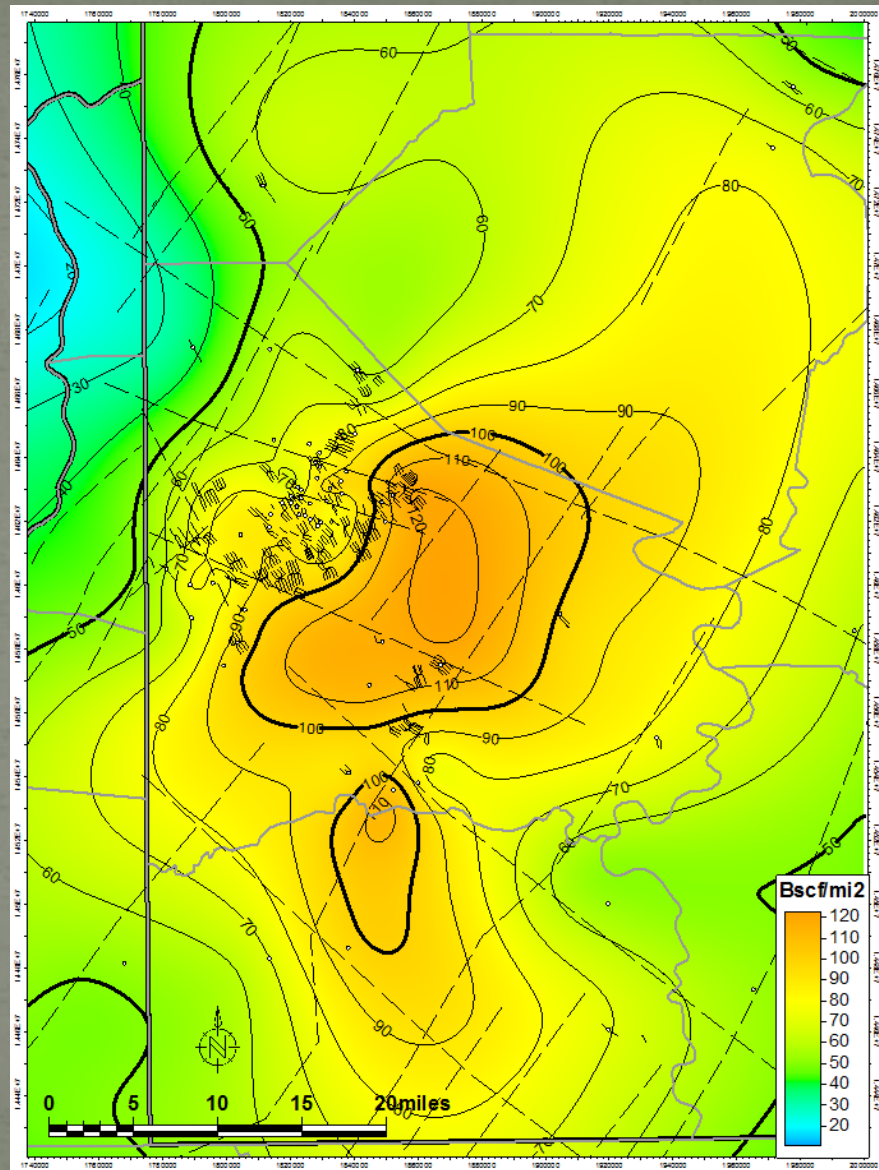
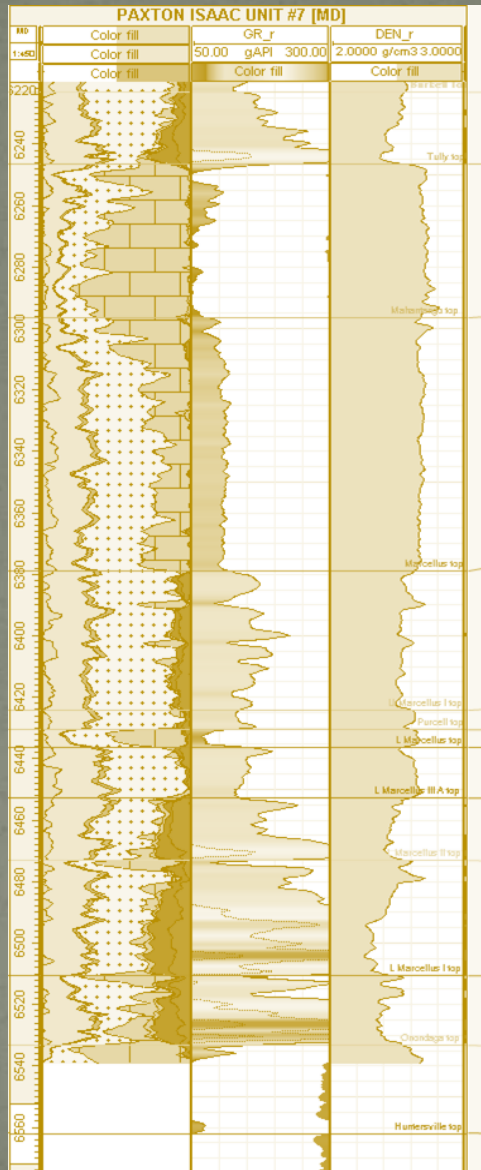
Eastern Greene County Well

Eastern Greene County Well



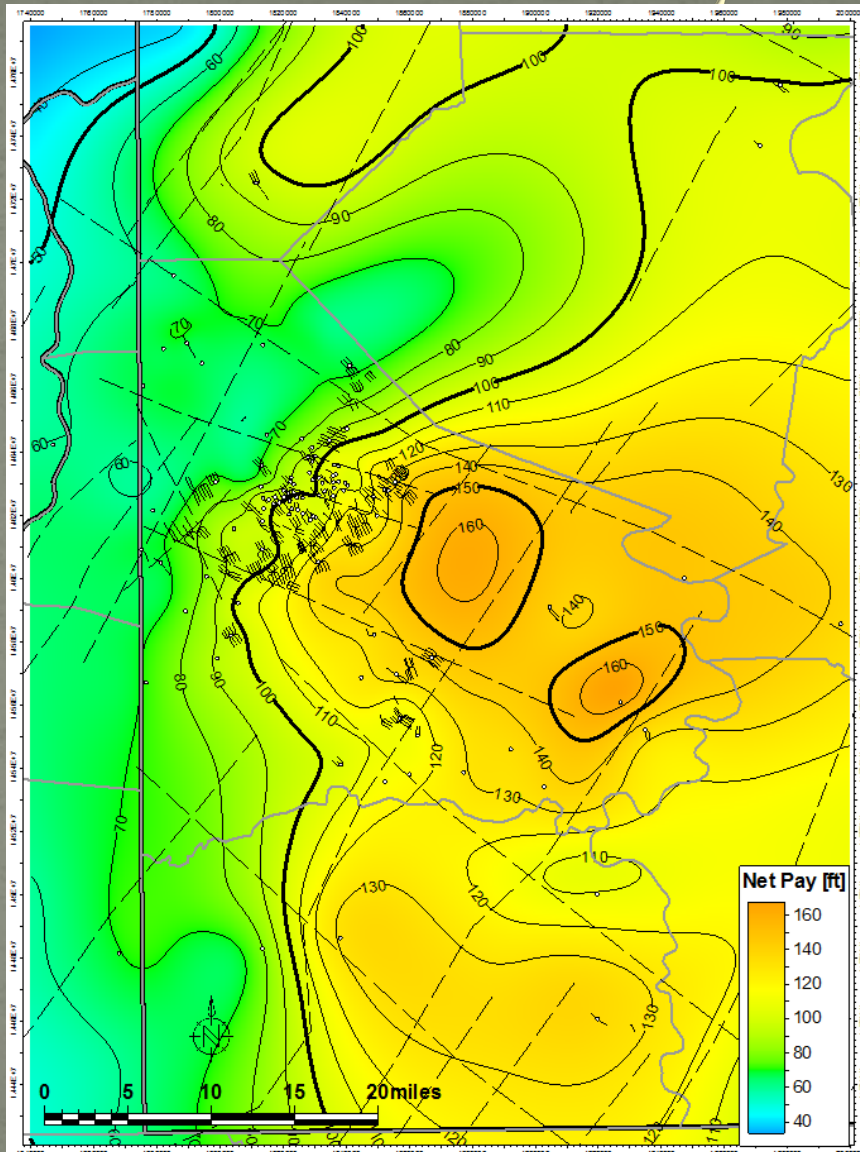
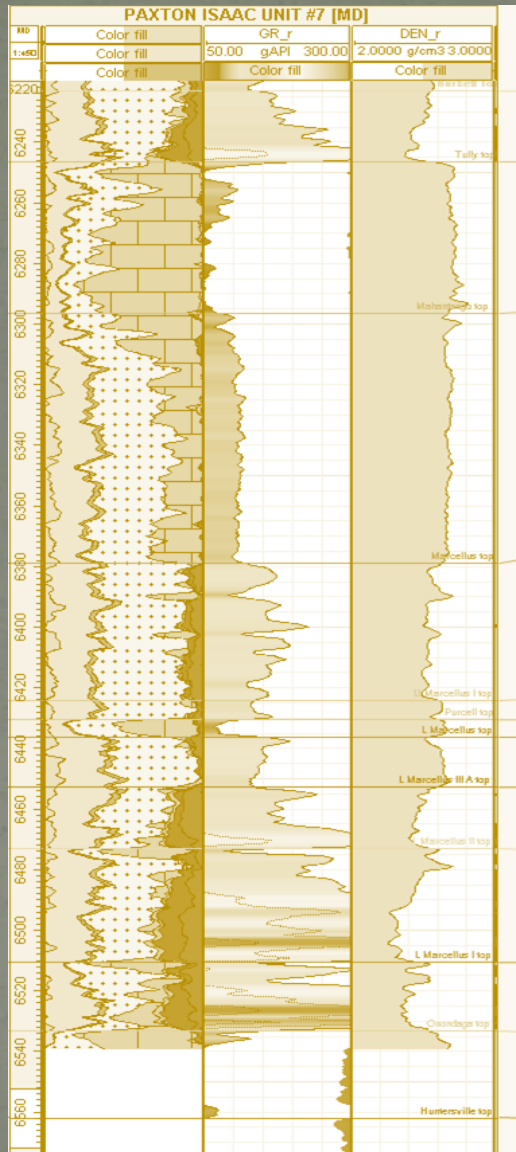
The number and width of vertical calcite-filled fractures increases significantly from the Western Washington County cores to the eastern Greene County cores.

# Net GIP: Marcellus Interval



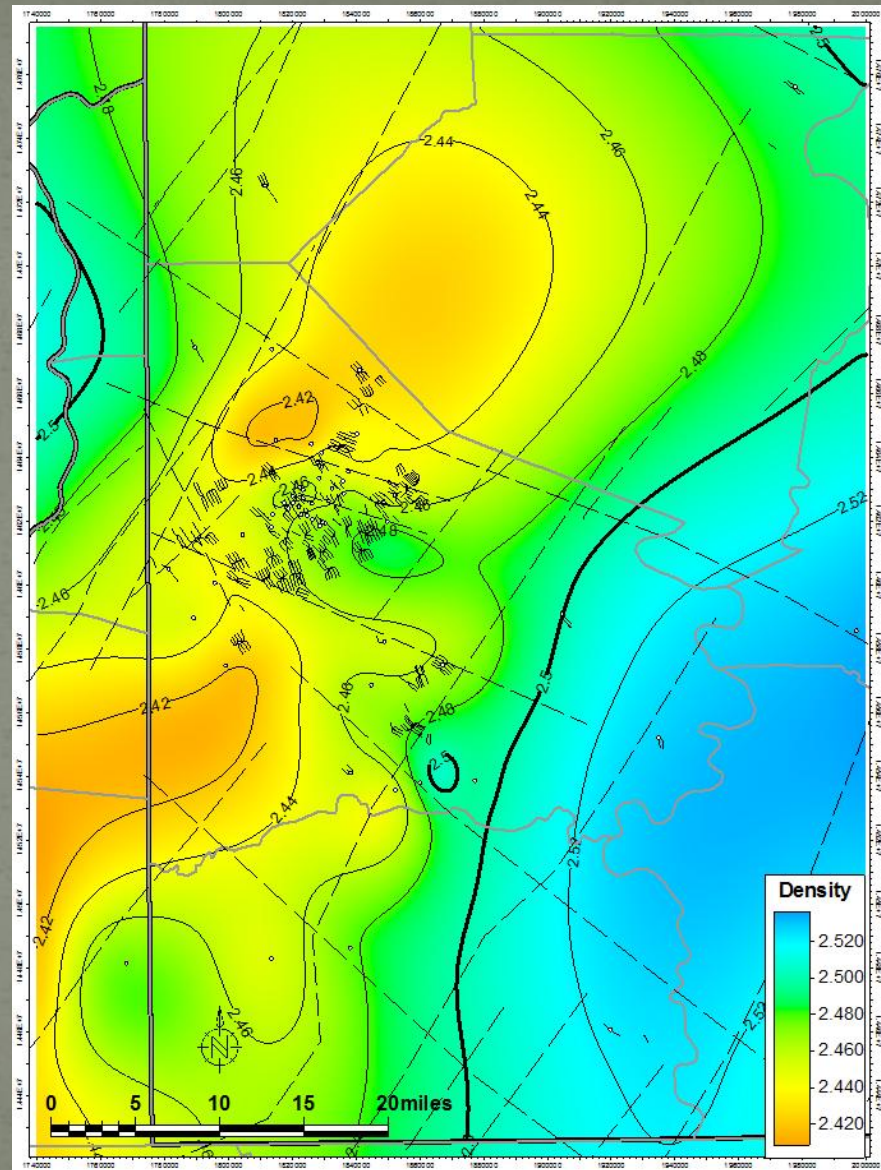
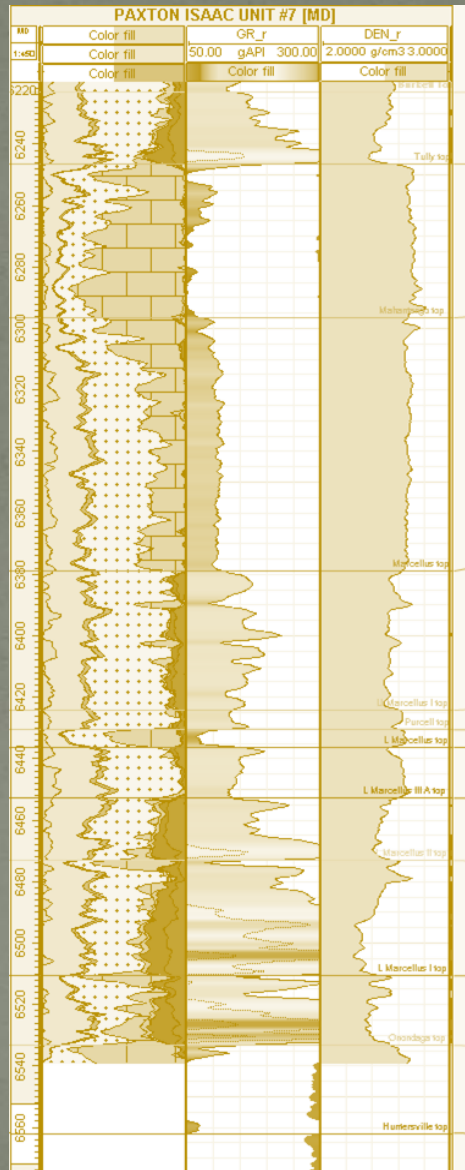
GIP ranges from 50 BCF/mi<sup>2</sup> to over 140 BCF/mi<sup>2</sup> with lower values in liquids rich portion of play. Note strong control by basement faults. Note NW portion of play in liquids rich area does not show high GIP. ?

# Net Thickness: Marcellus Pay



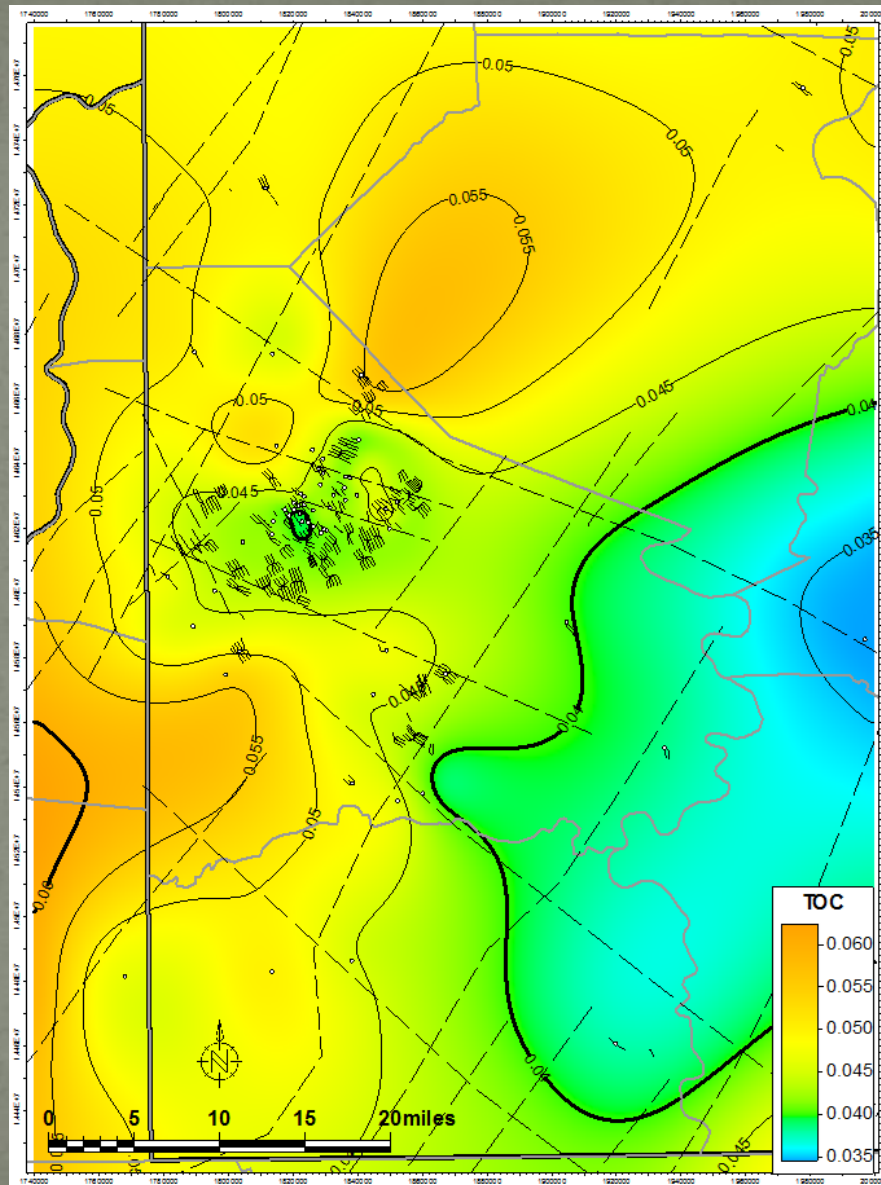
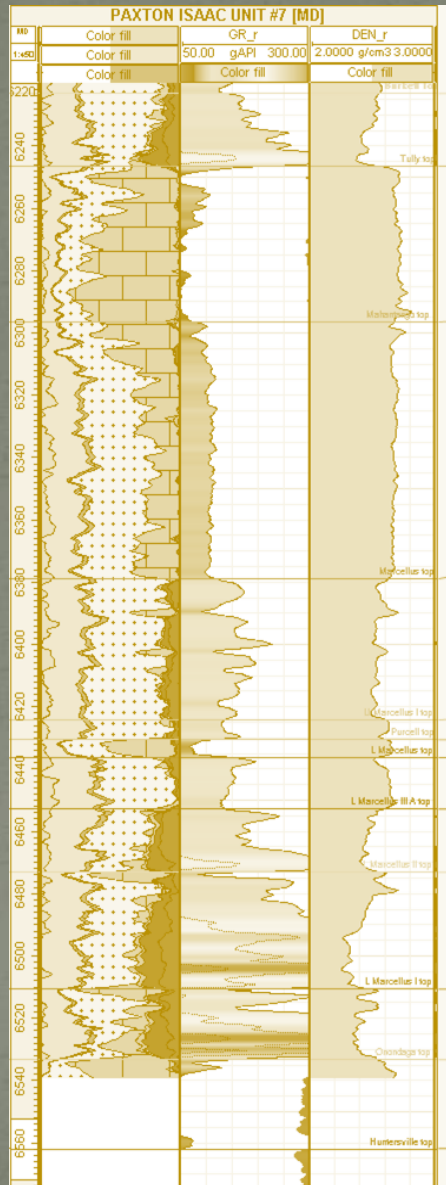
Net pay thickness ranges from 40 to 150 feet with rapid thinning associated with the western liquids rich portion of the play.

# Net Bulk Density Average: Marcellus Pay



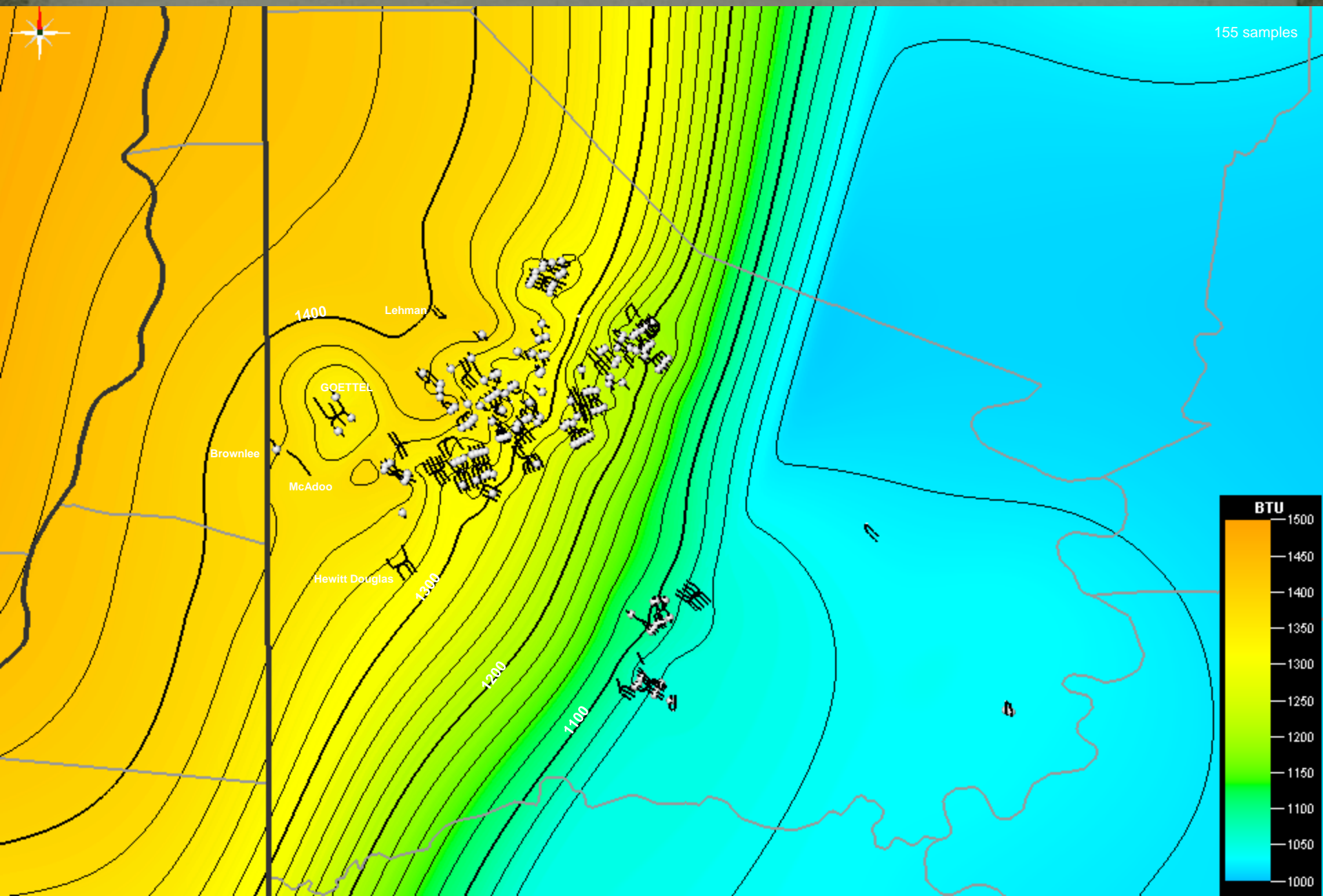
**Note the decrease in bulk density to the west suggesting increased porosity and permeability on a unit of pay basis. Note control of basement fault blocks.**

## Net TOC Average: Marcellus Pay

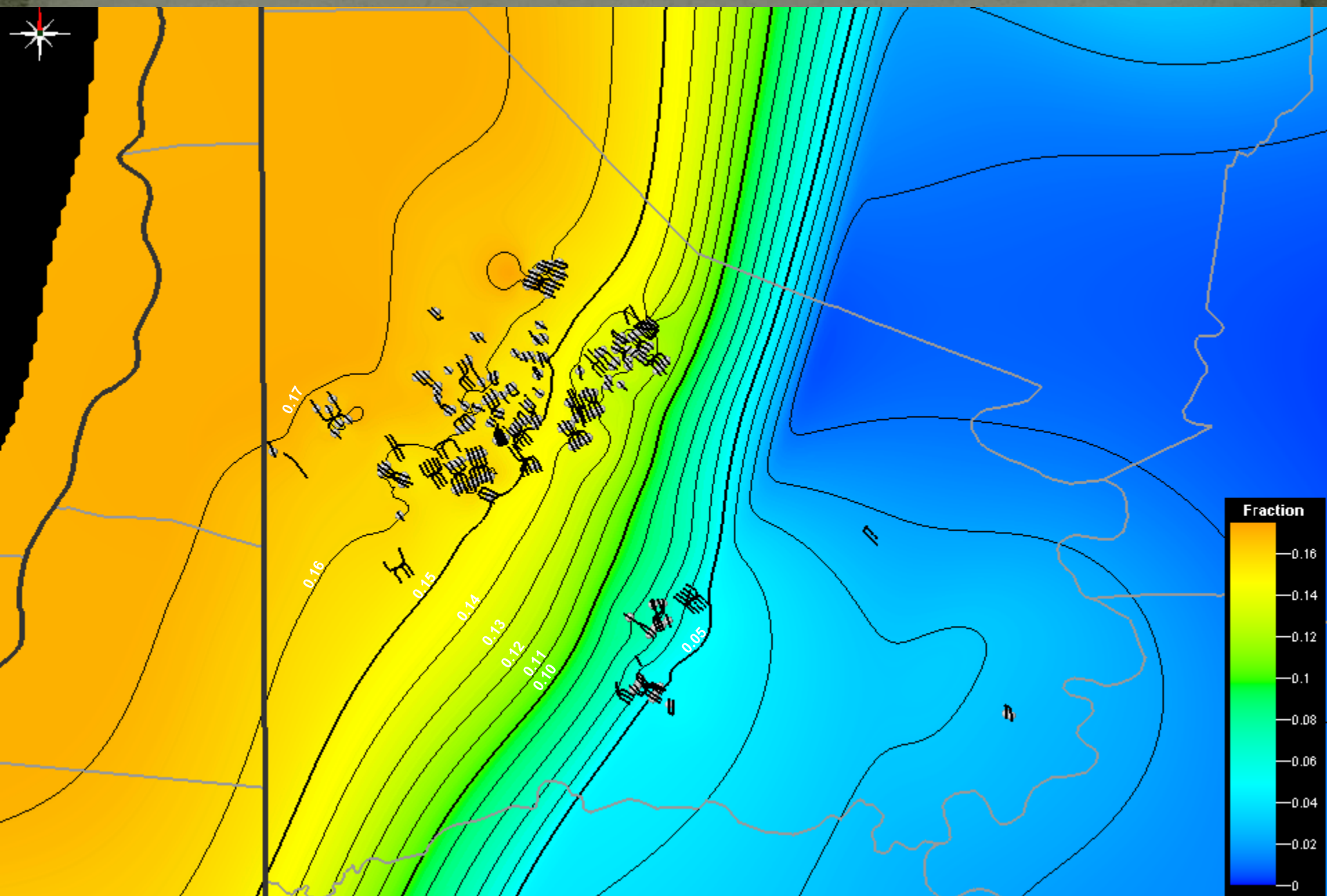


**Note the increase in average TOC content to the west and strong influence of basement faults.**

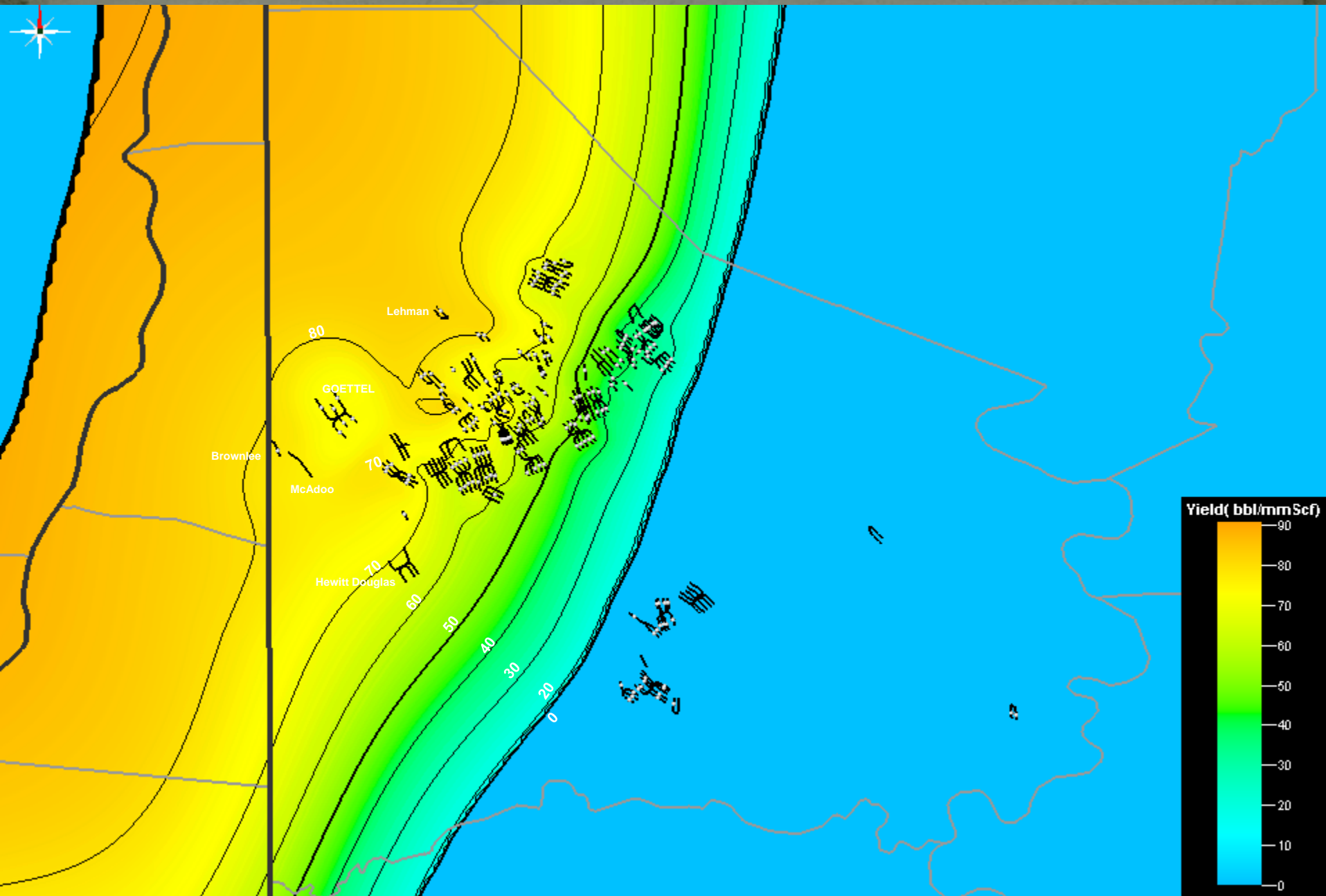
# Marcellus BTU Washington County PA



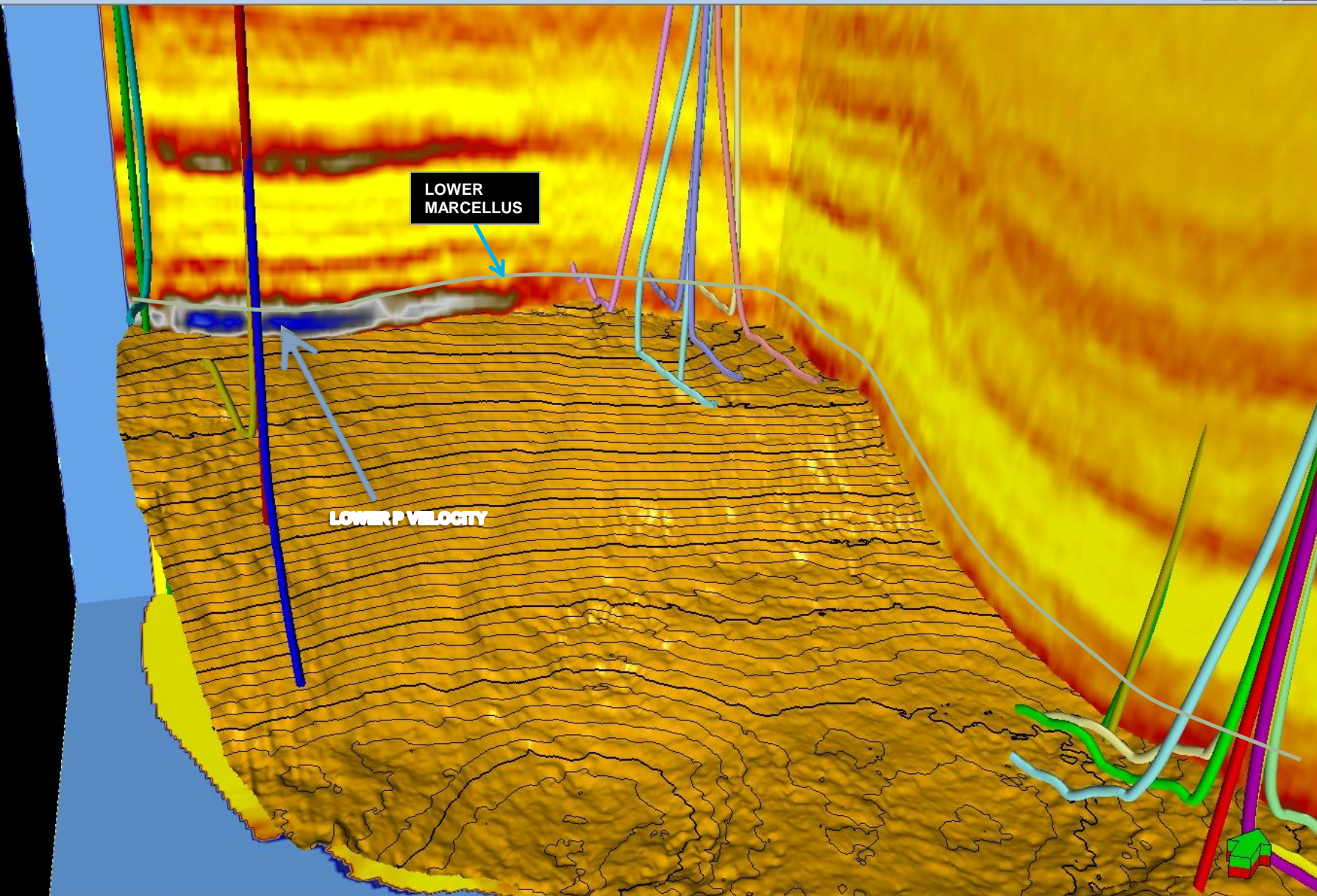
# Estimated Ethane % Washington County, PA



# Est. Marcellus NGL Yield Washington County, PA

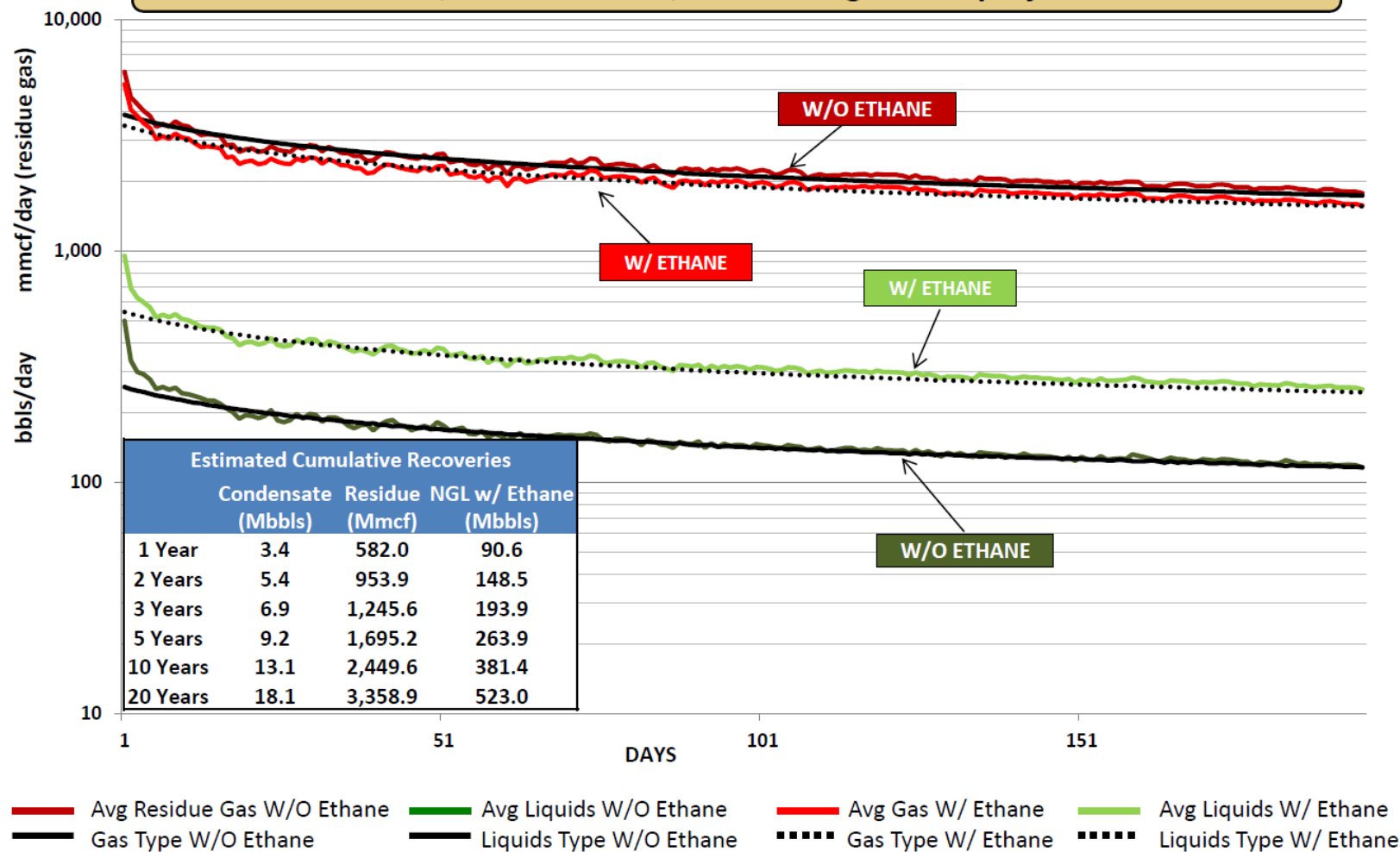


# SEISMIC EVIDENCE OF LIQUIDS IN MARCELLUS

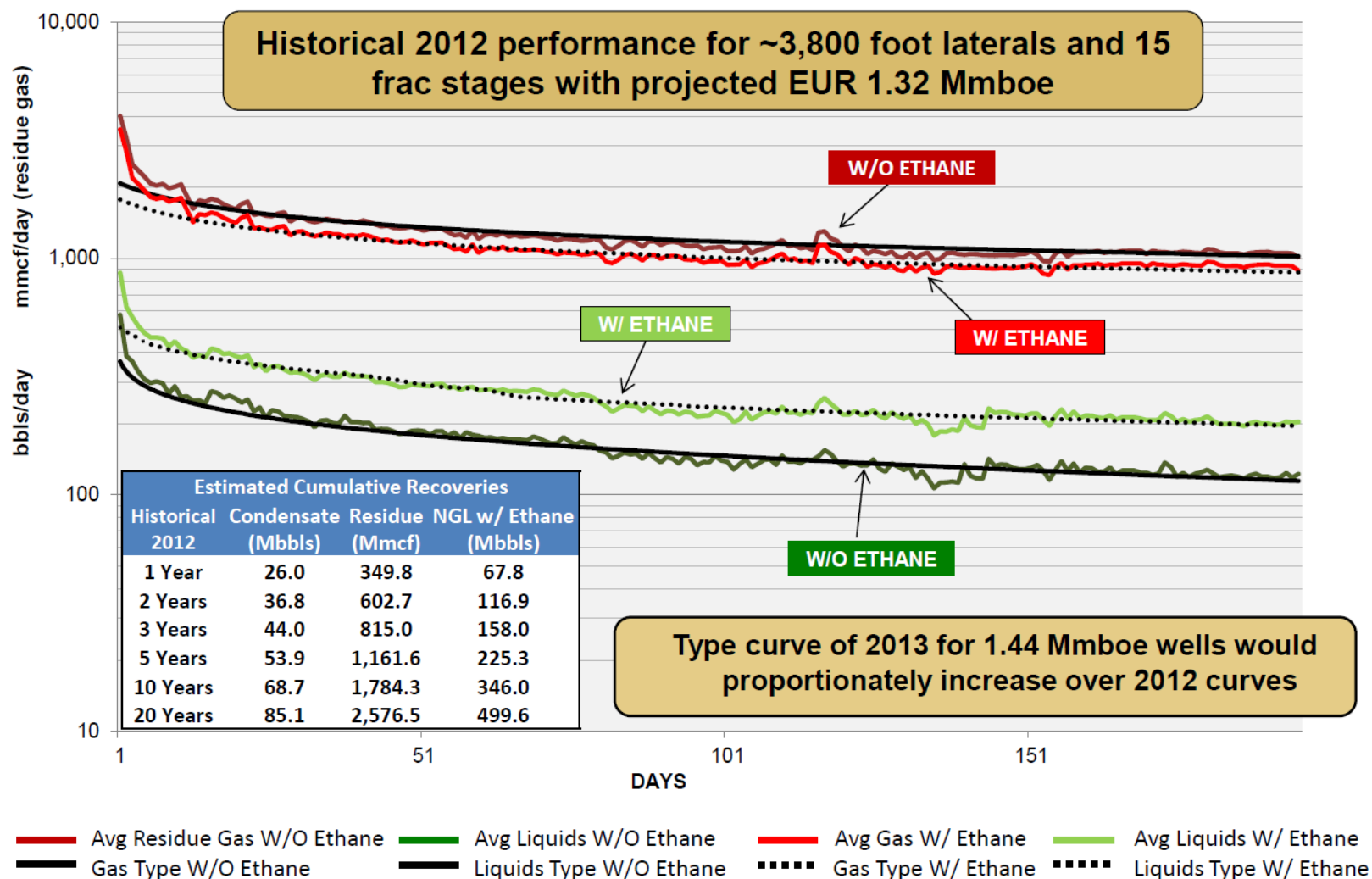


# SW PA Wet Area Marcellus Type Curve

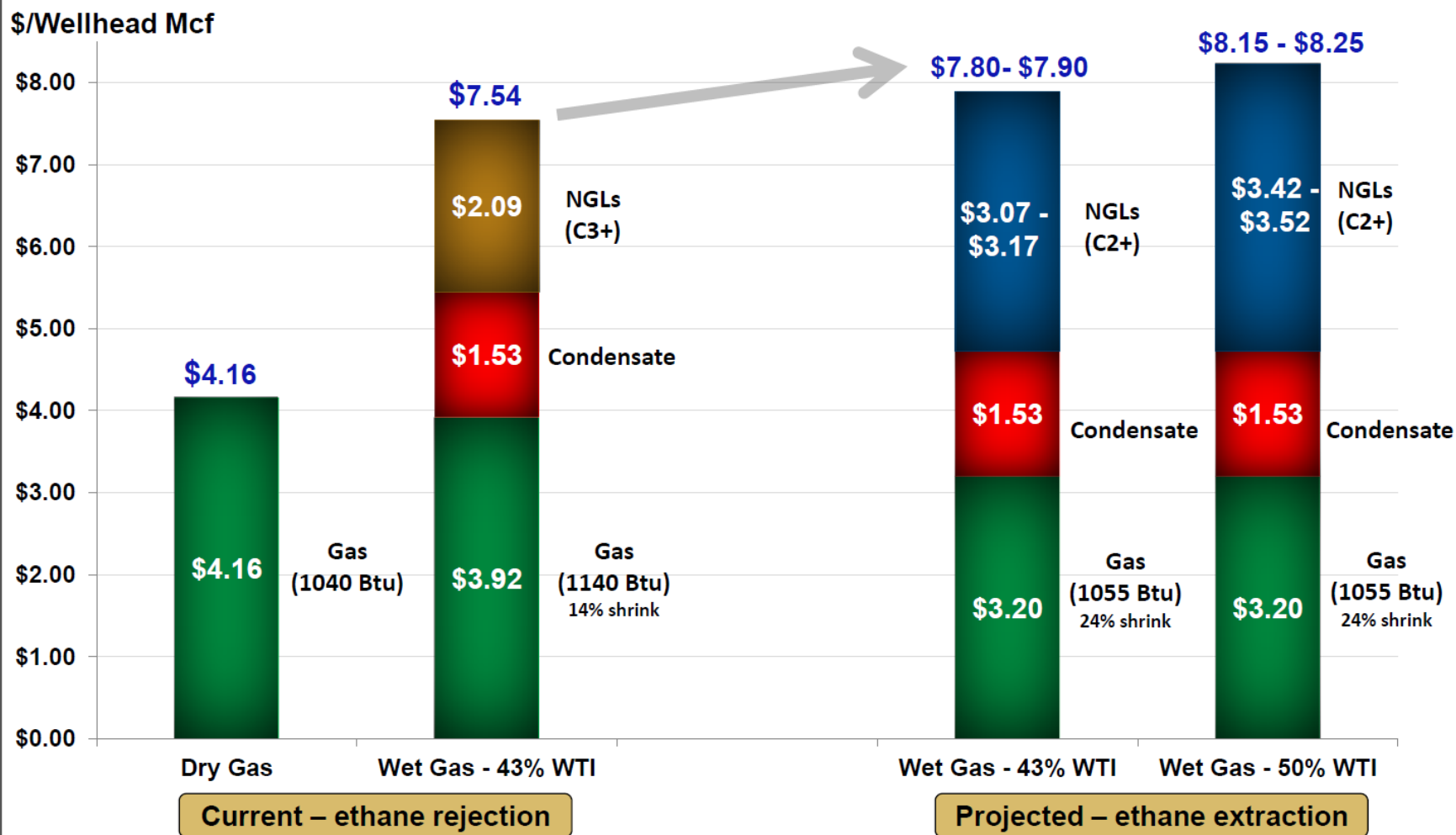
Performance for 3,200 foot lateral, 13 frac stages with projected EUR 8.7 Bcfe



# SW PA Super-Rich Area Marcellus Type Curve

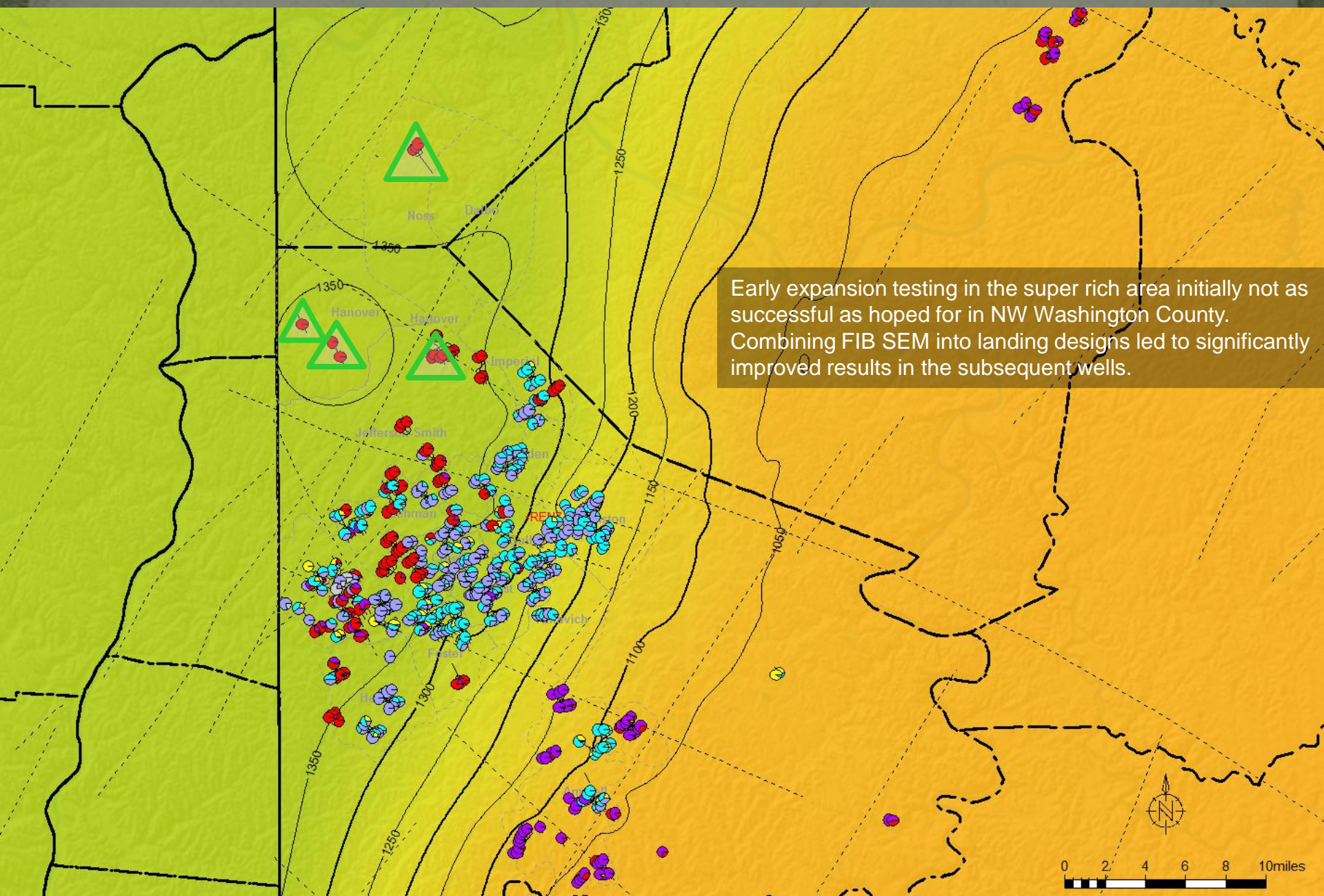


# Marcellus Wet Gas Provides Significant Price Uplift

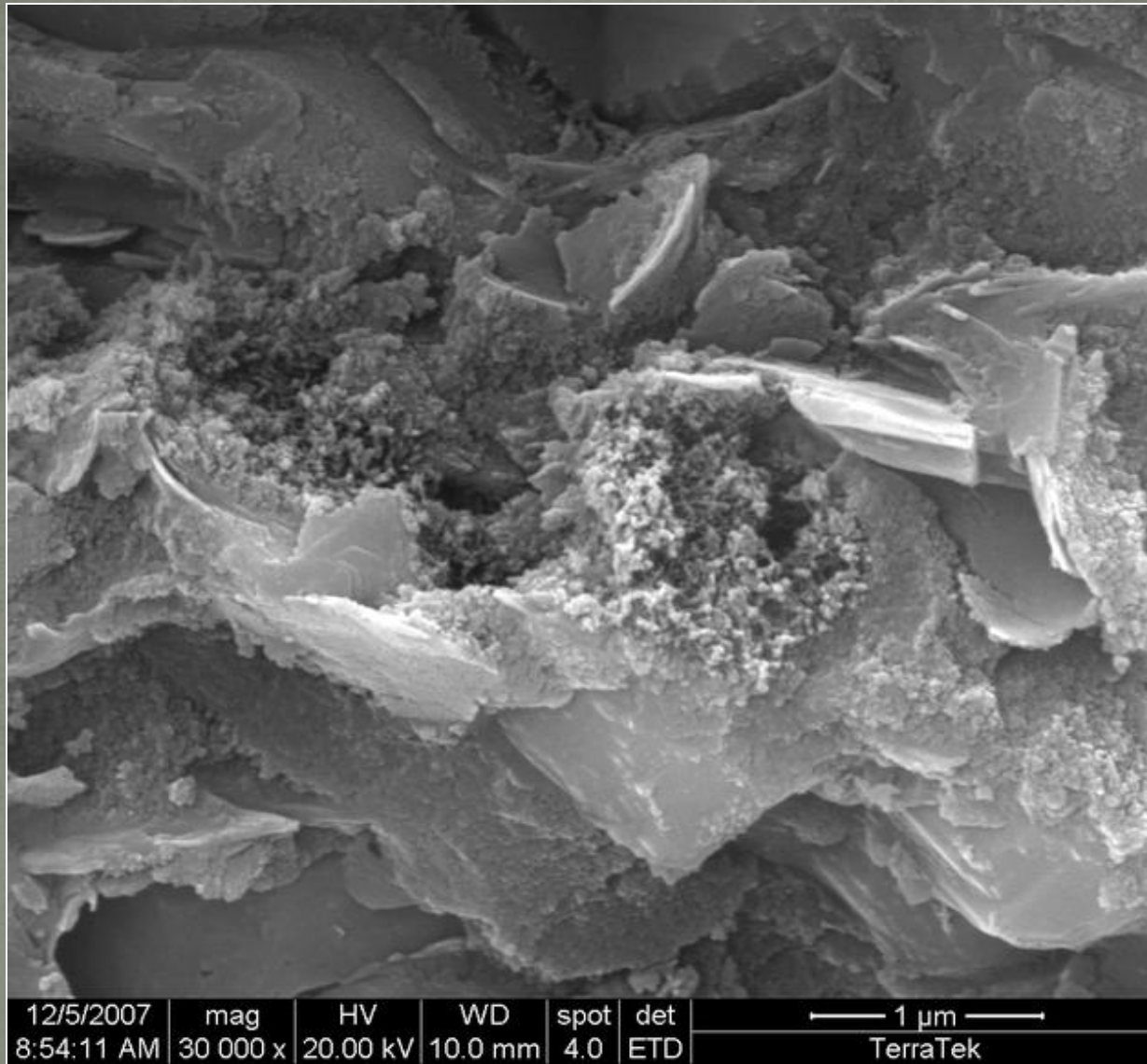


Assumptions: \$4.00 NG, \$90.00 WTI, 43% WTI, 2.27 GPM (ethane rejection), 5.60 GPM (ethane extraction), all processing, shrink, fuel & ethane transport included. Based on SWPA wet gas quality (1275 processing plant inlet btu). Wet Gas (Projected) based on full utilization of current ethane / propane agreements.

# Key FIB/SEM Landing Zone Studies – Super Rich Area

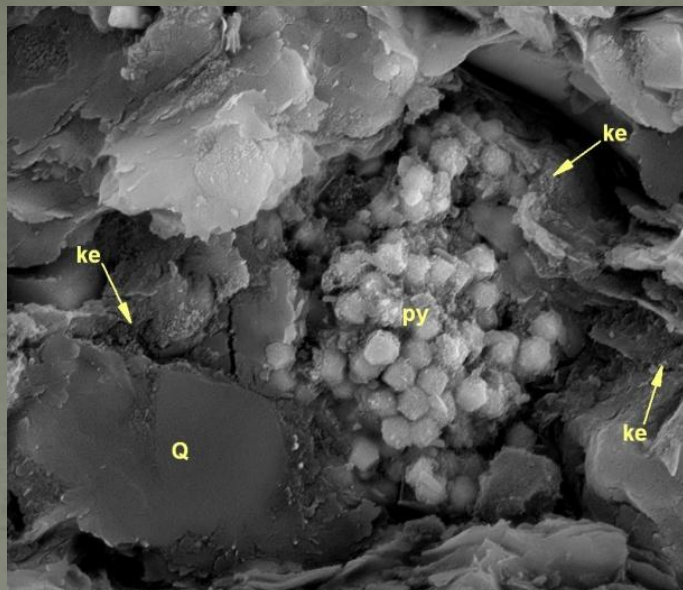


## 2D /SEM Images – Marcellus Shale SW PA

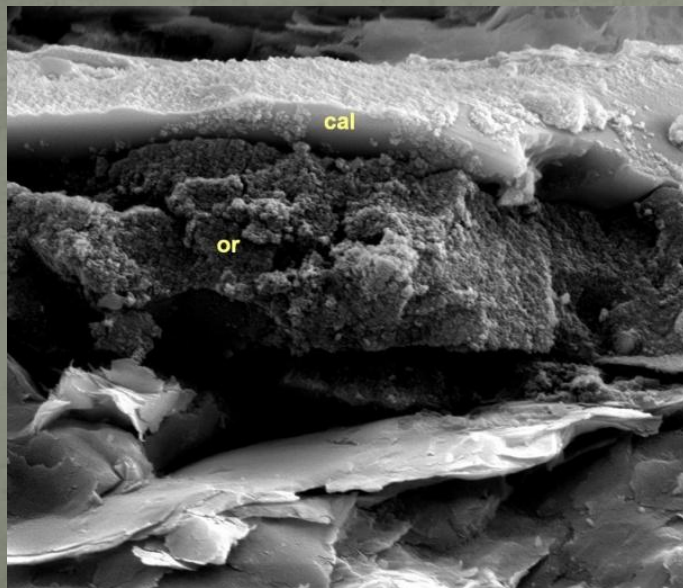


**Example standard SEM images are from NGL rich portion of SW Core area. Note large degraded organics and suggestions of larger pore sizes and high concentration of organics. Large pore sizes and degree of interconnectivity not effectively imaged by standard SEM.**

## Traditional SEM Method

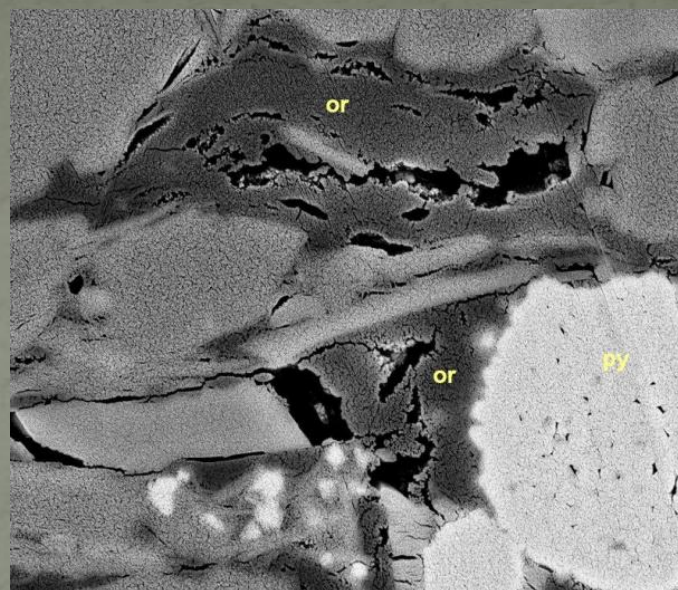


11/4/2009	curr	mag	det	WD	HV	HFW	3 μm
10:19:35 AM	0.18 nA	20 000 x	ETD	5.4 mm	15.0 kV	15.1 μm	TerraTek

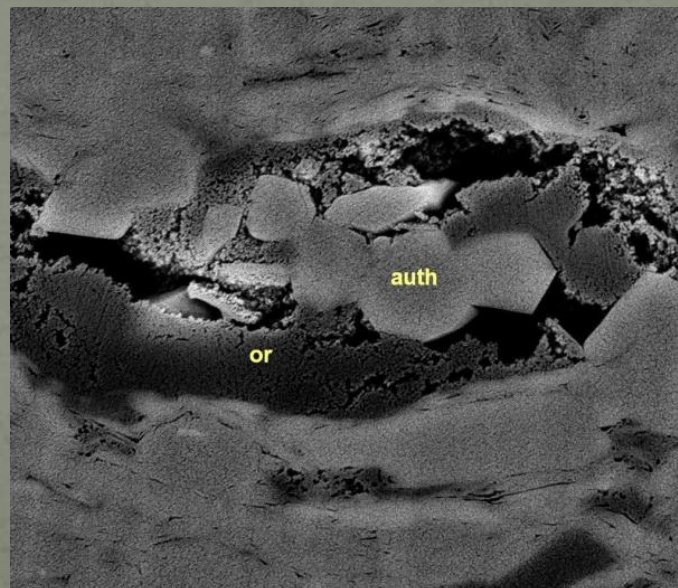


11/4/2009	curr	mag	det	WD	HV	HFW	2 μm
11:29:28 AM	0.18 nA	21 000 x	ETD	5.1 mm	15.0 kV	14.4 μm	TerraTek

## Ar-Ion Beam Milling Method



10/26/2009	curr	mag	det	WD	HV	HFW	mode	2 μm
3:51:19 PM	0.16 nA	20 000 x	TLD	5.1 mm	10.0 kV	15.1 μm	BSE	TerraTek

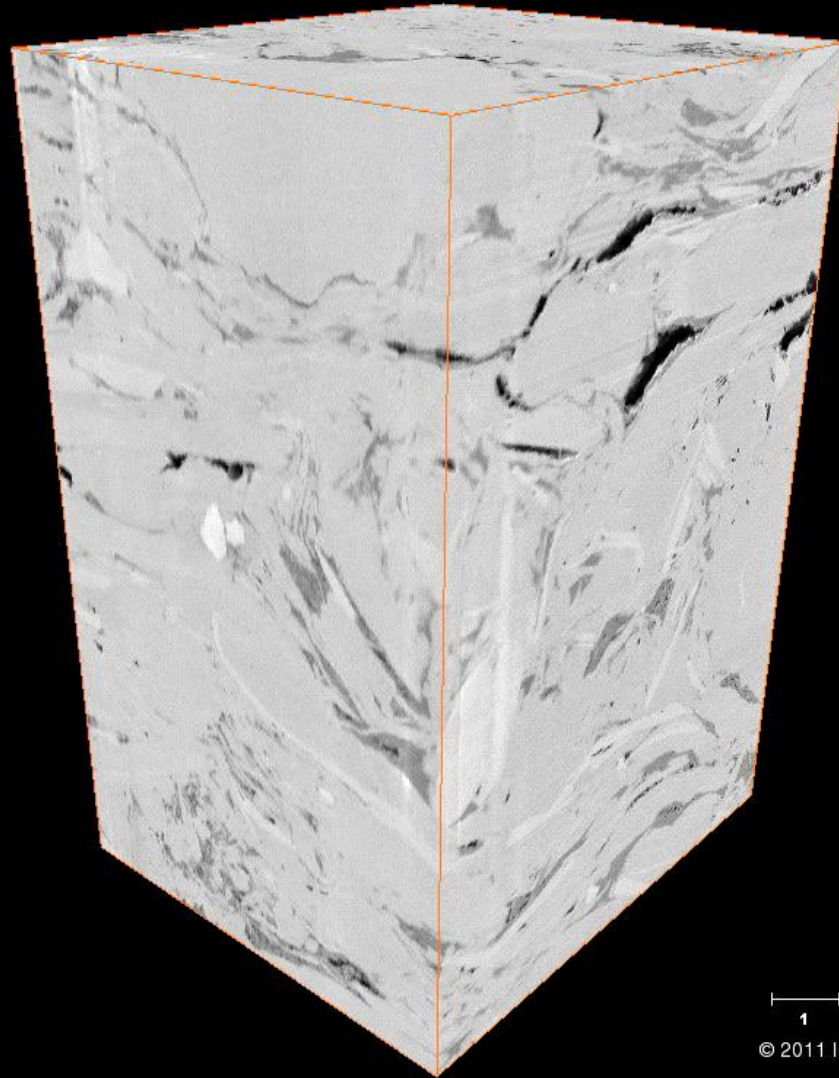


10/26/2009	curr	mag	det	WD	HV	HFW	mode	2 μm
2:34:39 PM	0.16 nA	20 000 x	TLD	5.2 mm	10.0 kV	15.1 μm	BSE	TerraTek

Use of Ar-Ion Beam milling techniques greatly aiding in showing role of organic porosity over standard 2D SEM

# 3D FIB/SEM Images – Marcellus Shale SW PA

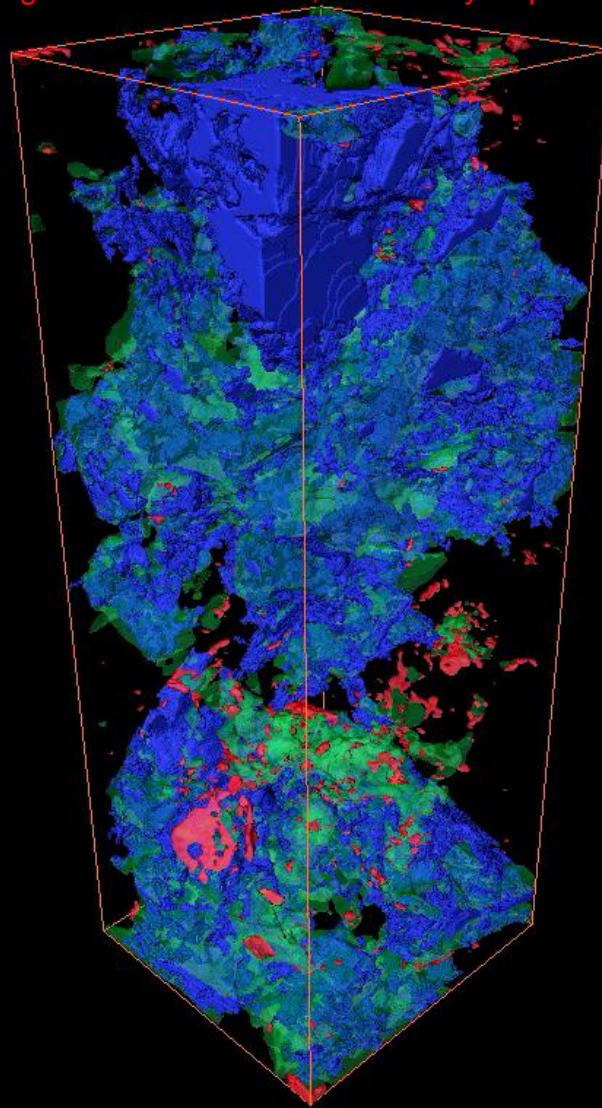
Click on image to view animation, which may require up to 1 min



Example FIB/SEM images are from NGL rich portion of SW Core area. Note large pore sizes and high concentration of organics. Large pore sizes and degree of interconnectivity only imaged by FIB SEM.

# 3D FIB/SEM Images – Marcellus Shale SW PA

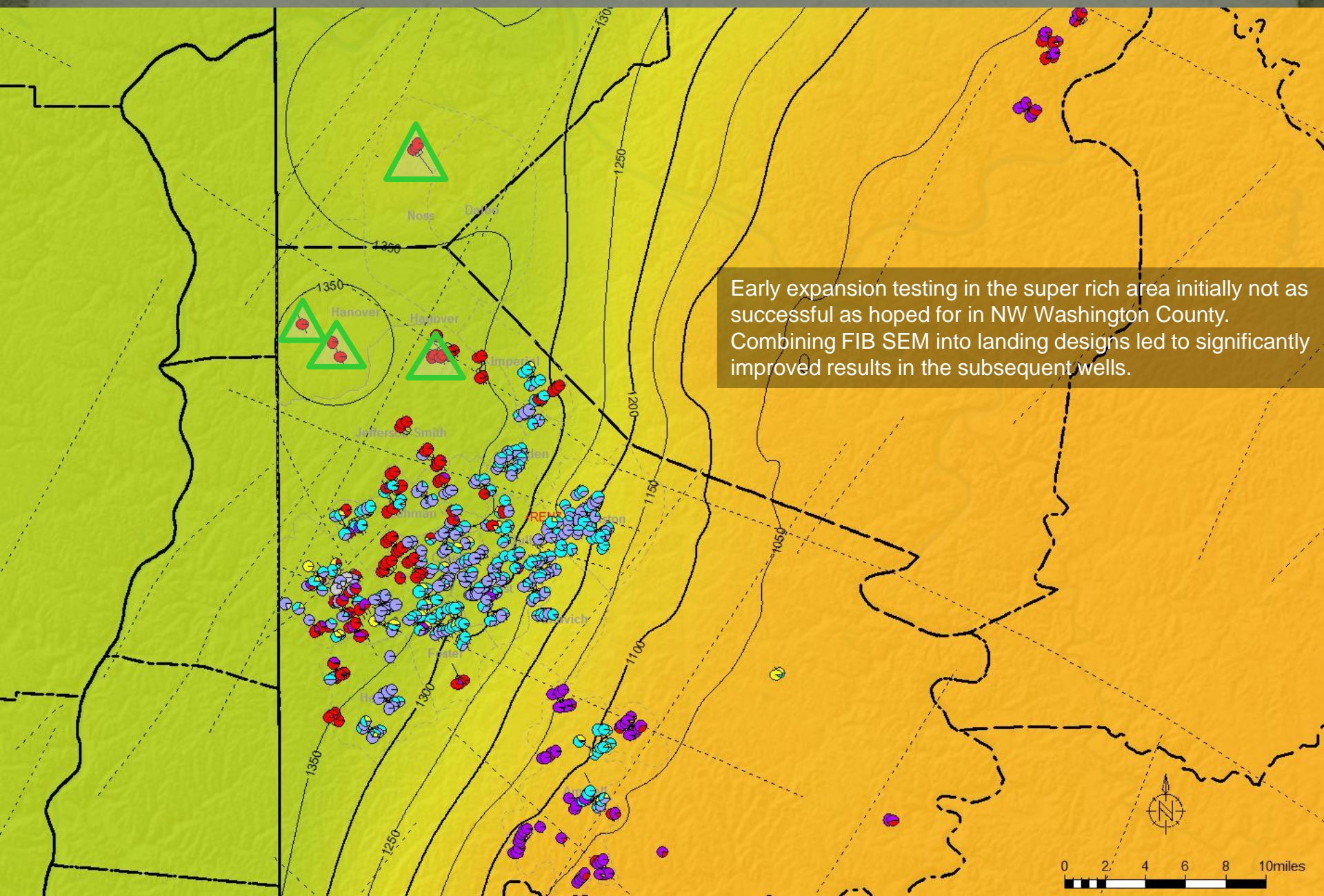
Click on image to view animation, which may require up to 2 min.



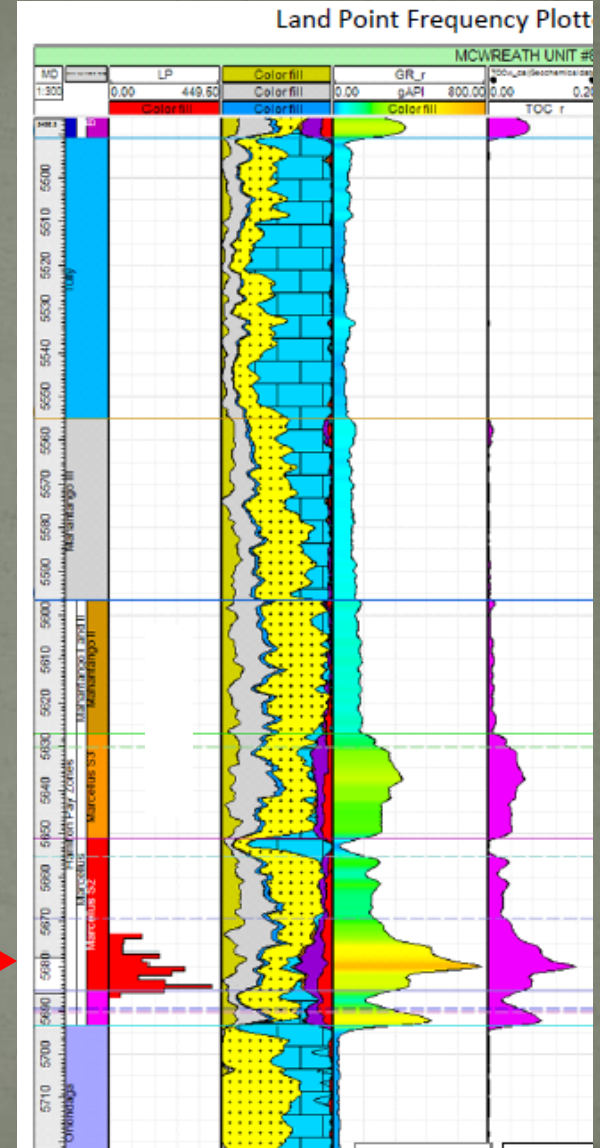
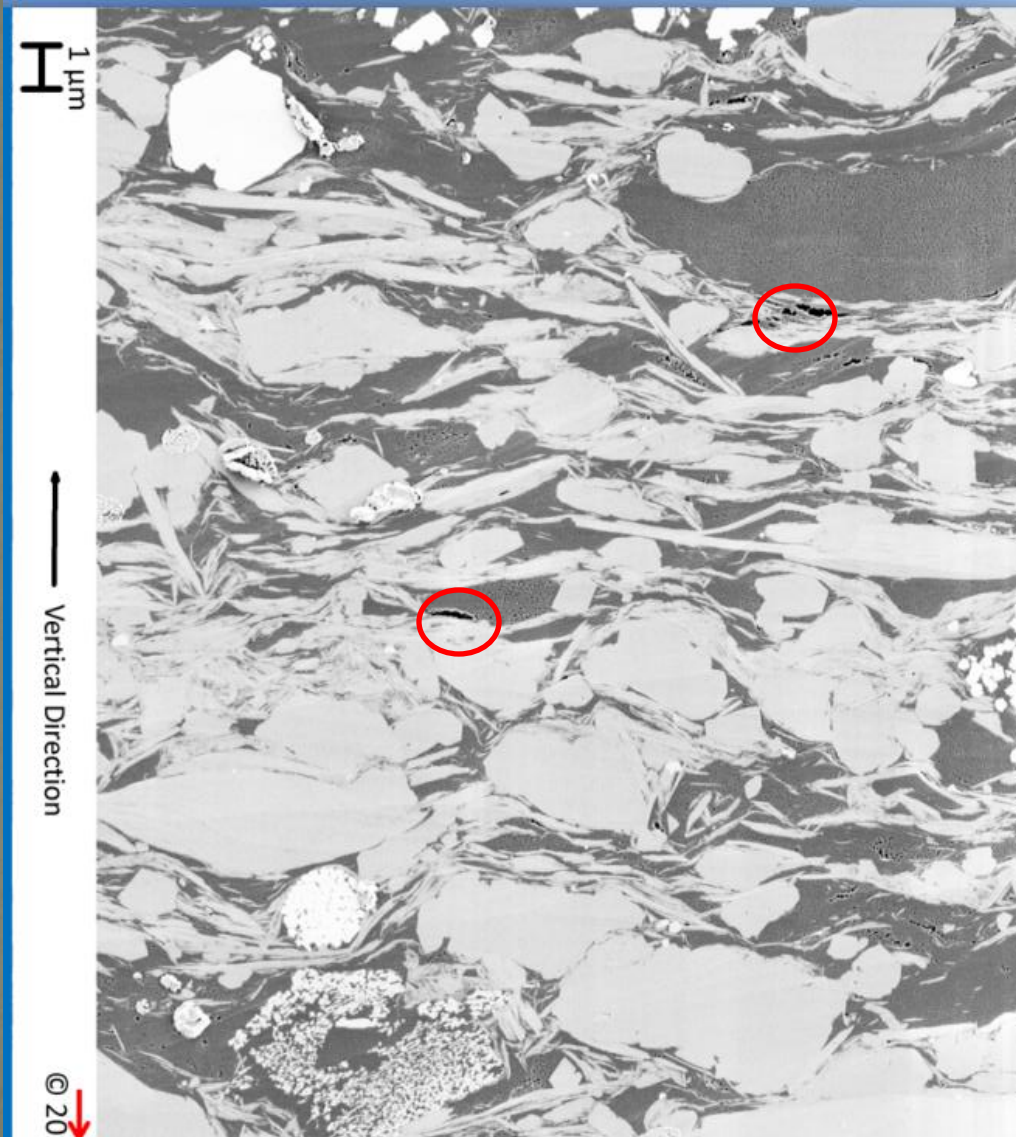
1 [microns]  
© 2011 Ingrain Inc.

**Example 3D FIB/SEM images are from NGL rich portion of SW Core area. Note large interconnected pore sizes and volume related to high concentration of organics combined with large pore sizes and surprising degree of interconnectivity.**

# Key FIB/SEM Landing Zone Studies – Super Rich Area

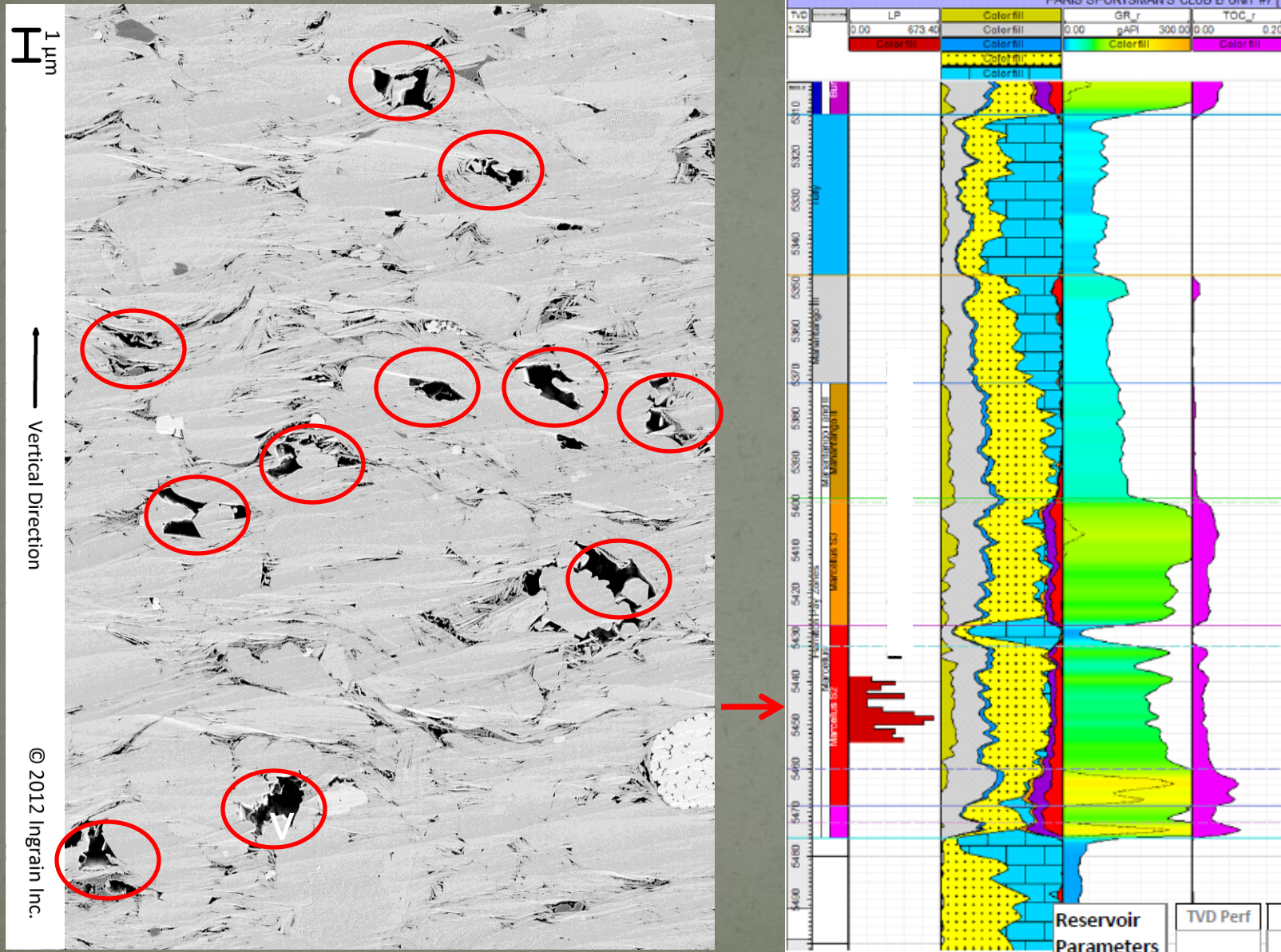


# Washington County Marcellus Test – FIB SEM & Targeting Example 1



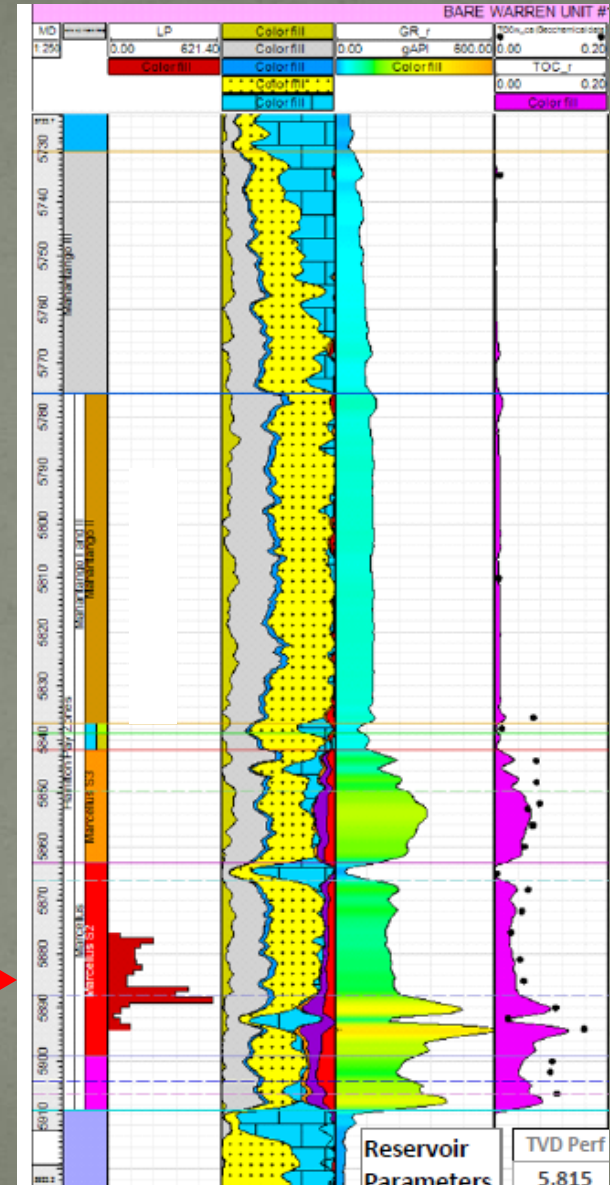
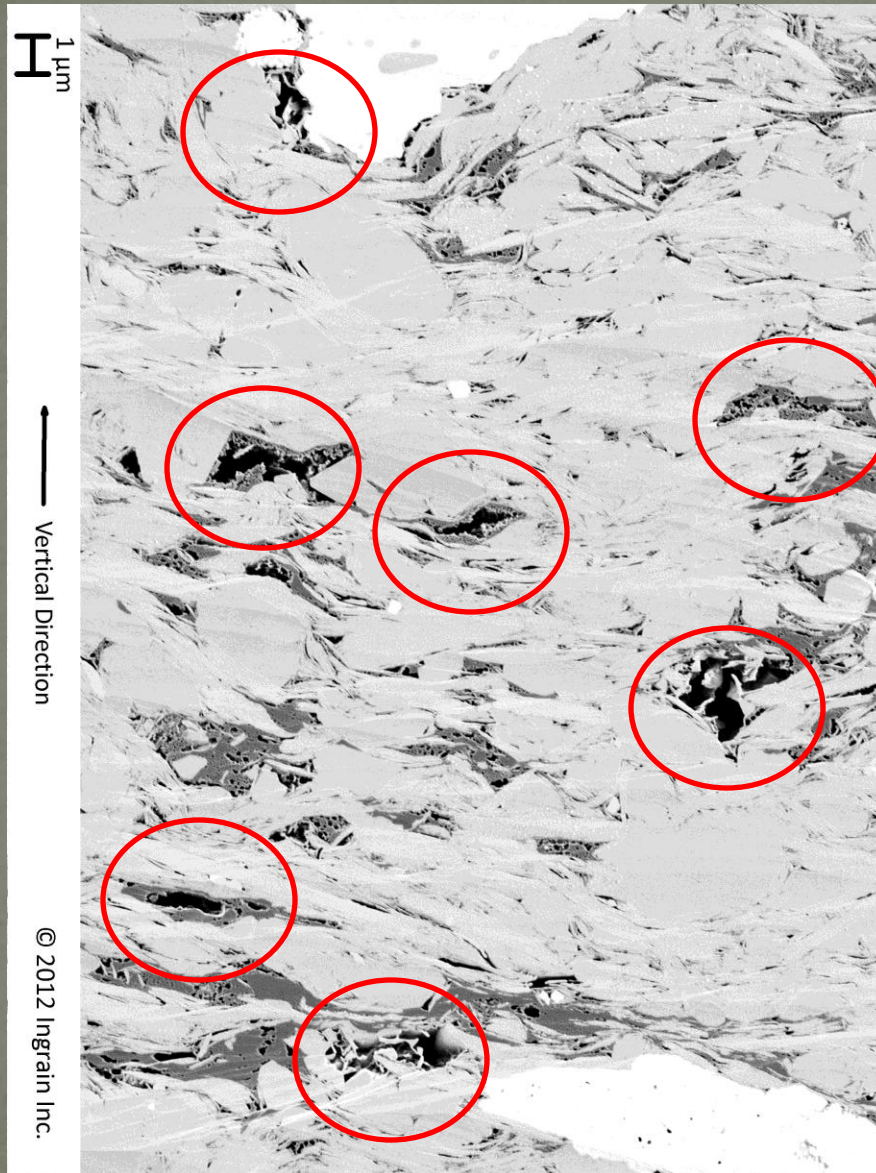
Note high TOC of sample but very small pore size. Effect on ability to produce liquids and ngl's.?

# Washington County Marcellus Test – FIB SEM & Targeting Example 2



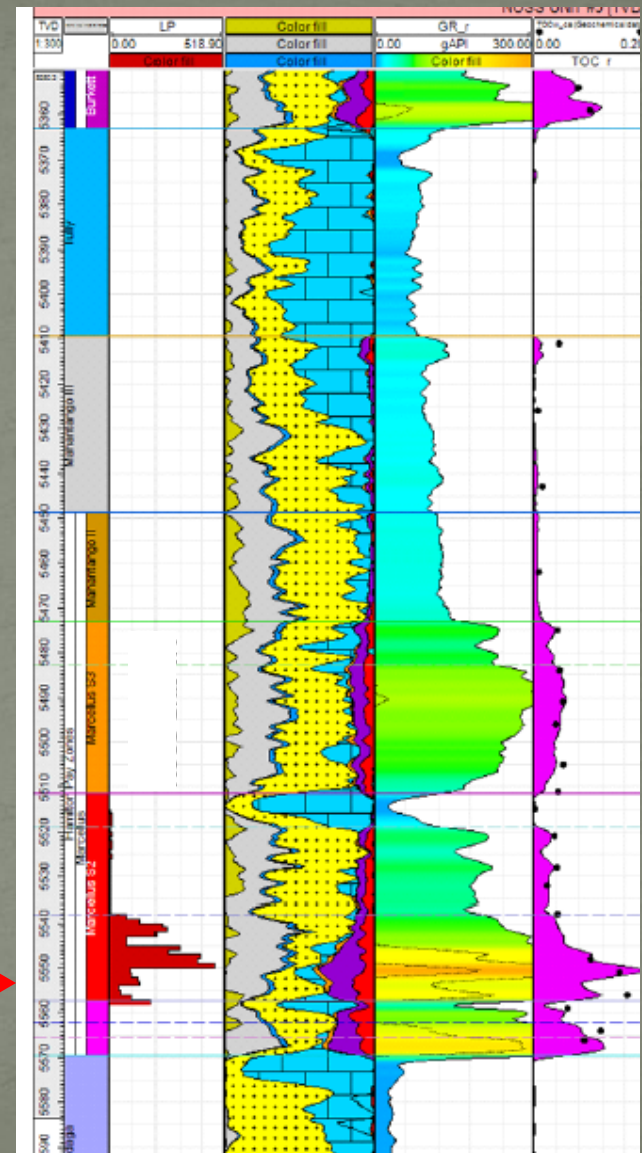
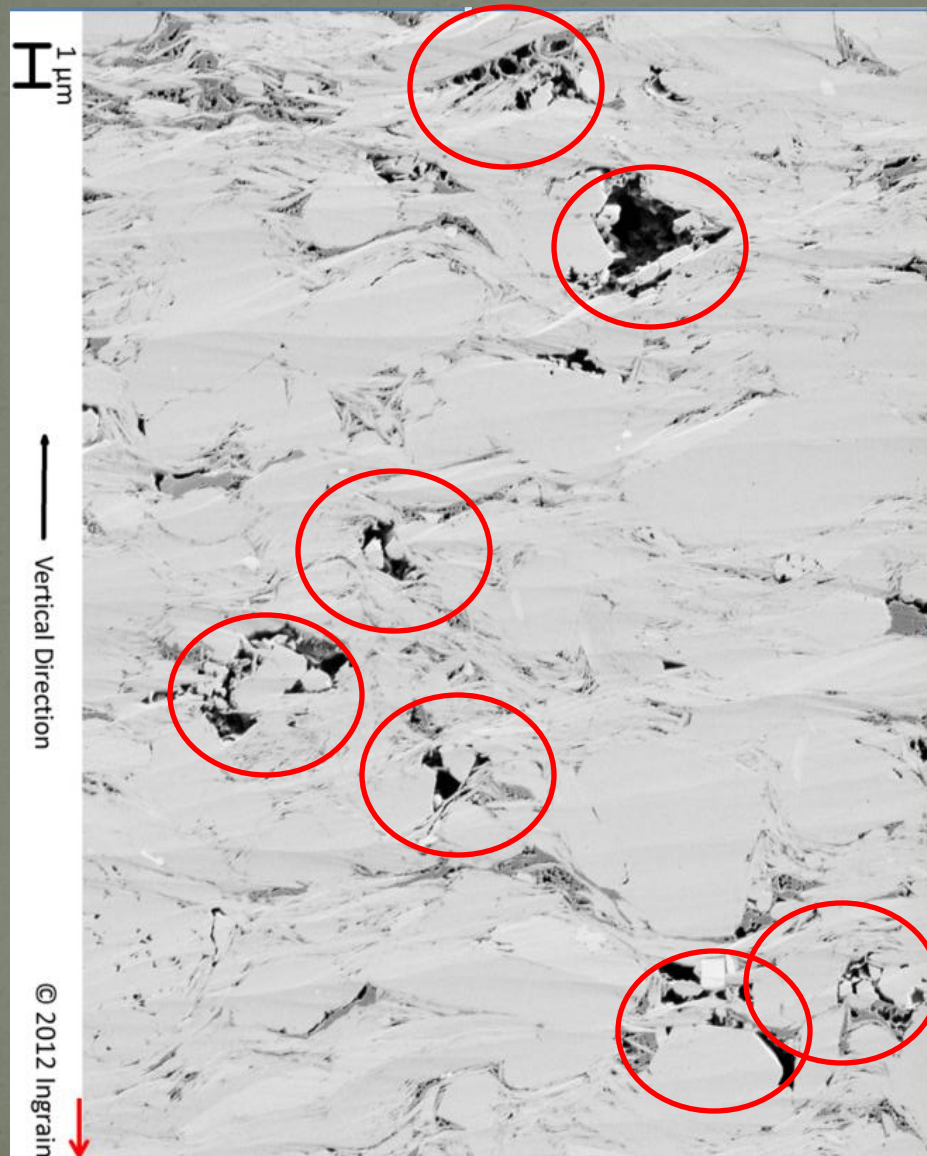
Again note greater amount of larger pores and a somewhat lower TOC content.

# Washington County Marcellus Test /FIB SEM & Targeting Example 3



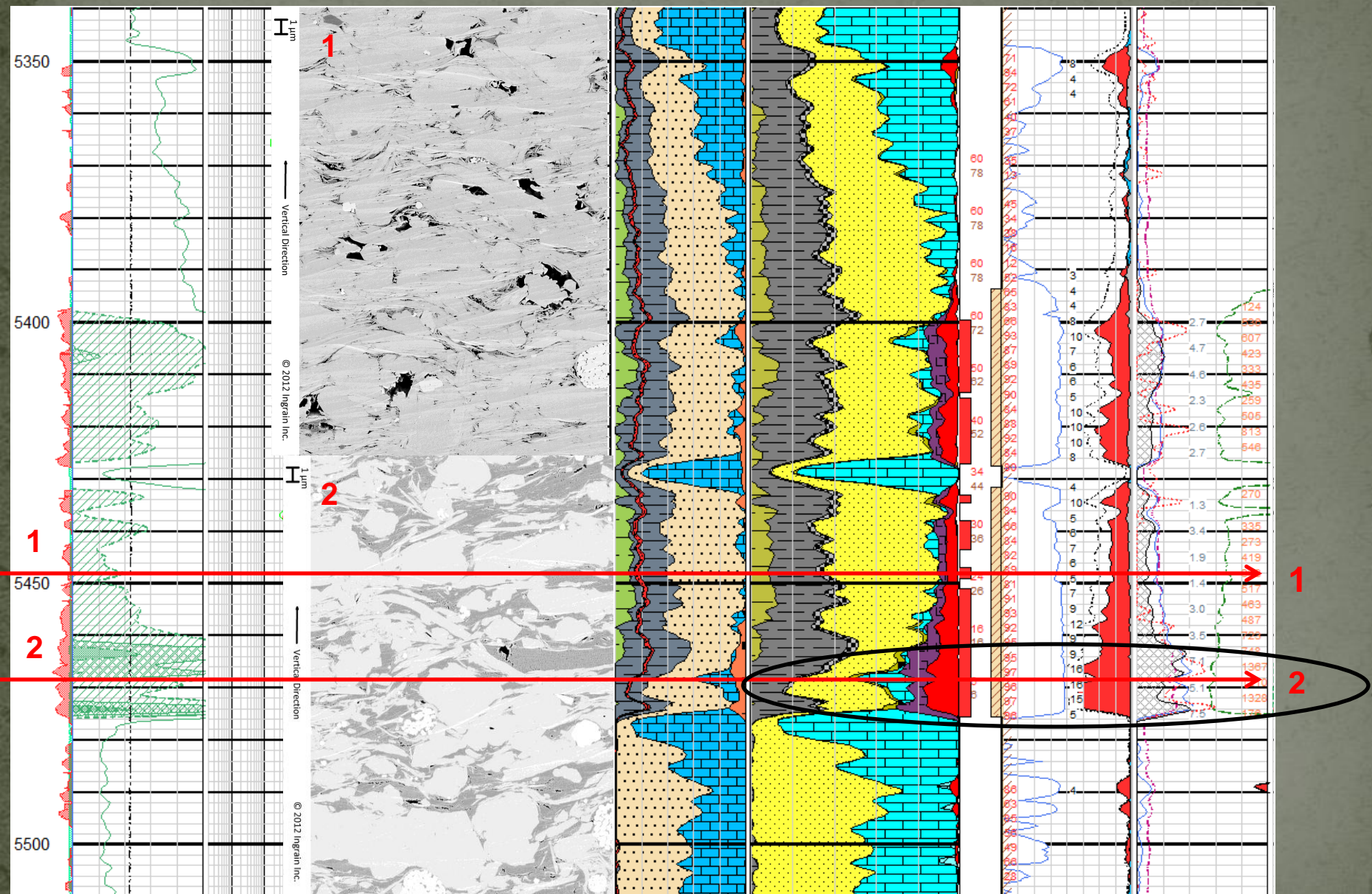
Again note larger concentration of large pores and presence of significant TOC, but not dominant.

# Washington County Marcellus Test/FIB SEM & Targeting Example 4



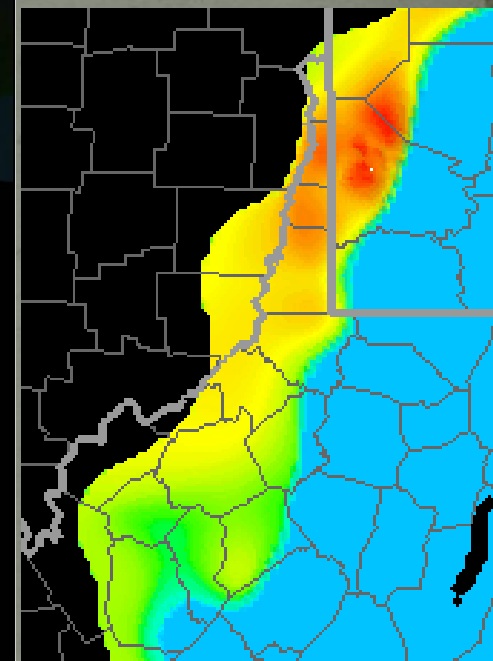
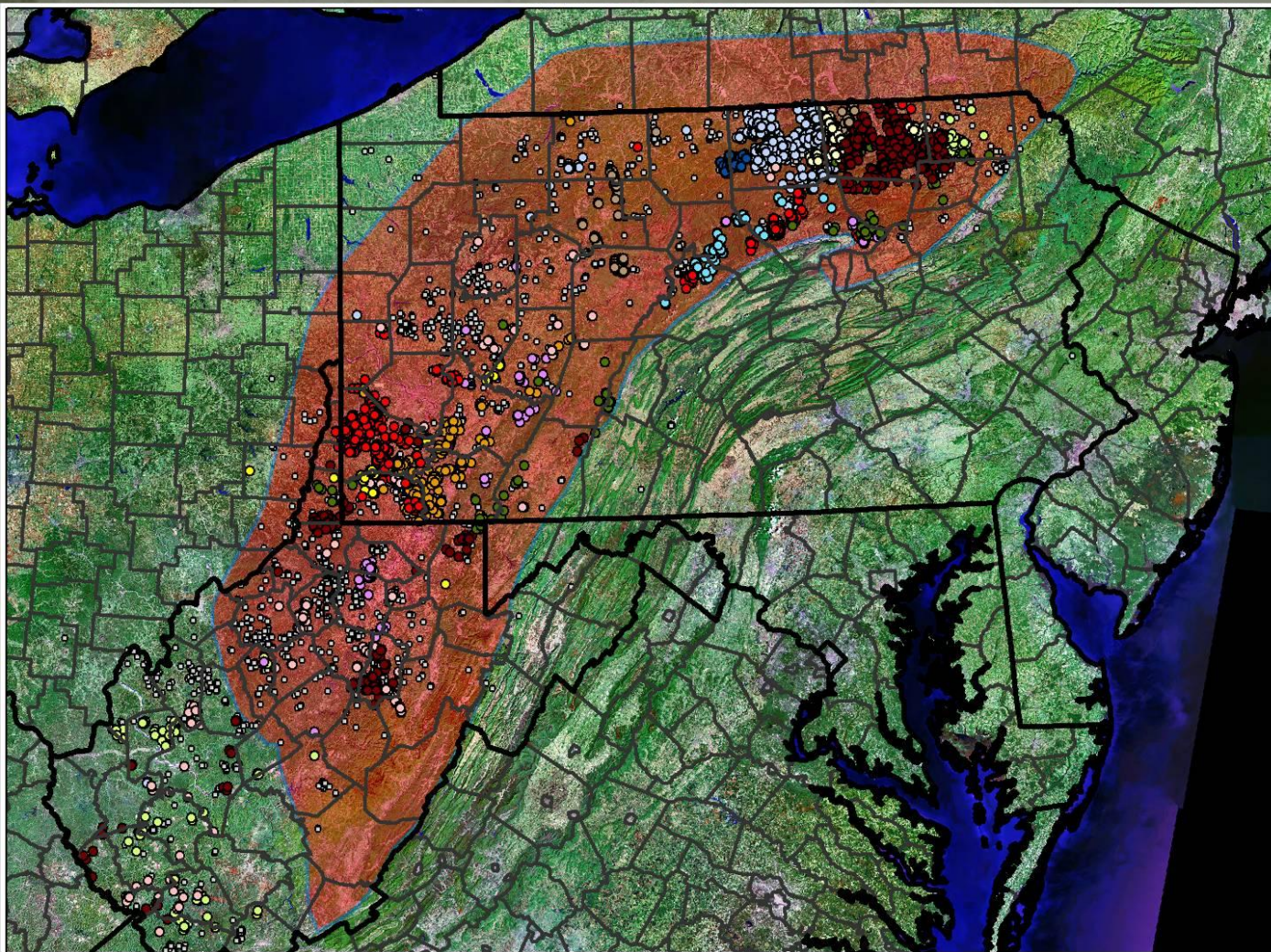
Note larger concentration of large pore throats and lower TOC content.

# Washington County Marcellus Test/FIB SEM & Targeting Example 5



Note bottom interval #2 is similar to the high TOC/low porosity interval observed in Well Example 1. The #1 interval has much bigger pore development. NOTE: This is opposite of interval of high porosity & permeability

# Marcellus Shale Play – Giant Status!!!! Future!!!!



**Marcellus Play Potential – 84 TCF/3.5 Billion Bbls liquids (USGS 2011) to 489 TCF (Engelder PSU 2009)!!!  
What about the resource potential of the Genesee Group and Utica/Point Pleasant intervals?!?!?!?**