Discovery of the Utica Shale: Update on an Evolving Giant*

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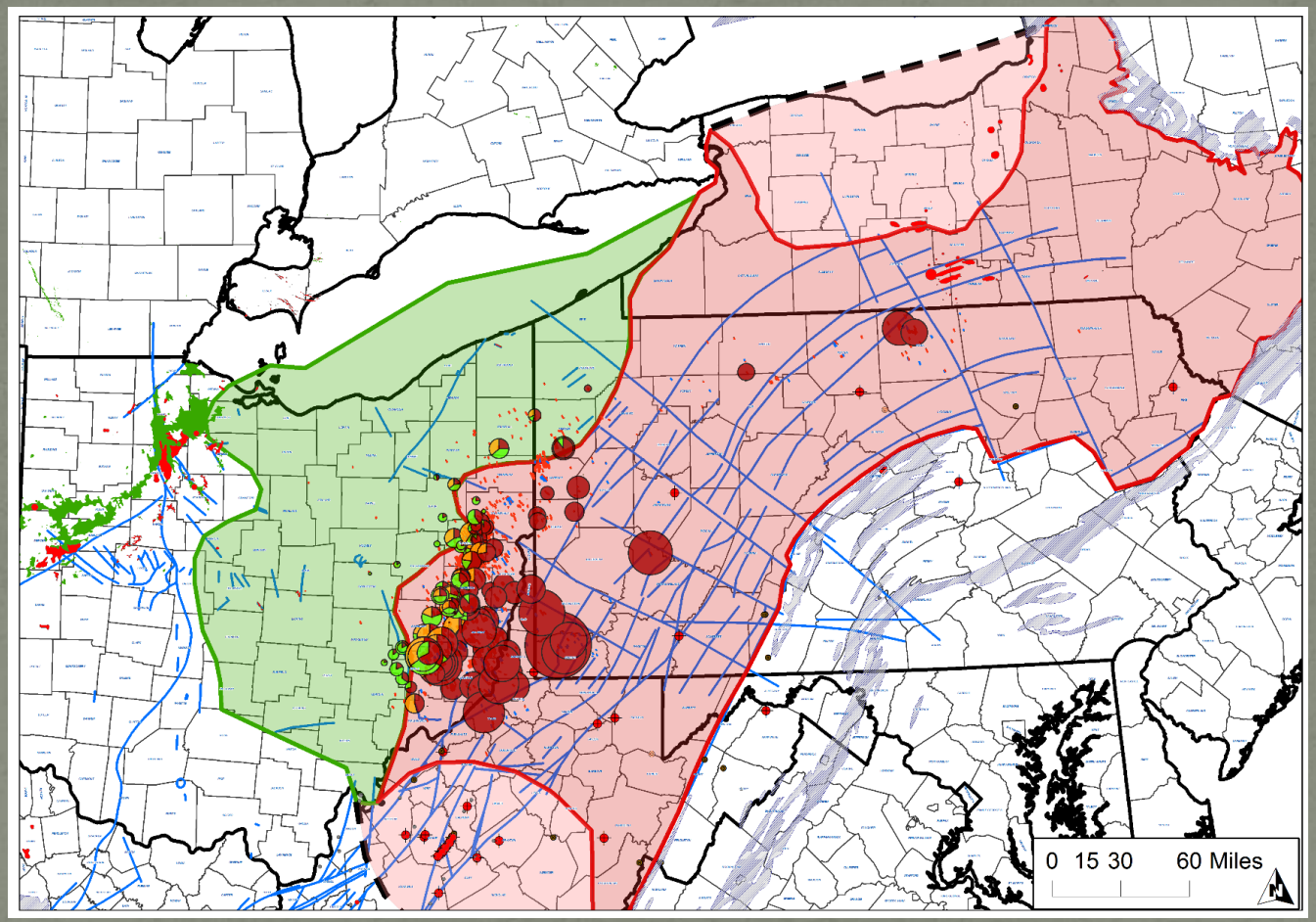
Abstract

The Utica-Point Pleasant play has grown rapidly since horizontal discovery and commercialization in PA (2010) and Ohio (2011) with current production of approximately 5 BCFE/d and an active rig count of 25 as of early 2017. The U.S. portion of the play covers a large extent within the Appalachian Basin, including parts of Pennsylvania, Ohio and West Virginia. While modern horizontal drilling is focused on the organic-rich Point Pleasant Member in Eastern Ohio and Southwestern Pennsylvania, a long history of testing and development can be traced back to several key attempts to commercialize the play in both the US and Canadian portions of the Appalachian Basin beginning in 1858 in Ontario and in 1888 in northern New York. Early industry focus of the modern horizontal play was in the wet-gas and oil windows, as some touted the liquids content and possible similarity of the Utica-Point Pleasant to the evolving Eagle Ford oil play of Texas. However, current activity trends are focusing deeper and deeper into the highly over-pressured dry gas portions of the play. Key productivity drivers for the play include pore pressure gradient, depth, thermal maturity, TOC content, porosity & permeability, frac containment, gas in place, facies changes in key reservoir targets, and the regional influence of basement faulting. Although significant evolution and understanding of the play has been achieved since modern commercialization, many concepts and drivers have yet to be completely understood. Play extents are not yet fully realized and future growth potential remains quite significant.

Discovery of the Utica Shale: Update on an Evolving Giant



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William A. Zagorski & Taylor G. McClain
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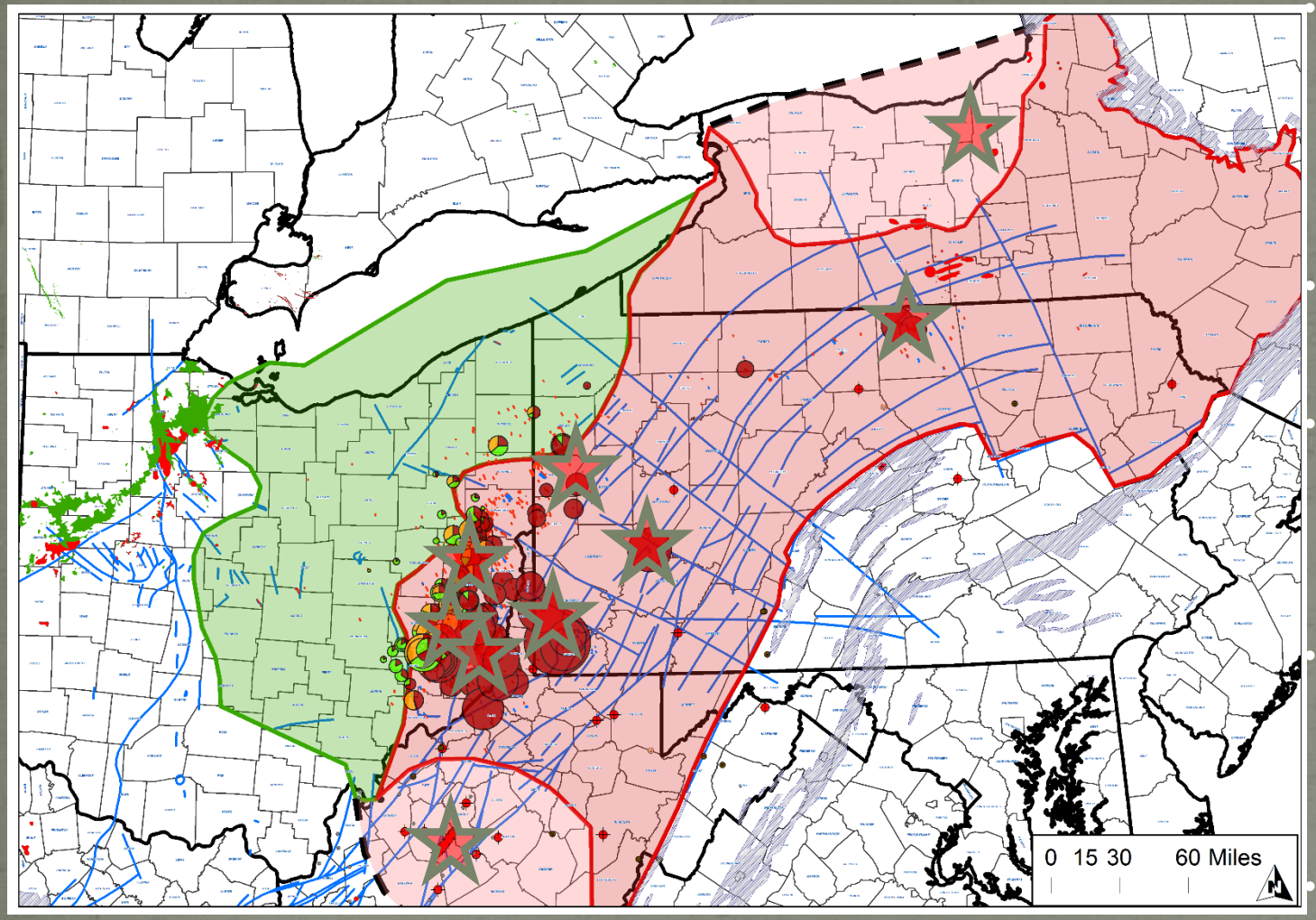
Present Day Extent Utica Point Pleasant Play



Play Boundaries – USGS (2009)
Proposed Extensions - This study.

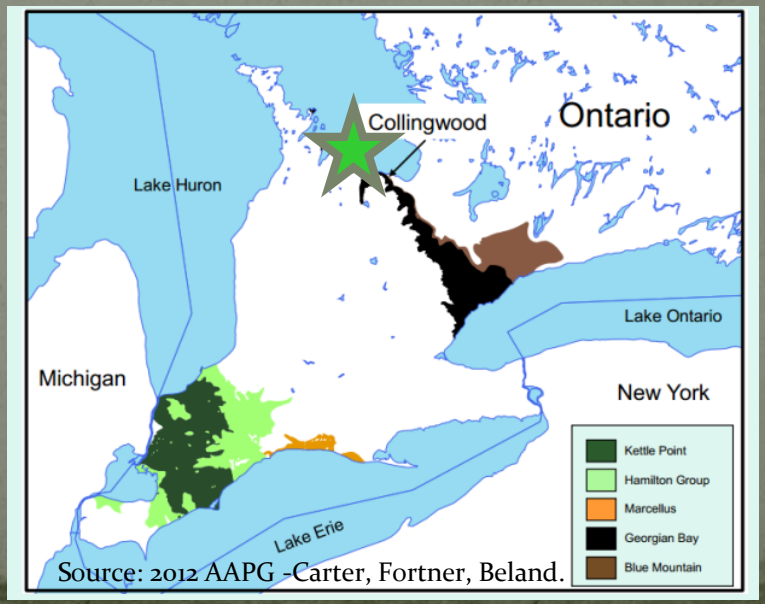
Milestone Fields/Wells

- Current production from Utica-Point Pleasant Play is 5 BCFE/day.
- 25 Rigs running as of early 2017.
- Current focus is on deeper dry gas portion of the play.
- Modern horizontal play commercialized in 2010.
- However interest in the play started much earlier……

Early Utica Oil Production – Ontario
1859 – 1863 - Collingwood Oil Shale Extraction

In 1859 – Craigleith Shale Oil Works - Reported oil production from member of Collingwood Shale. North American oil discoveries in 1858 and 1859 made the operation uneconomic by 1863.

Source: Wikipedia



Source: 2012 AAPG -Carter, Fortner, Beland.

Early New York Trenton Gas Production

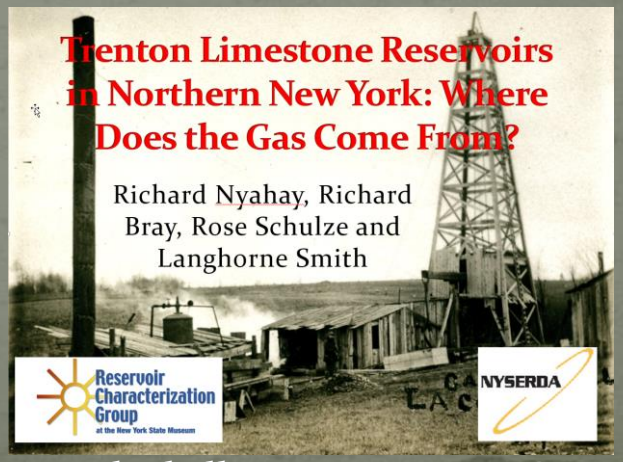
Source: Zagorski 2007

- 1888 Sandy Creek Field.
- Wells were shallow 600' to 2,800' in the Trenton FM.
- Flow rates and pressures initially high but were low volume producers.
- Early recognition as a shale gas play by several geologists.
- Activity waned after 1940.
- Renewed interest in late 1990's.

Previous Work

"That the gas is confined to the shale partings and shale layers can be observed at any well during the drilling of the Trenton. The drill first strikes a hard, dense limestone layer which is usually only a few inches thick but is hard to penetrate. As the drill breaks through this layer the gas rushes forth, sometimes under enormous pressure which may even blow the tools out of the hole. When drilling is again resumed it is invariably found that the layer under the hard dense limestone is a calcareous shale… No increase in volume is realized until another hard dense limestone is reached. Unquestionably the limestone acts as a cap rock."

Early geologic review of play.



Early drilling NY Trenton Gas

Example Well Records – Note Gas Shows and Pressures!

Bottom of Oswego 1885'
Top of Trenton 2540
Present depth 2670'

Gas at 415' Niagara

Gas at 1748' Oswego

Gas at 2670' Trenton

Rig burned, will build new rig according to Boyce and drill deeper.

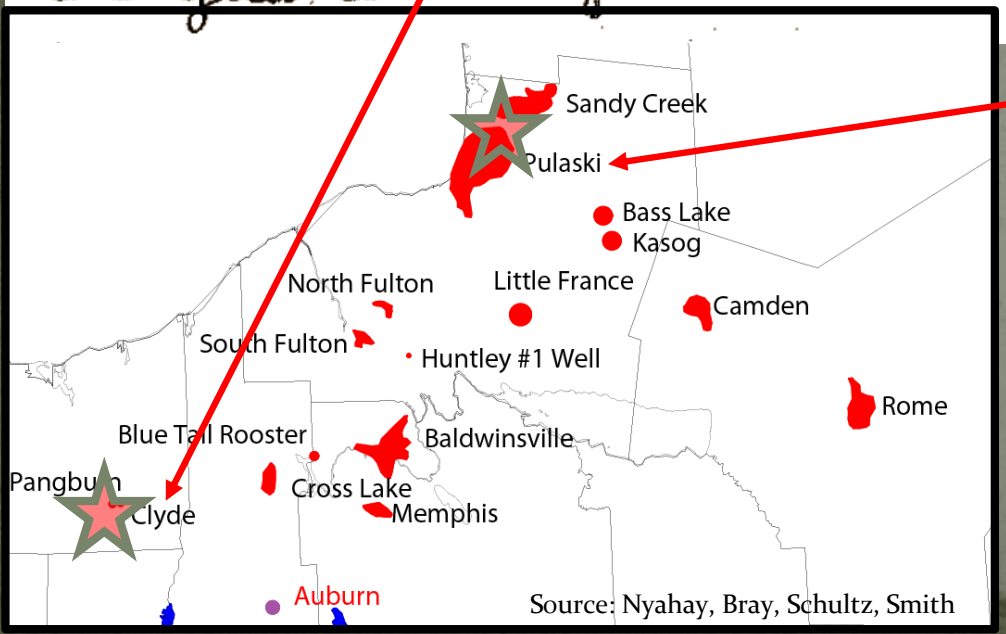
October 1 log

October 27 12' more

See Gillette's letter of Nov. 7

"When shut in, pressure lifted 633 feet of casing and drive pipe out of hole and scattered it about the land. One 80-foot length was thrown 600 feet from the well."

-Scout card from well in Pulaski Field



Source: Nyahay, Bray, Schultz, Smith

Bender Gas Well Contacted Powerful Gas Pocket at One O'clock This Morning

Explosion Skyrockets Two Ton Drill, Disrupts Cable and Fires Rock to Top of Derrick--Work Proceeds for a Main Vein.

The Bender gas well, which is being drilled on the Harvey Dunn farm near this village, struck a pocket of gas this morning at 1 o'clock that hoisted the 3,800 pound drill, dislodged the cable from its track and sent a volume of rock and water into the air to an altitude about the height of the towering derrick.

This is the fourth time within the week that pockets of gas have been struck. Yesterday morning a pocket, capable of flowing 50,000 cubic feet of gas daily, blew in at 8:45 o'clock. Each succeeding strike comes with greater force and the explosions increase in noise. Excitement this morning is running high at the well. Engineer Cady is supervising the two shifts of workmen who have resumed operations to drill on until the main vein is hit. The well is now down 950 feet.

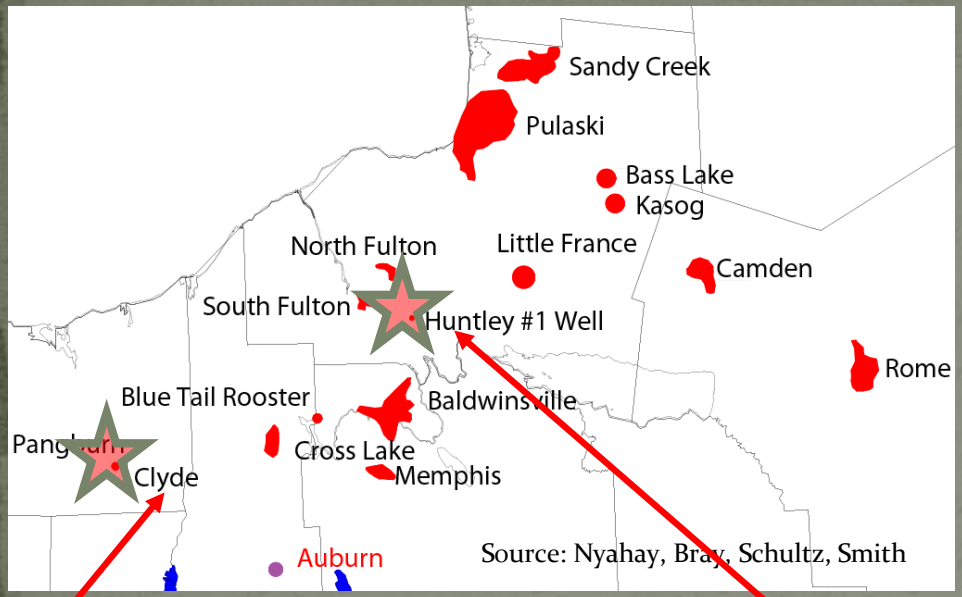
The young gusher that came to light at 1 a. m. today has permeated the air about the premises with a strong odor—sample of the real stuff. The gas is strong enough that some of the workmen complain of it making their heads ache. The flow of gas, from the six inch hole, can be felt on the hand when held six to eight feet above the platform, visitors report.

The monotony of just drilling has reached a different stage—for the workmen stand ready to hustle for their lives with each re-curring explosion. Engineer Cady is highly jubilant over the prospects of the well to date and ventures his belief that within a week they will tap a major vein.

Warning is given to any visitor to the premises that smoking is absolutely forbidden.

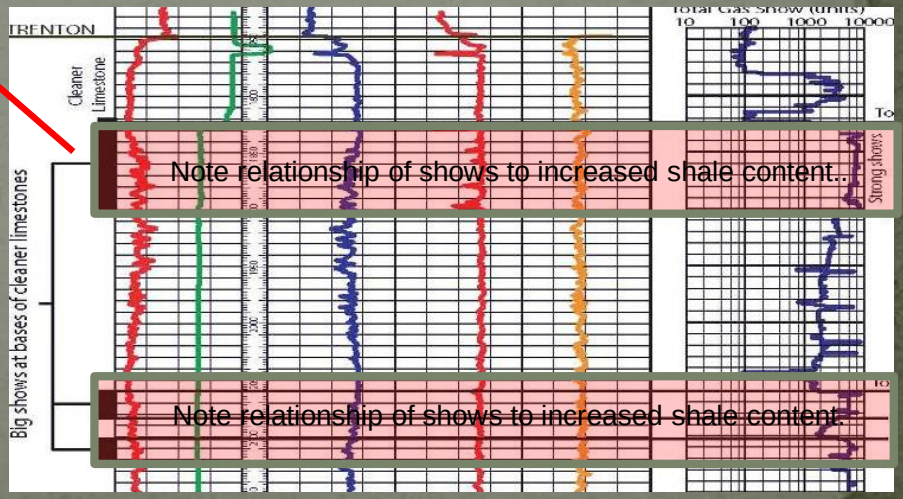
Gusher Blows in at 10:15 Today

Modern NY Trenton Gas Fields – Lake Ontario Shoreline



- After 1999 exploration efforts in the Trenton Black River play led to renewed interest in this play.
- Play was recognized as a source rock/unconventional type play and was successfully tested in 2003.
- Play concept was to target fractured zones defined by 2D/3D seismic and drill and complete natural.
- Testing of the play stopped after 2007 as regulations in NY discouraged horizontal drilling and large scale hydraulic fracturing.

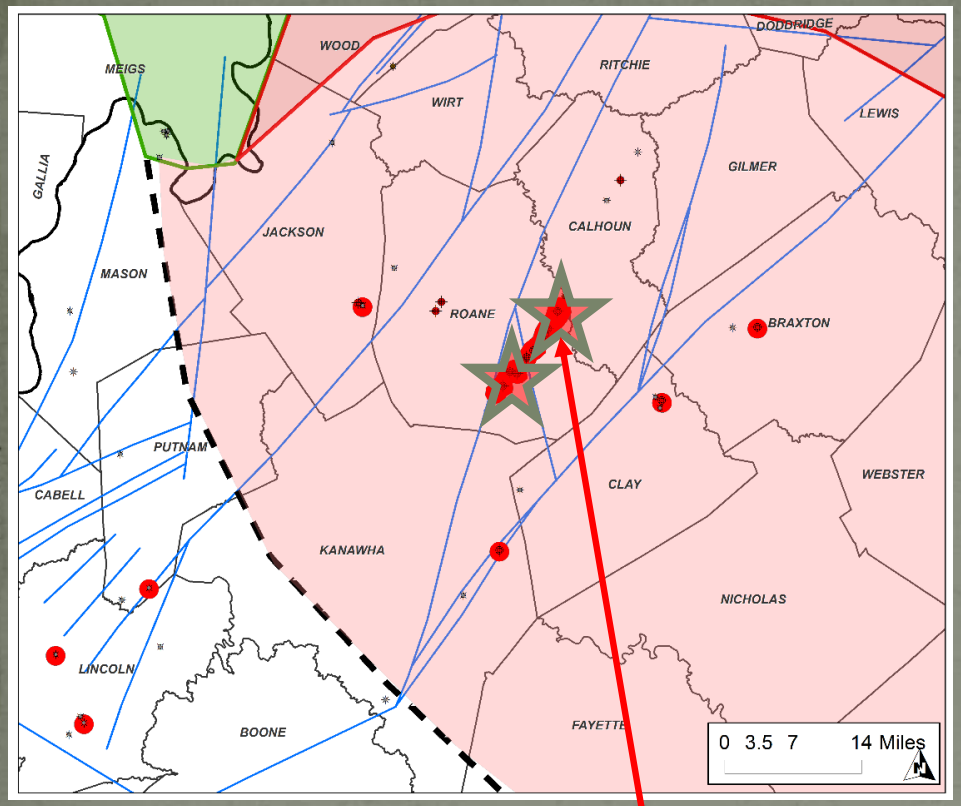
Source: Zagorski 2003



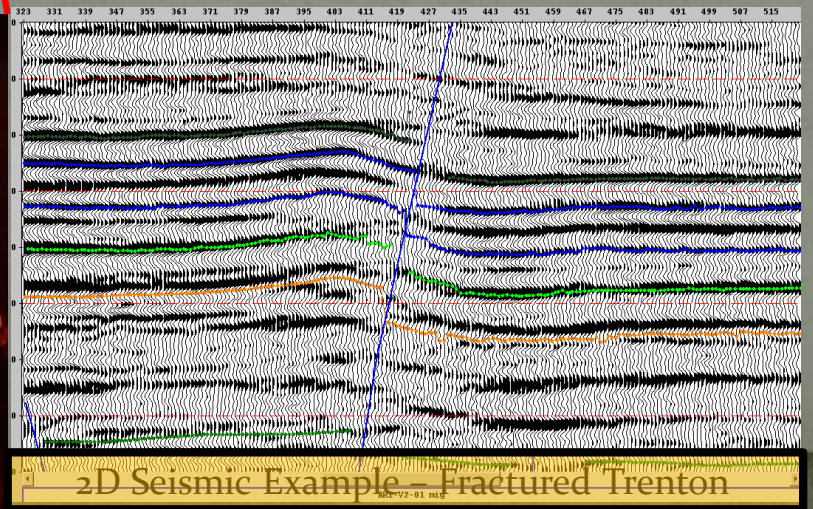
Source: Nyahay, Bray, Schultz, Smith

Huntley #1

Trenton Black River Over Pressure Play – Cottontree Field - WV



- Discovery was Cottontree Field in Roane County, WV.
- Original drilling targeted highly fractured areas in search of dolomitized Trenton Black River carbonates using mainly 2D seismic coverage.
- Reservoir is highly over pressured. Pervasive gas shows in section even in dry holes.
- Several other tests drilled in WV but all looking for fractures not source rock plays.
- Similar to Utica Point Pleasant play but thicker and less organic rich.

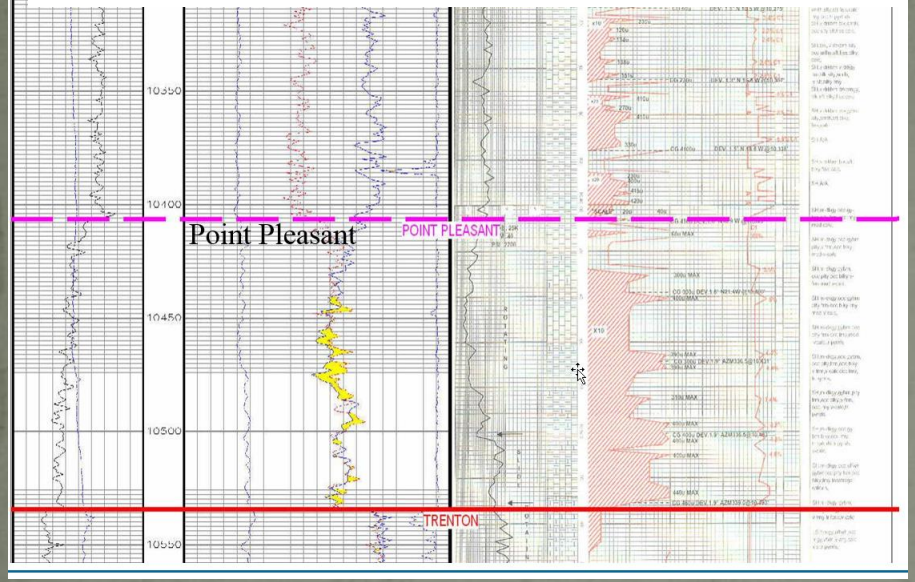


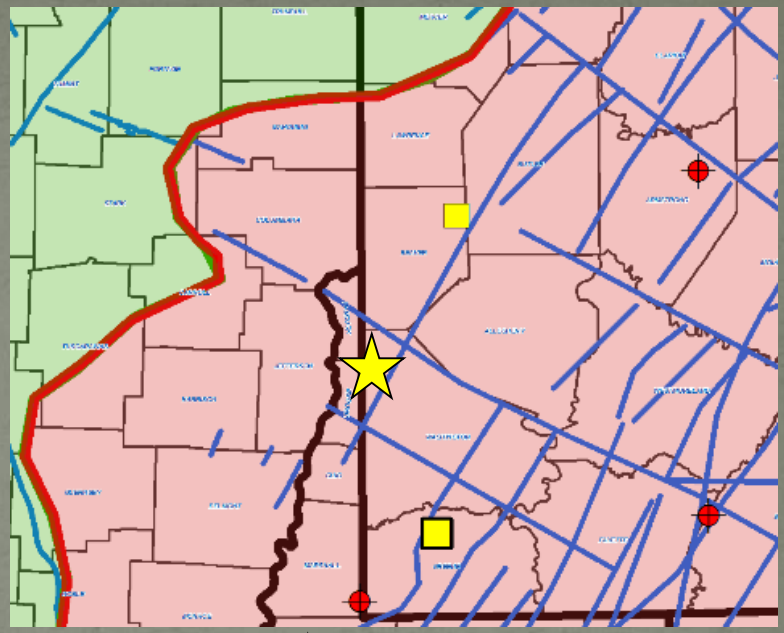
2D Seismic Example – Fractured Trenton

- Play not considered source rock play initially.

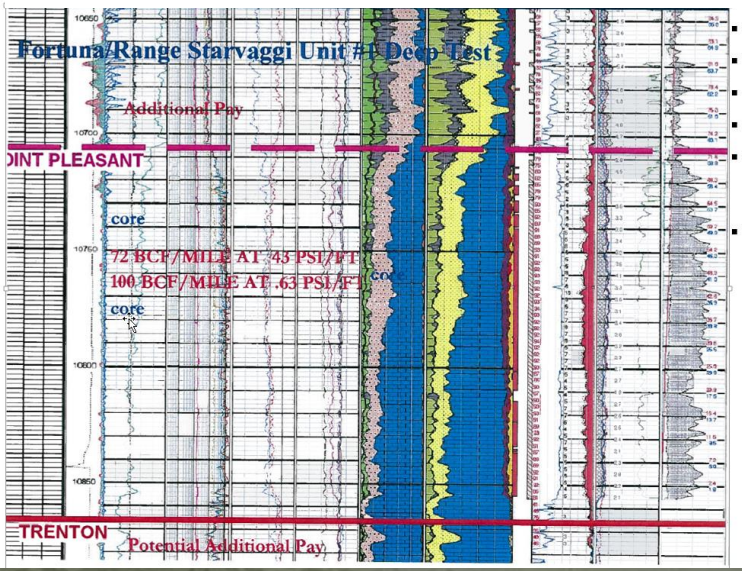
2000 -Emerging Deep Play in SW PA – Encouraging Shows

Key 2003 test showing significant gas shows in Utica Point Pleasant

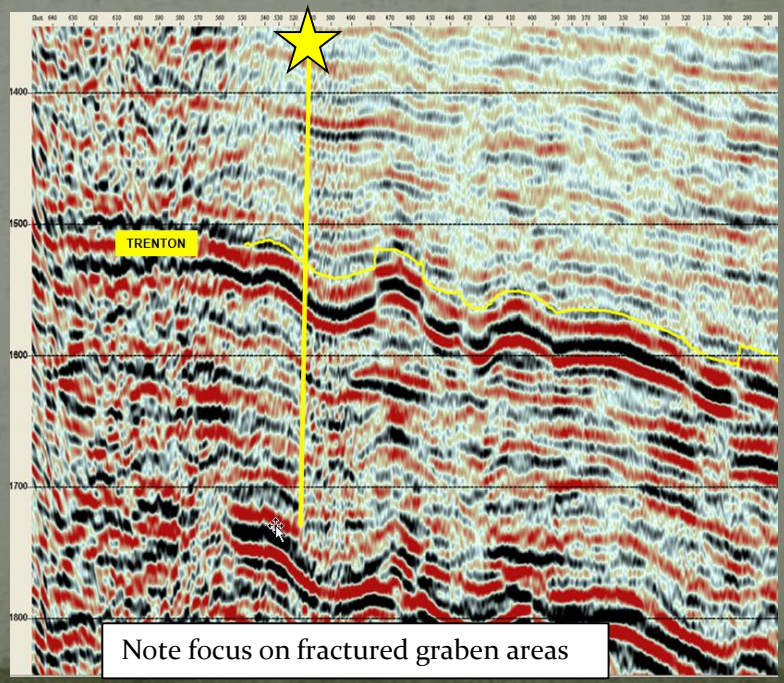




Key deep test in 2006 confirming reservoir quality and significant GIP



- Drilled 7/2006
- Washington Co
- TBR test
- Sidewall Cored
- Gas Shows throughout interval
- Organic content confirmed



Note focus on fractured graben areas

Early NW Pennsylvania Deep Shows – Not Widely Known

World's Deepest Cable-Tool Test Is Completed

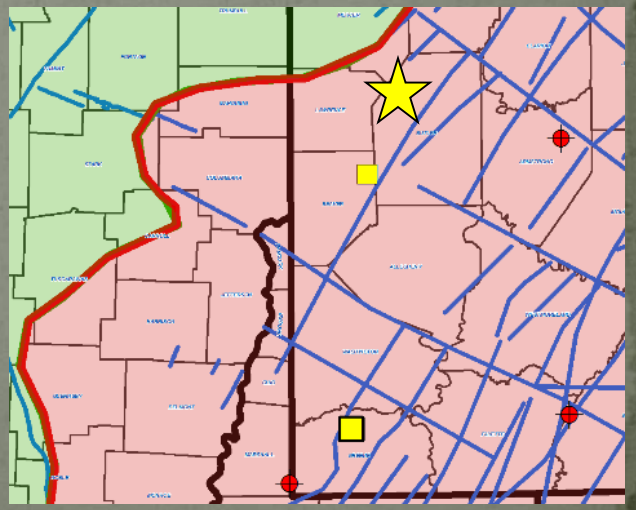
*by John T. Galey**

THE deepest cable-tool hole in the world, so far as can be ascertained, has recently been completed by Manufacturers Light and Heat Co. on the Jesse G. Hockenberry farm, Mercer Township, Butler County, Pennsylvania. This wildcat was abandoned, after it showed considerable salt water, at 10,096 ft. in what is considered to be an Upper Cambrian sand. Stratigraphically, the test is the deepest yet drilled in Western Pennsylvania, Eastern Ohio, or

View of rig which drilled the 10,096-ft. deep test in Butler County, Pennsylvania. Inset: Charles E. Bennett, president, The Manufacturers Light & Heat Co., which firm drilled the deep test here described

Drilling Difficulties

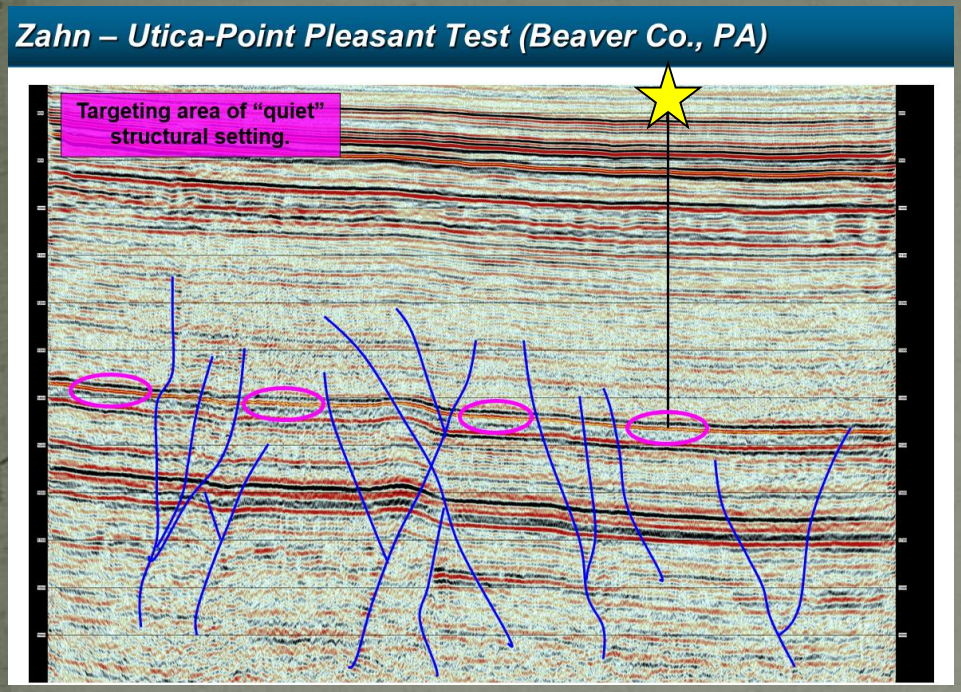
There were only two major obstacles to be overcome in drilling, and these were encountered commencing at a depth of 8,510 ft. and extending to 8,710 ft. where 11 gas pockets with various degrees of explosive force were struck. Some of these gas pockets would make gas at the rate of from 5 to 10 million cubic feet of gas per day, but would last only a matter of a few minutes. The gas pockets all occurred in soft shale and after each one, it was necessary to clean out the hole before new hole could be made. At a depth of 8,710 ft. in the last of three gas pockets the tools were stuck. They were jarred for 80 hours in hope of switching off the drilling line. Acid was dumped into the hole in an attempt to weaken the line and the tools again jarred. The process was repeated and finally

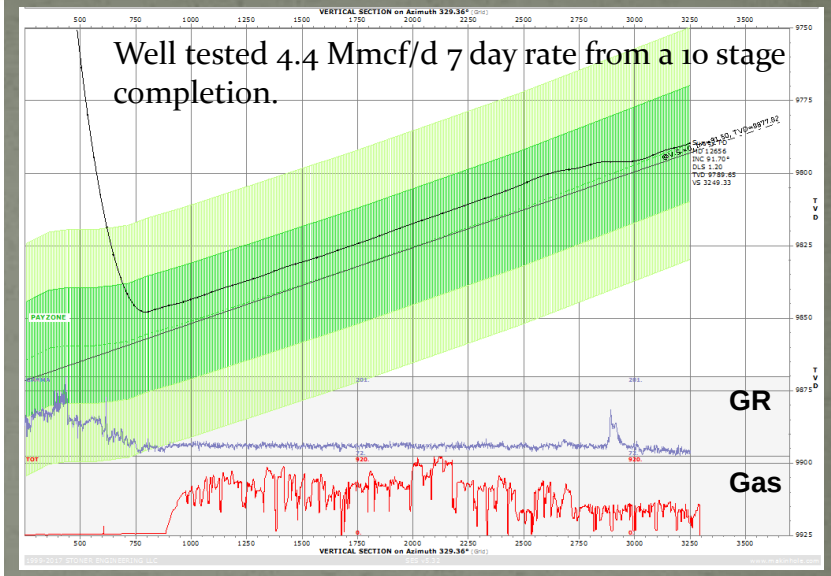


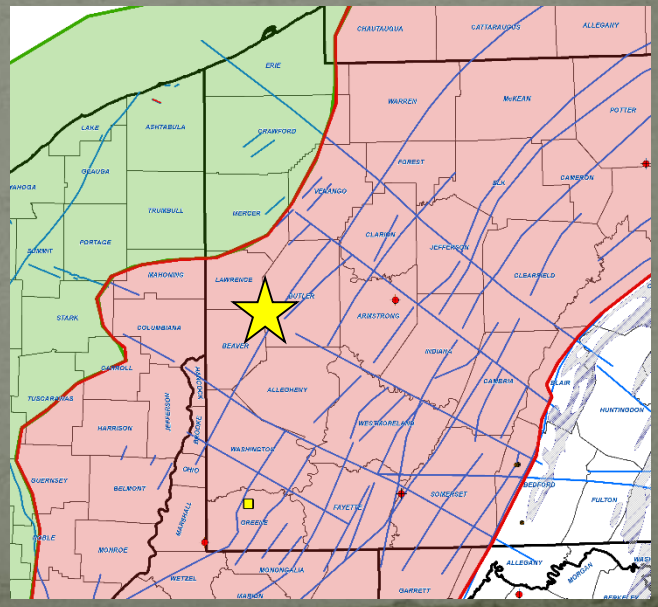
Note report from famous AAPG explorer John T. Galey!
The volumes reported in the article did not make it to the official well records.

My source – Surprise email in 2008 from D. Beardsley.....
Another famous AAPG explorer.....remember the Trenton Black River play.....Cottontree? NY Steuben County discoveries?

RRC Zahn Horizontal Discovery – 2010 Beaver County, PA

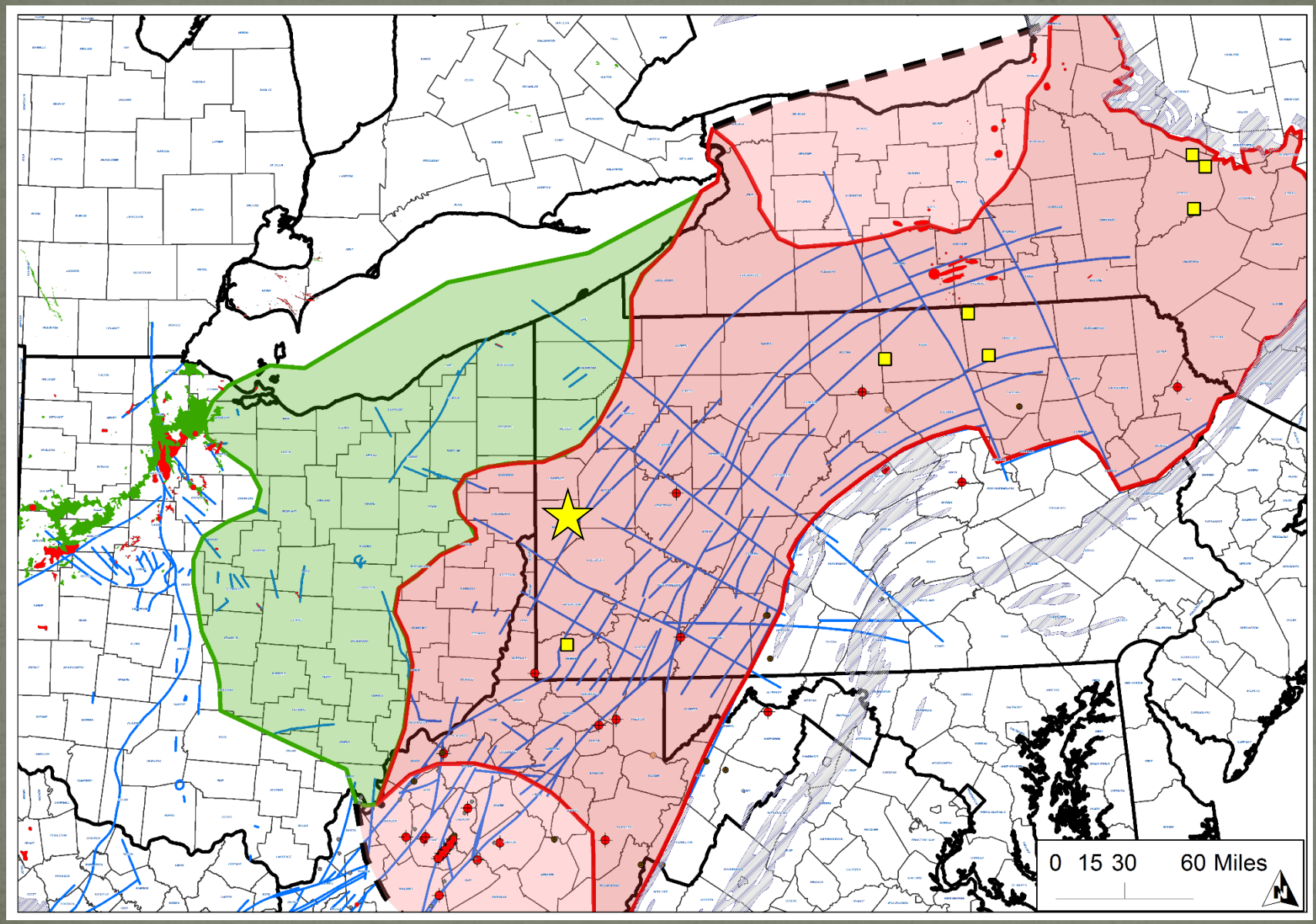






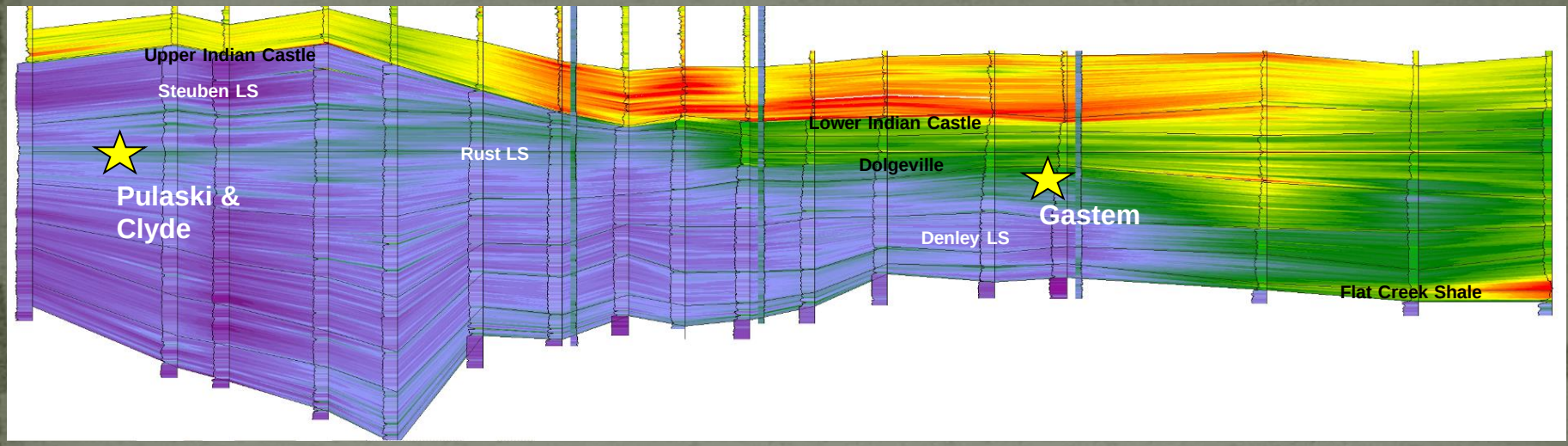
RRC Zahn represented first successful horizontal completion of the Utica Point Pleasant in the USA.

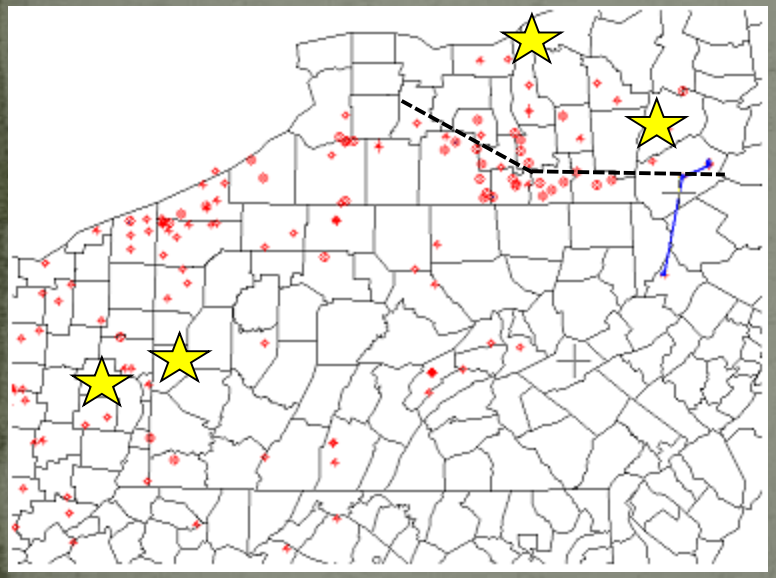
Utica-Point Pleasant Play Activity as of 2010



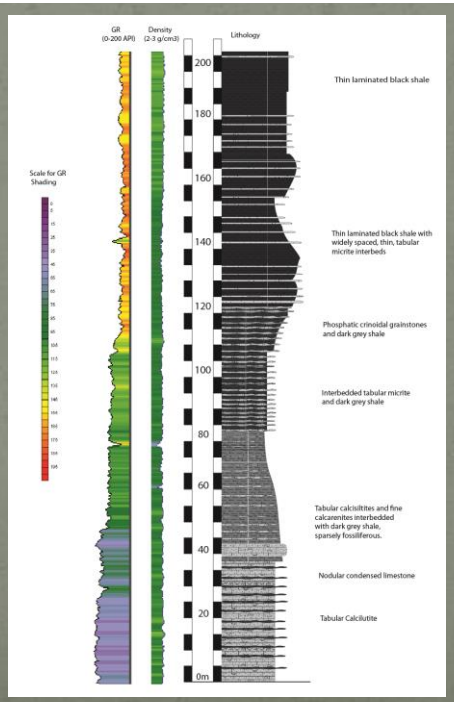
Unlike the Barnett and Marcellus plays, early vertical tests between 2004-2009 were unsuccessful.

Undergraduate Idea - Study the Utica Shale

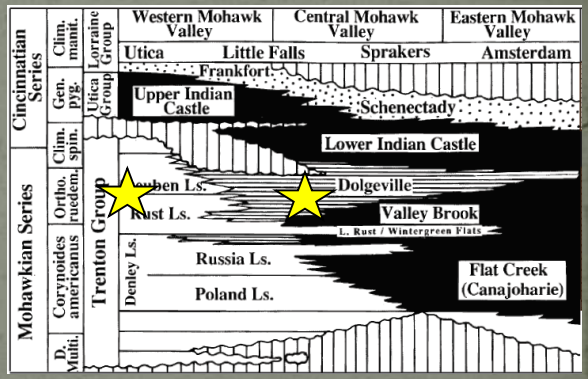




Study area and well dataset

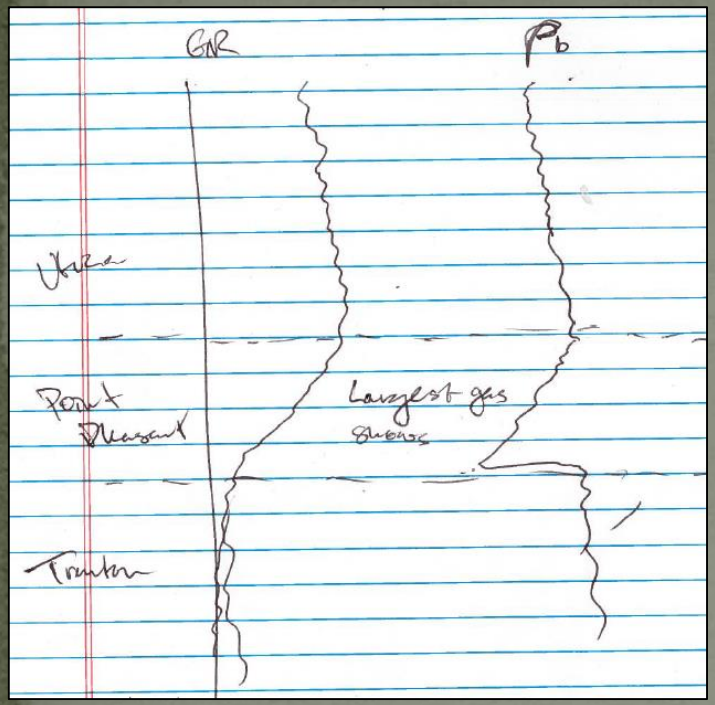


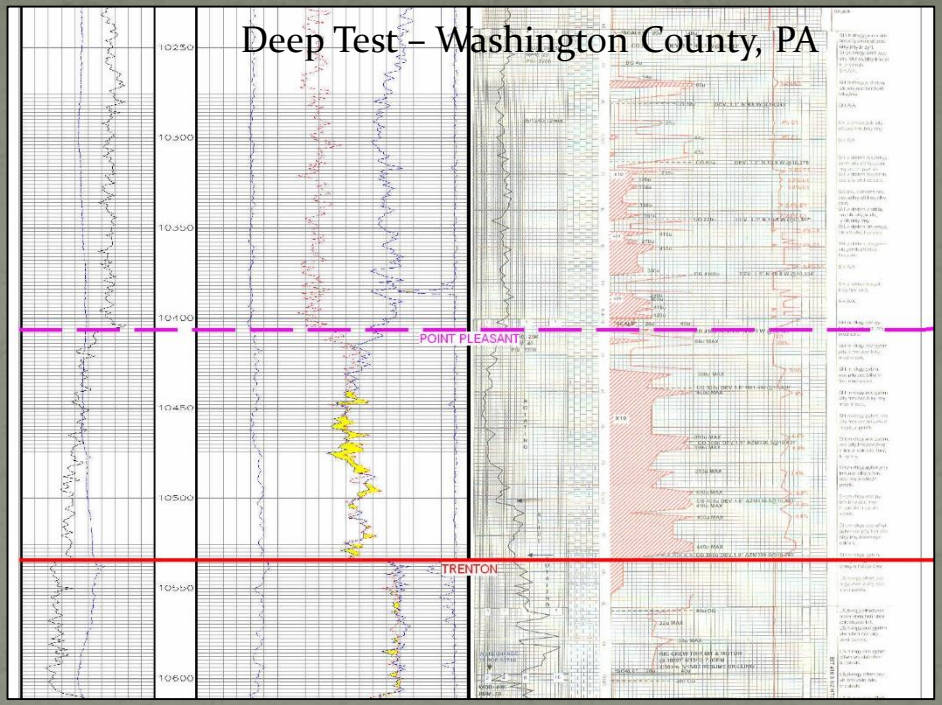
GR log tied to outcrop section

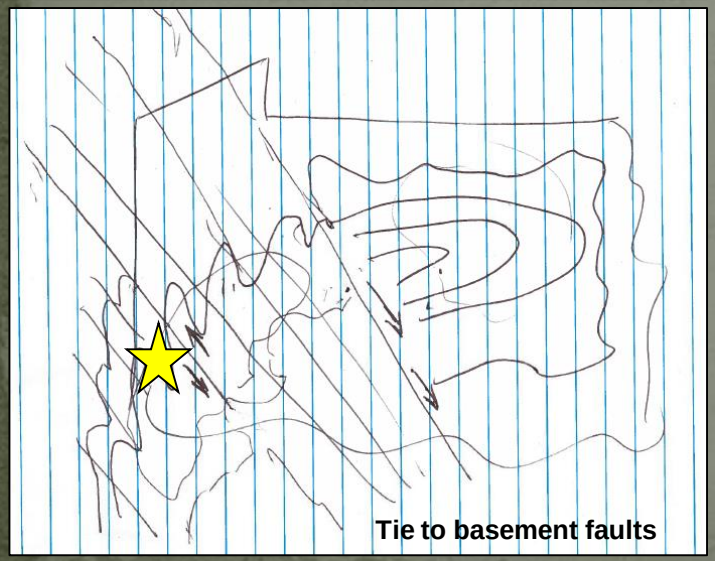


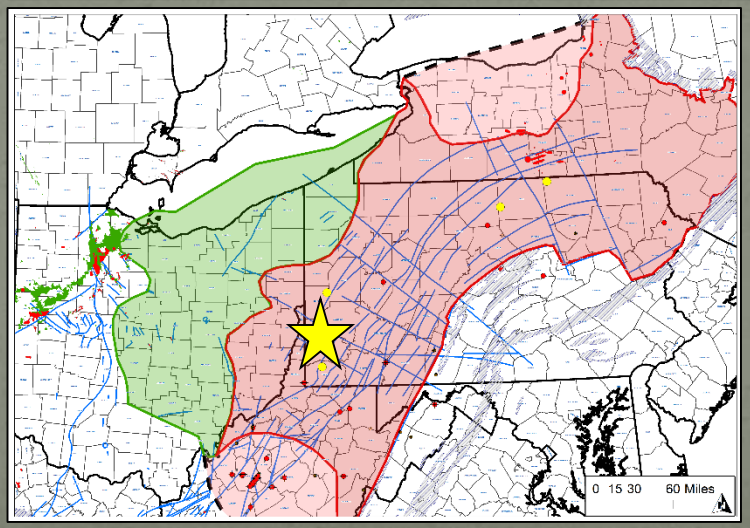
- Completed PSU undergrad thesis study of Utica using publications and outcrops in New York State and Central PA to tie into subsurface.
- Initially compared to Marcellus, focus on areas of thick high-GR black shale.

Critical Thinking Moment – Focus on the Point Pleasant!



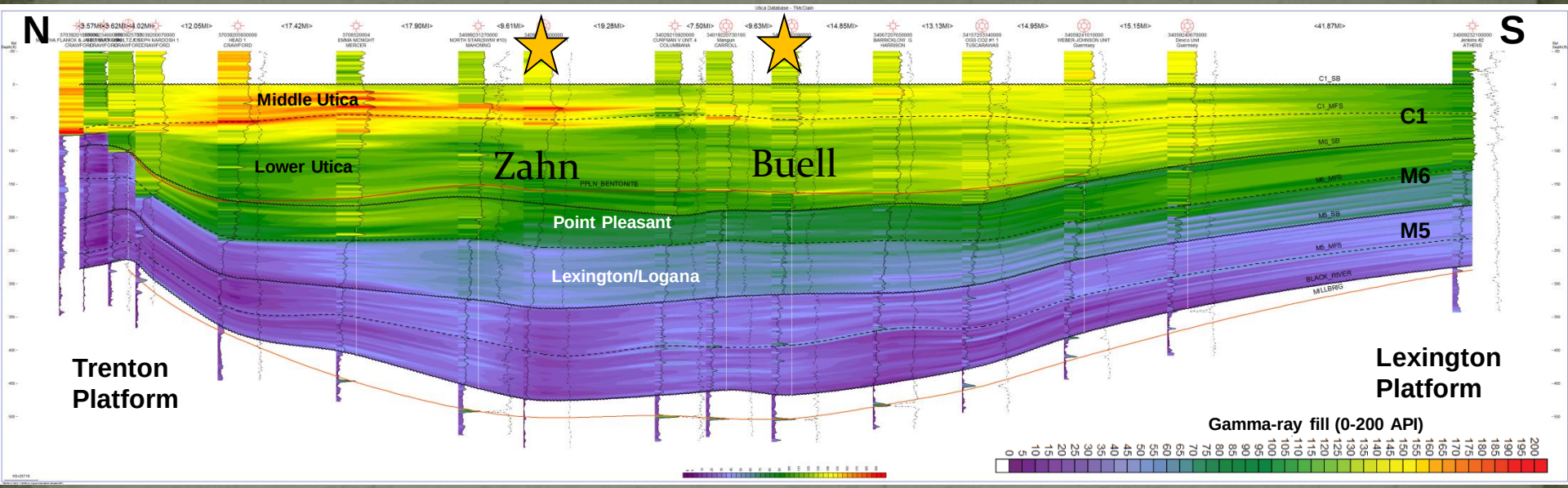


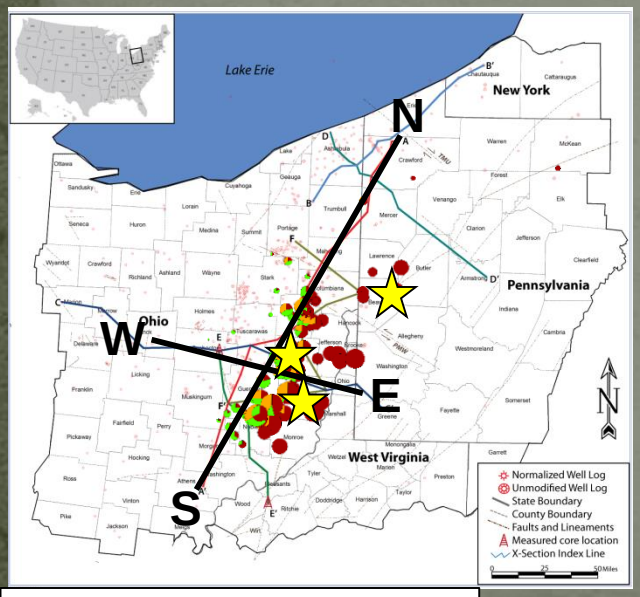




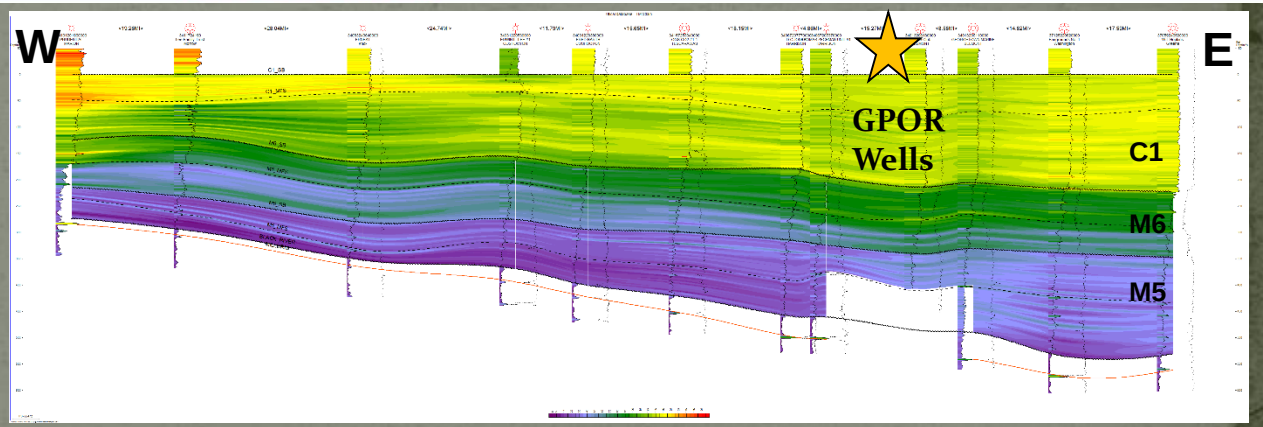
- Focus on density log, look for low bulk density signature.
- Ties to highest TOC and gas shows.

Developing A Stratigraphic Framework



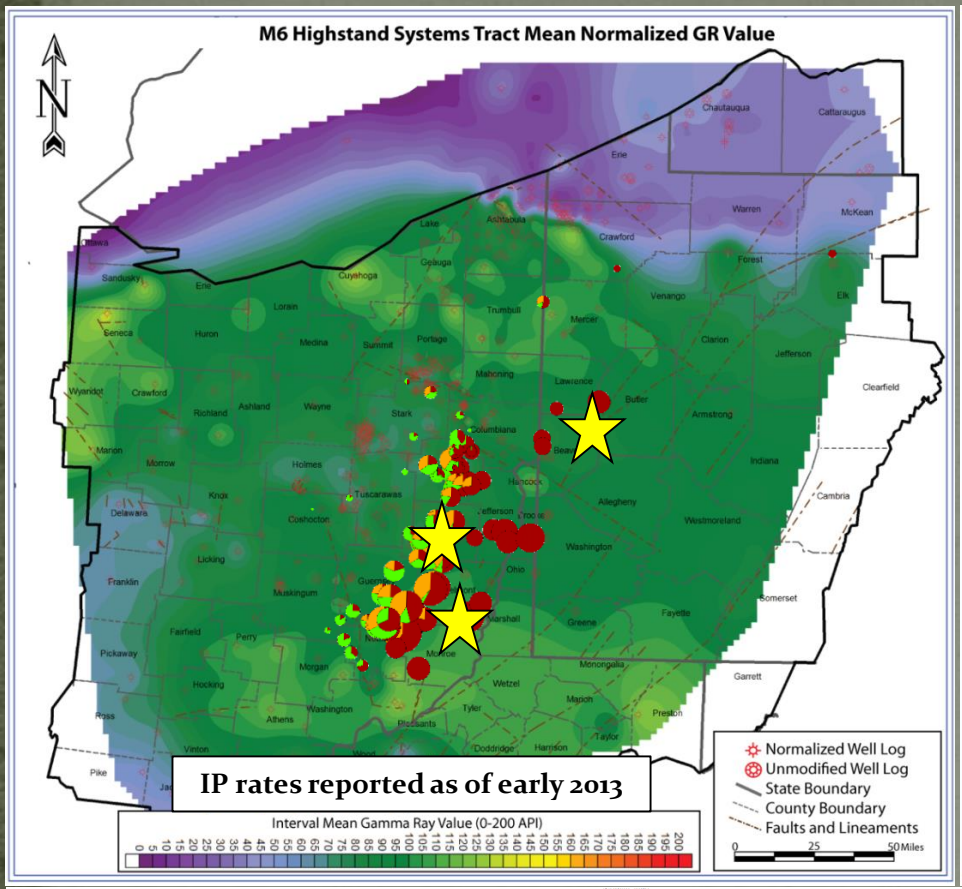


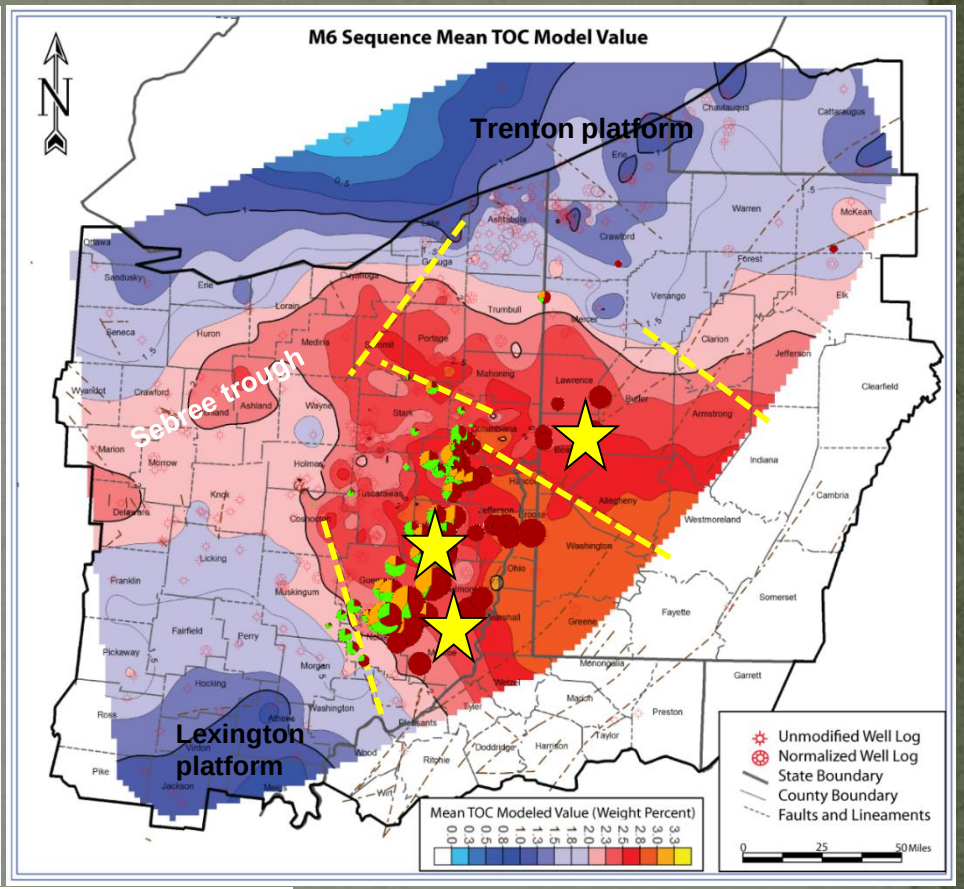
IP rates reported as of early 2013

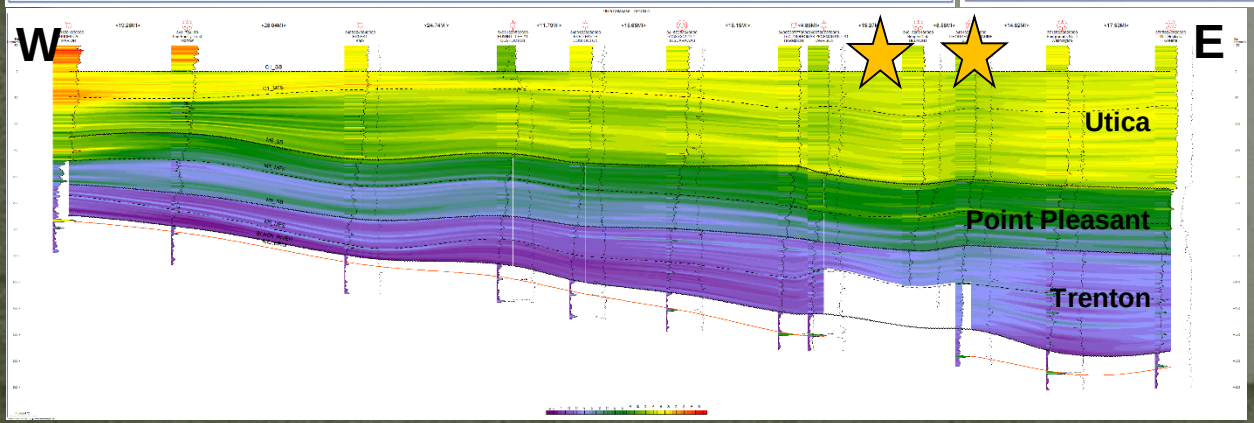


- Detailed correlation of sequence stratigraphy on smaller scale.
- Investigated the distribution of the organic-rich facies and tied to production test rates.
- Identified key reservoir facies and sequences (M5, M6, C1).

Comparing Production Trends to Sequence Stratigraphy

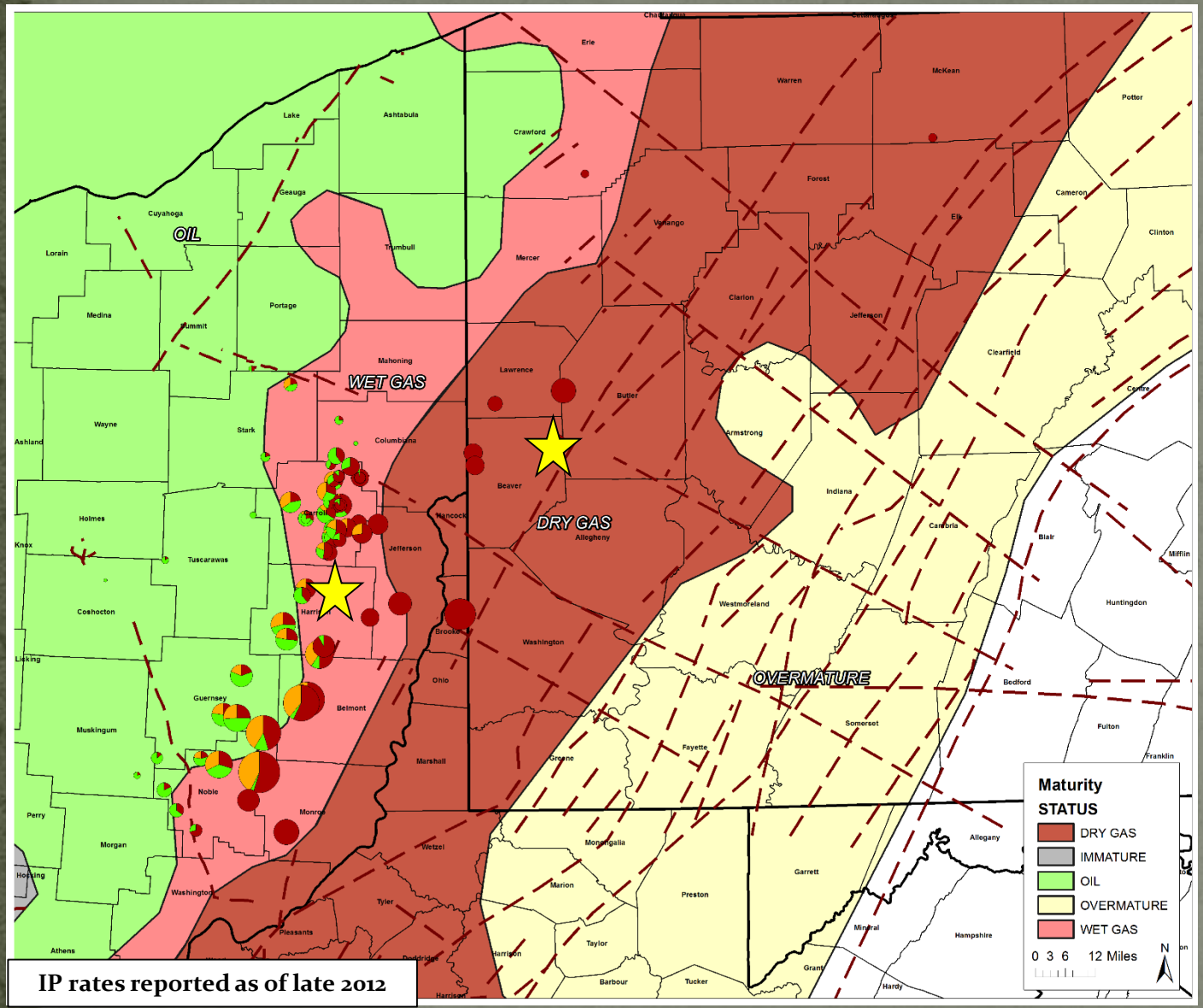






- Observed poor tie between GR and production rates.
- Observed strong tie with density/TOC! Content.
- Noted the strong influence of basement faulting on the play.

Comparing Production Trends To Thermal Maturity

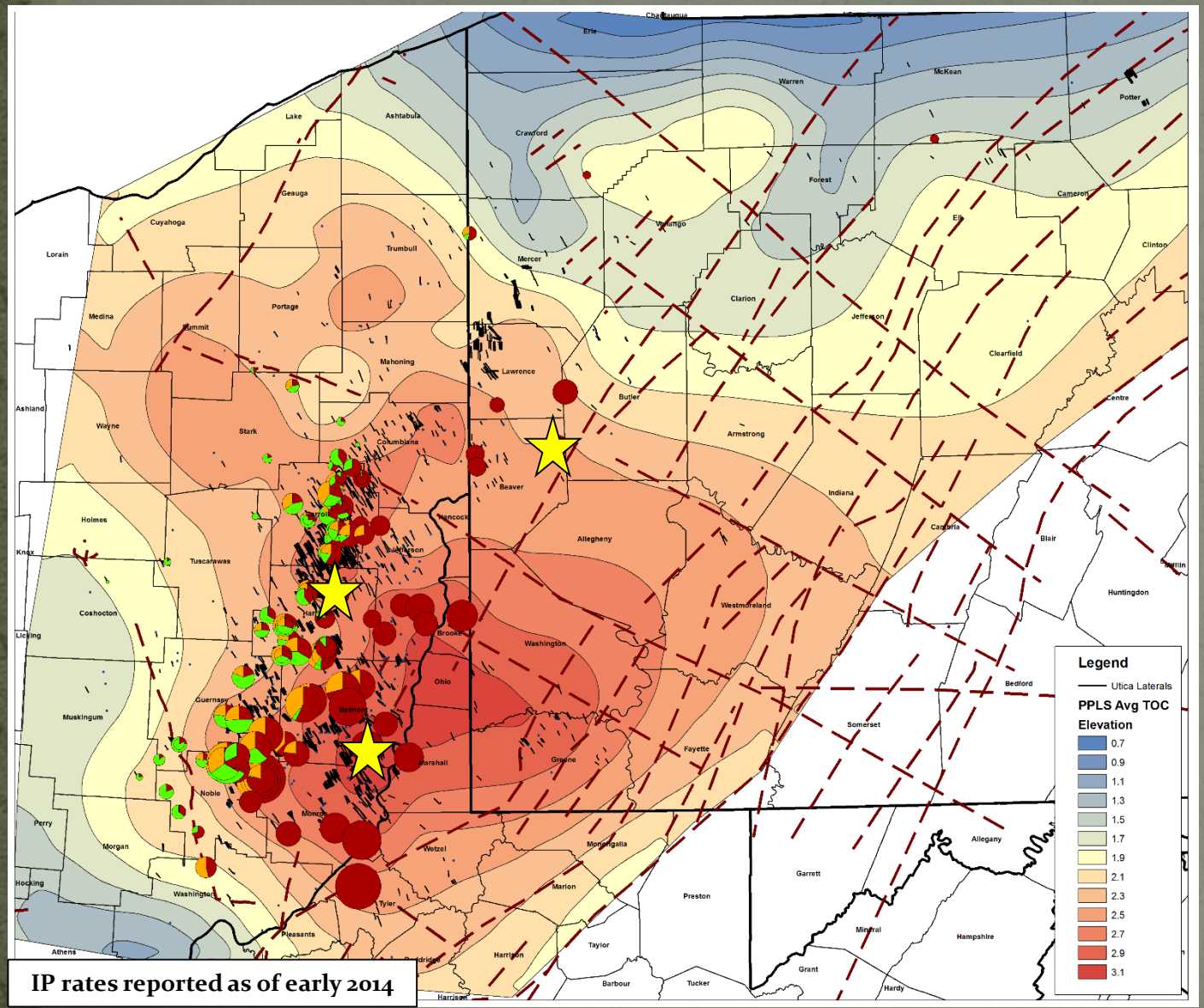


IP rates reported as of late 2012

Modified from Hulver 1997, Rowan 2006, Patchen et al 2006

- Thermal maturity is a key parameter to productivity in shale plays.
- Early thinking of the Utica Play touted liquids content and possible analog to the evolving Eagle Ford oil play of TX.
- Initial challenge was to accurately predict and project the the liquids rich play fairway.
- Early CAI/Ro work predicts NE-SW trending liquids window in Eastern OH and extending into Northwest PA.

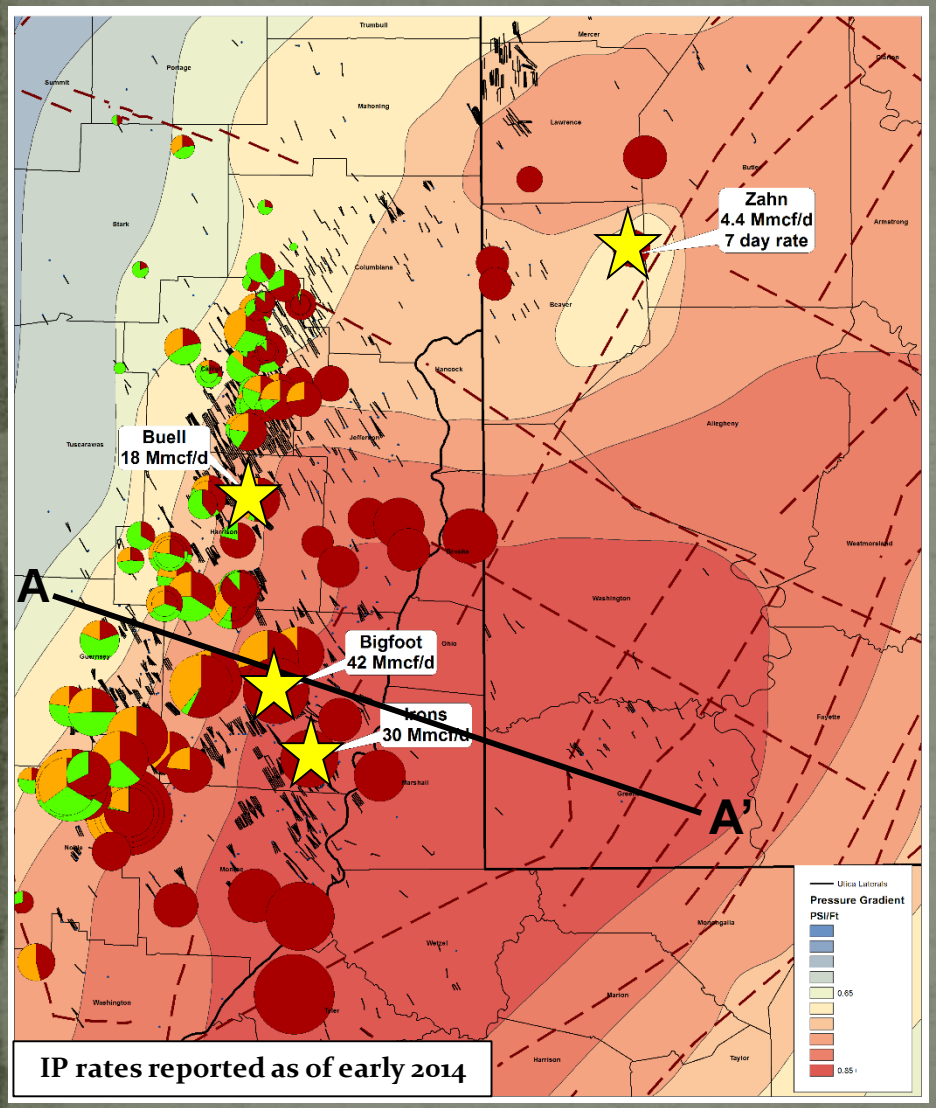
Transition of Play From Liquids To Deeper Dry Gas



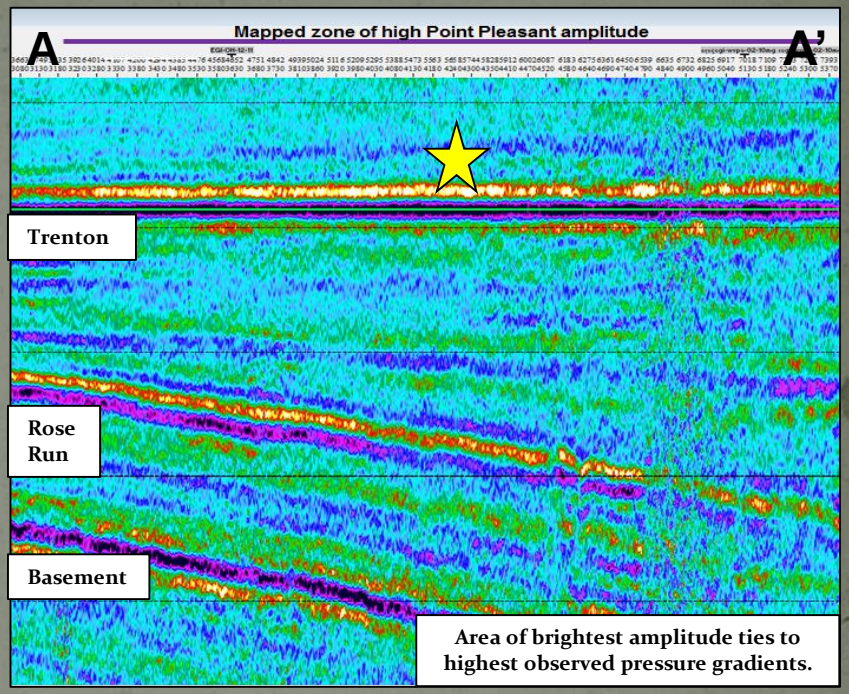
IP rates reported as of early 2014

- Tests in Eastern OH demonstrated 40% higher IP rates than in initial industry focus areas.
- A strong correlation between highest IP rates and areas of highest average Point Pleasant TOC is observed.
- By 2014 industry activity was testing deeper dry gas window advancing the productive areas of the play to south and east.
- Reservoir mapping projected the play to extend into SW PA.

What Else is Driving This Play? – Over-Pressure!

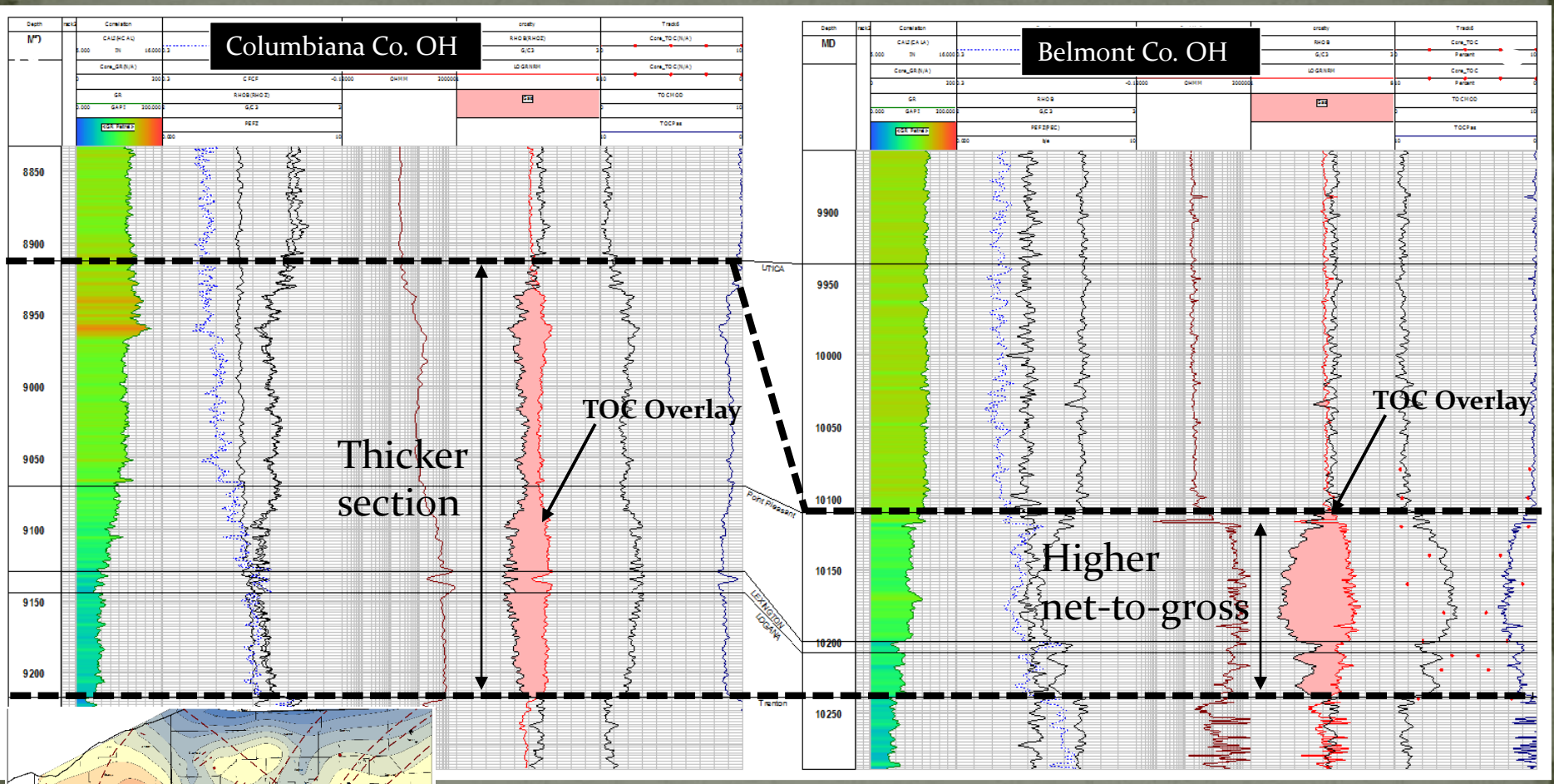


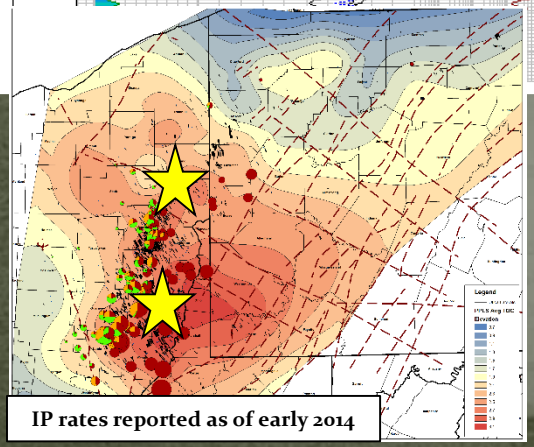
Note clear association of increasing productivity with increased pressure gradient.



- Correlated production volumes to pressure gradient trends.
- Noted trend of increasing pressure gradient with increasing depth.
- Correlated seismic attributes to observed pressure trends.
- Best wells are associated with gradients of greater than 0.8 psi/ft.

Comparing Reservoir Thickness to Reservoir Quality

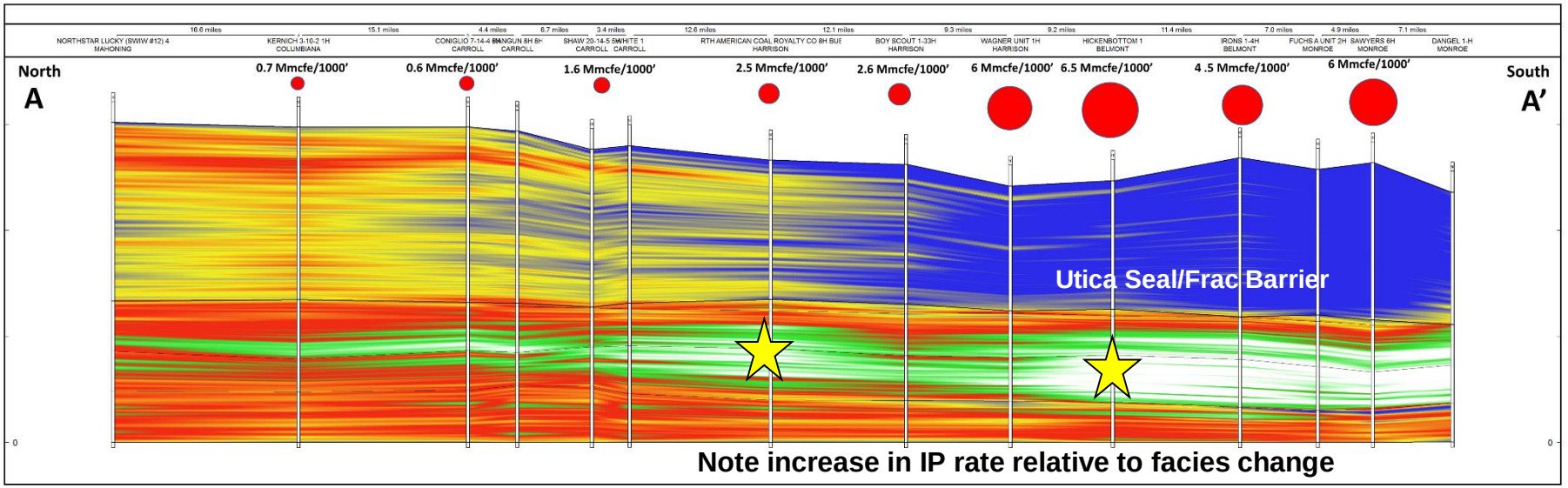


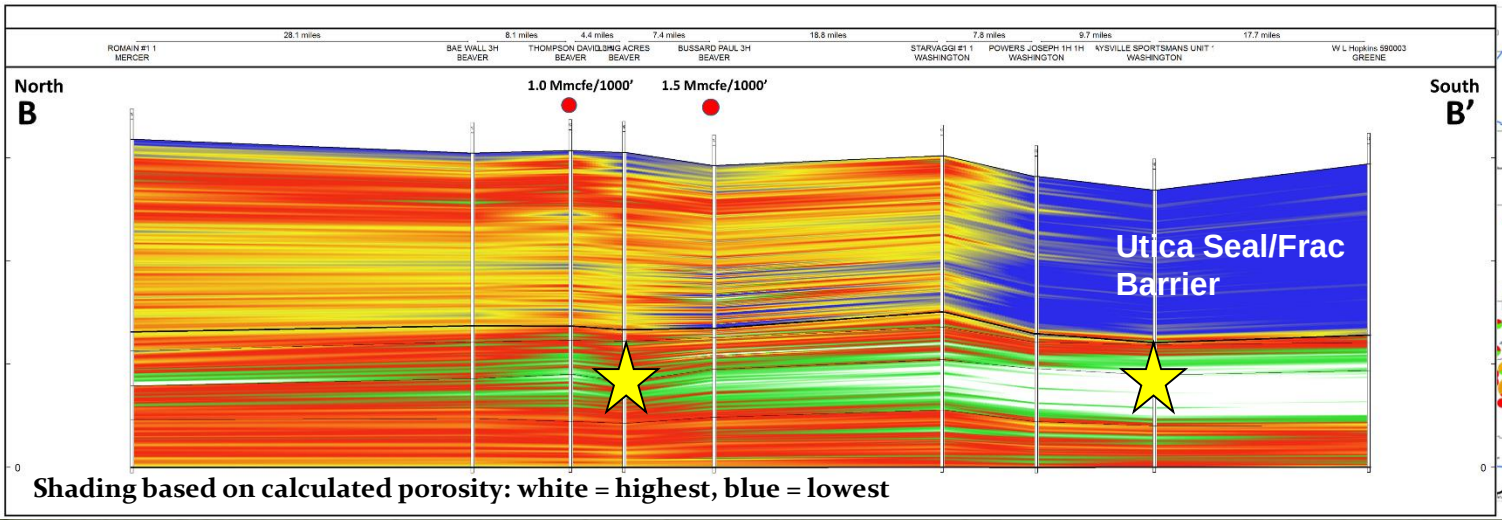


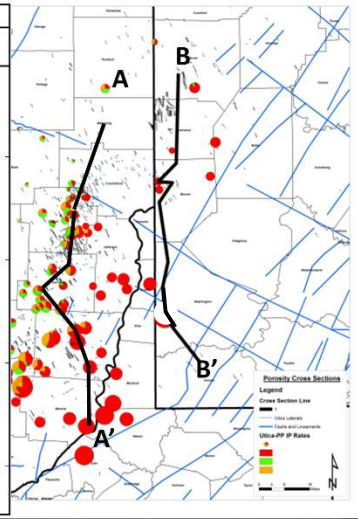
IP rates reported as of early 2014

- Wells to north contain thicker section of lower reservoir quality rock.
- High rate wells to south show condensed section of higher quality reservoir rock.

Stratigraphy Matters! Key Play Driver – Reservoir Quality and Frac Containment

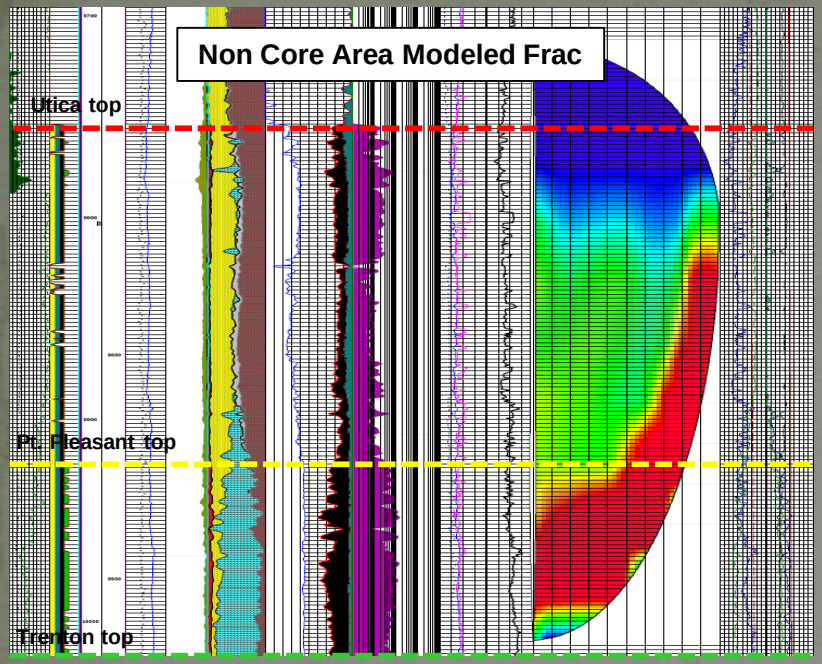




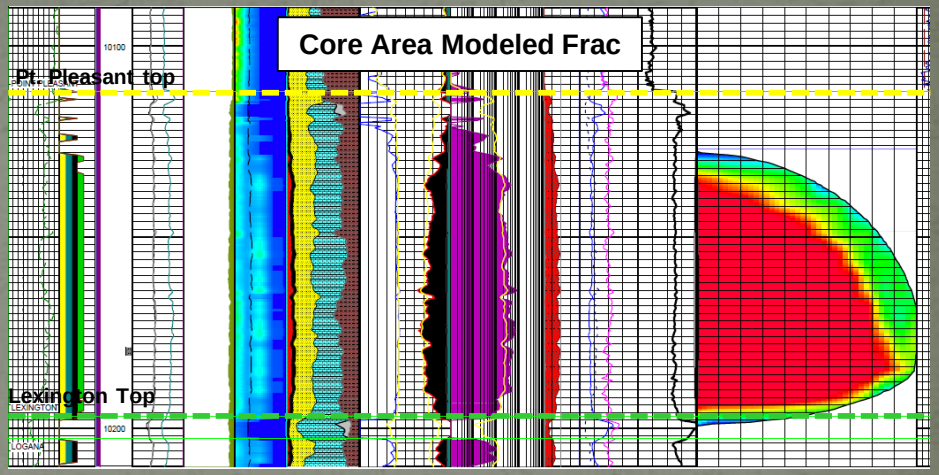


Regional cross sections showing facies change from organic rich Utica shale to non organic seal and IP's.

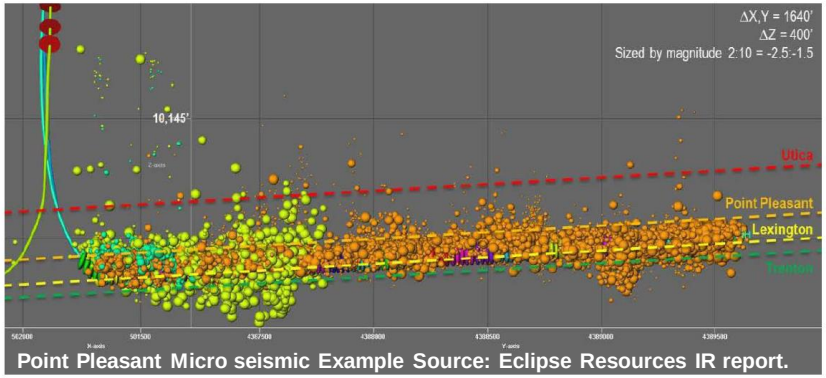
Examples of Frac Containment Using Reservoir Modeling



Example frac model of Utica seal area.



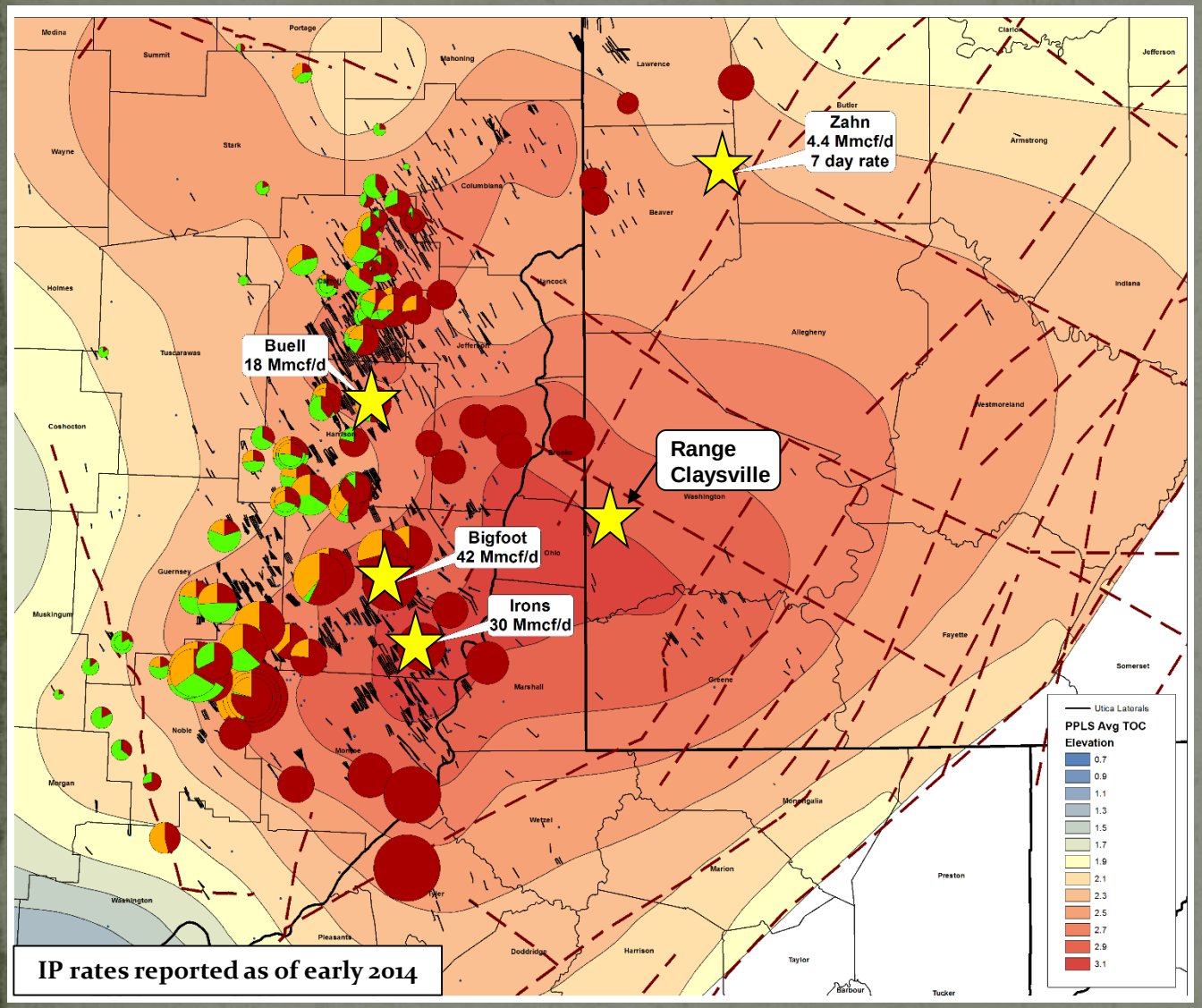
Microseismic confirms majority of the frac energy stays within the Point Pleasant



Point Pleasant Micro seismic Example Source: Eclipse Resources IR report.

- Frac containment is a key driver when comparing IP/1000' rates and EUR estimates.
- Areas with the best Point Pleasant to Utica rock property contrasts and the highest pressure gradients are optimal.
- Optimizing proppant placement across the highest pressure, highest porosity intervals is critical.

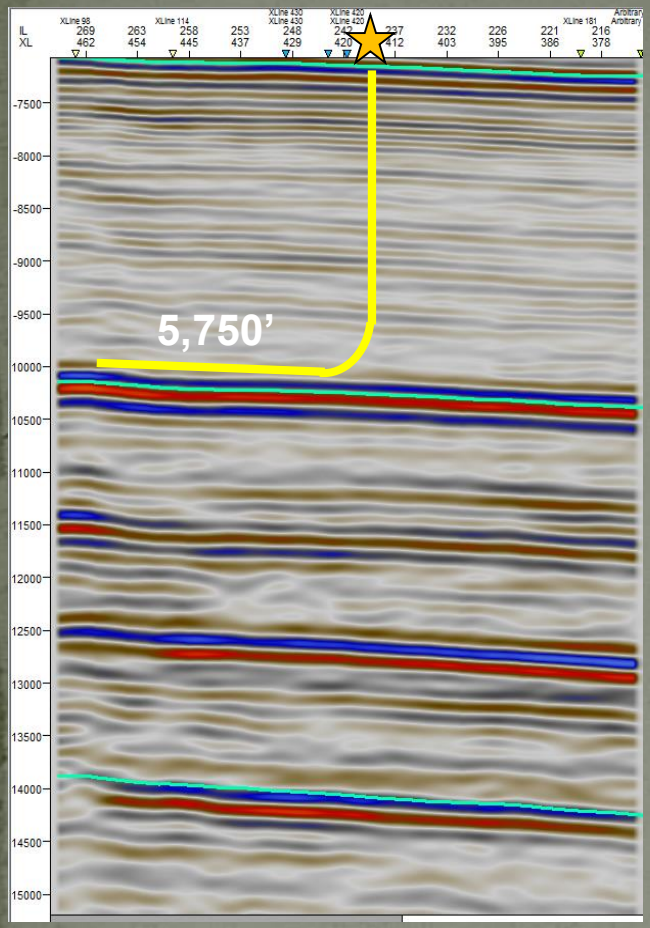
2014 - Dry Gas Play Expands Into PA and WV

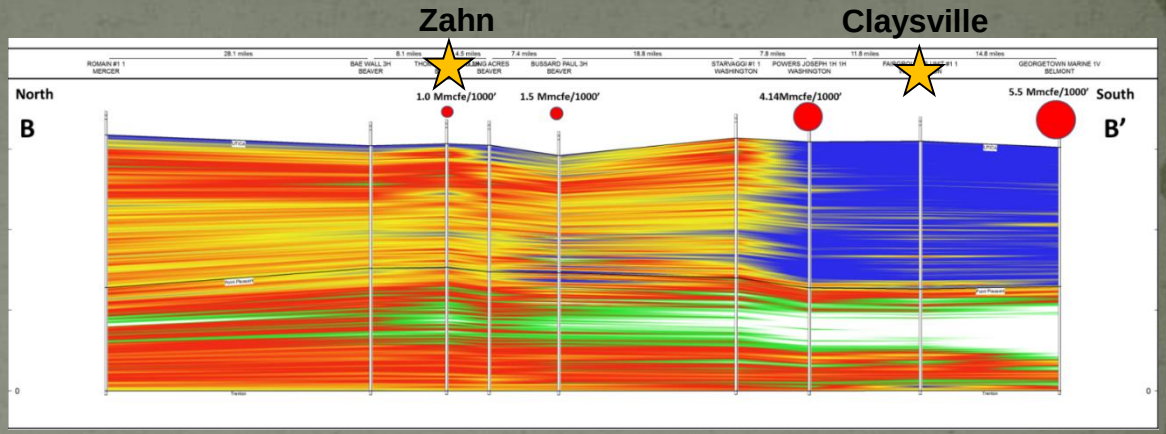


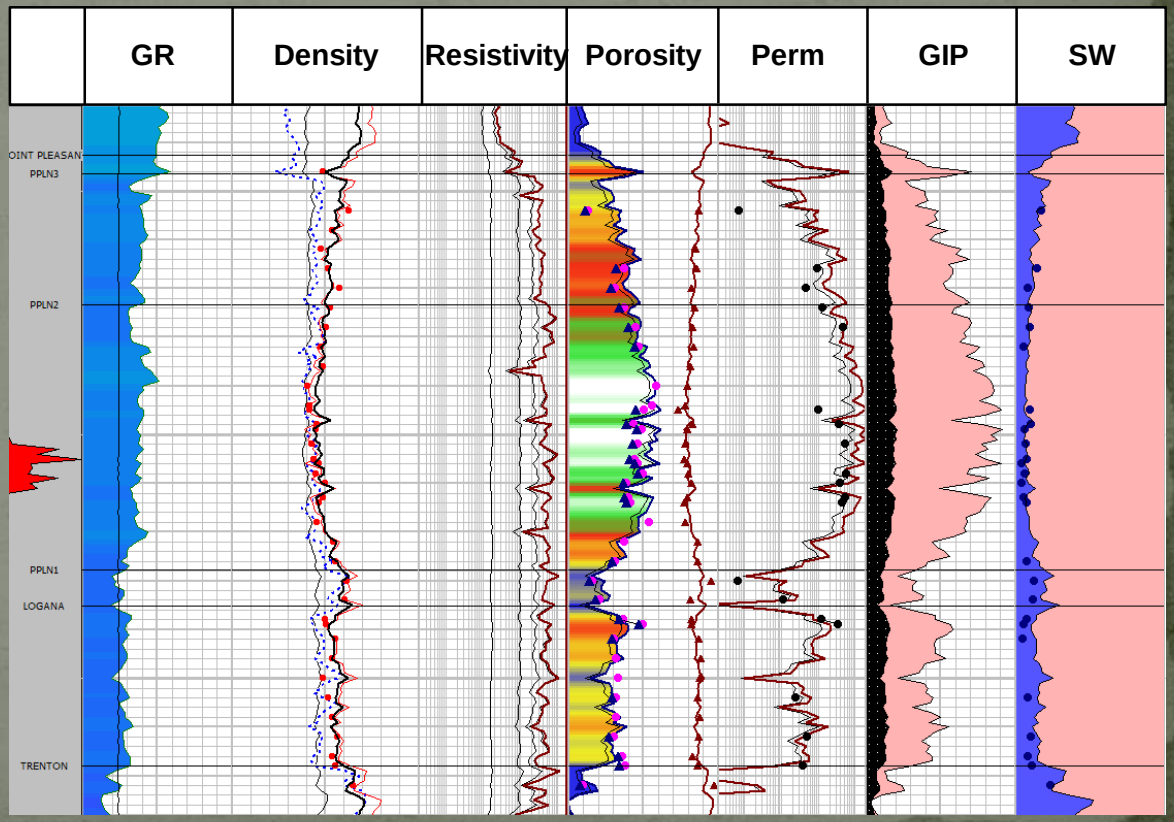
Note increase of IP/1000 rates as play grows eastward.

- By 2014, industry testing had extended the dry gas play into the WV Panhandle and PA.
- Established the relationship between overpressure/TVD, frac containment to facies change, and the projection of key reservoir quality indicators into SWPA.
- Exceptional flow rates were being reported from key wells in eastern Ohio.
- Range Resources first successful horizontal test of SWPA dry gas Utica Point Pleasant play was drilled and completed in late 2014.

Utica – Point Pleasant Reservoir Characteristics, SWPA





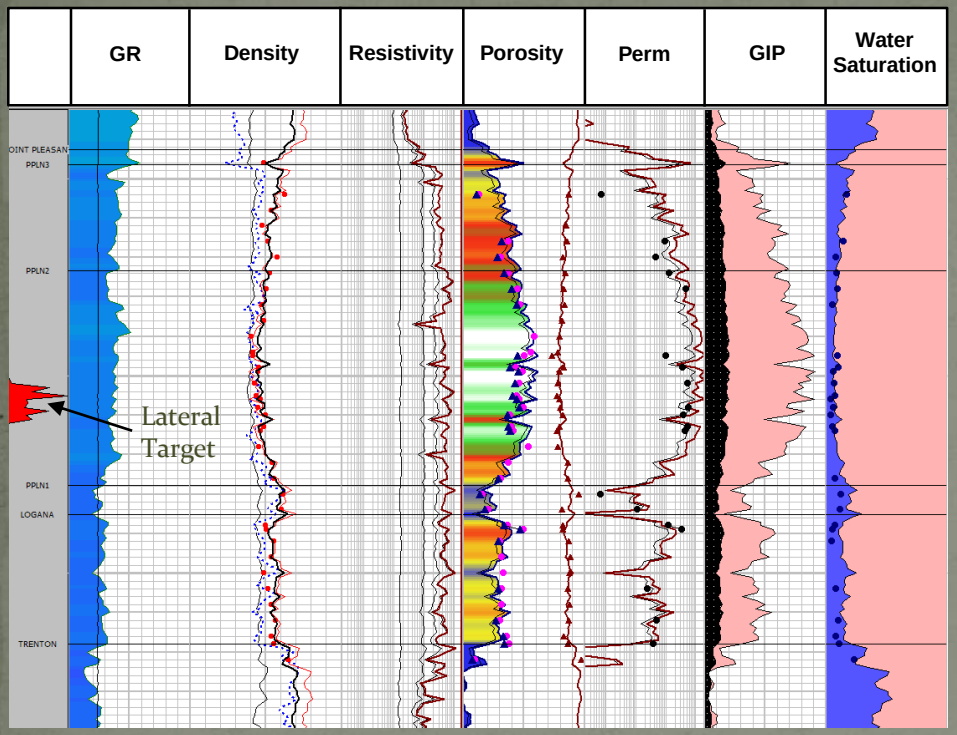


- Targeted and drilled structurally quiet area defined by 3D seismic coverage.

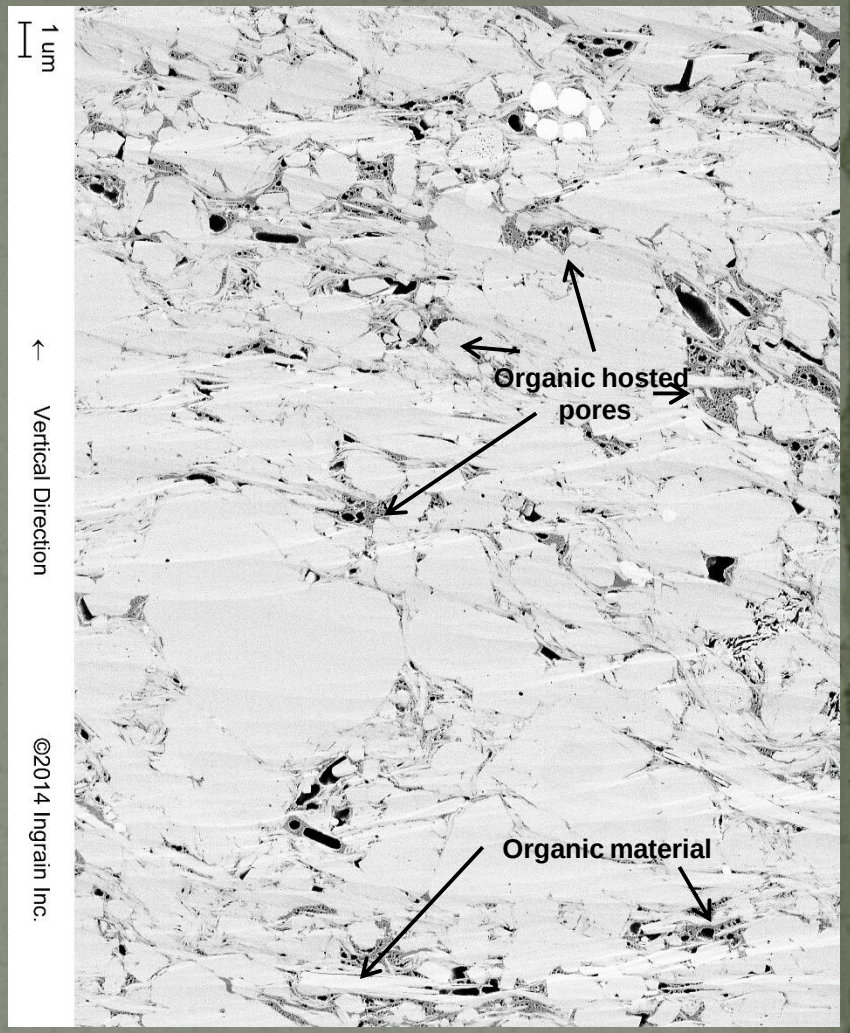
- Log and core data show excellent reservoir characteristics in the Point Pleasant target.

Claysville Sportsman’s Club Point Pleasant section

Key Point Pleasant Reservoir Quality Indicators



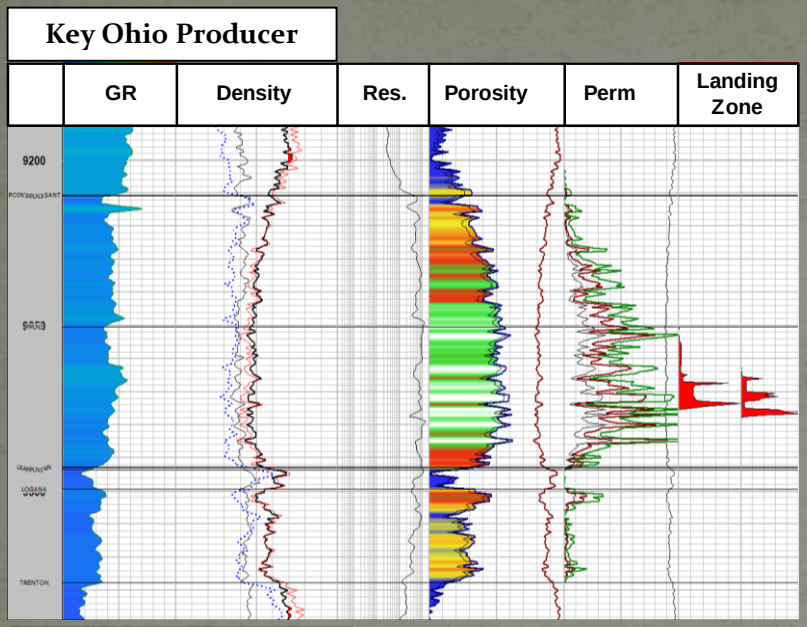
	GAS IN PLACE ANALYSIS: Claysville Sportsman 11H				
		Bulk Density (g/cc)	Gas Content (scf/ton)	GIP (scf/acre-ft)	GIP (BCF/section)
Utica to Trenton	Free Gas	2.64	240.4	863,811	140.9
	Sorbed Gas		23.5	84,488	13.8
	Total Gas in Place		263.9	948,299	154.7
	GAS IN PLACE ANALYSIS: Claysville Sportsman 11H				
		Bulk Density (g/cc)	Gas Content (scf/ton)	GIP (scf/acre-ft)	GIP (BCF/section)
Utica	Free Gas	2.73	148.2	549,663	46.3
	Sorbed Gas		9.9	36,534	3.1
	Total Gas in Place		158.1	586,197	49.3
	GAS IN PLACE ANALYSIS: Claysville Sportsman 11H				
		Bulk Density (g/cc)	Gas Content (scf/ton)	GIP (scf/acre-ft)	GIP (BCF/section)
Point Pleasant	Free Gas	2.56	338.5	1,177,676	93.0
	Sorbed Gas		38.1	132,404	10.5
	Total Gas in Place		376.5	1,310,080	103.5

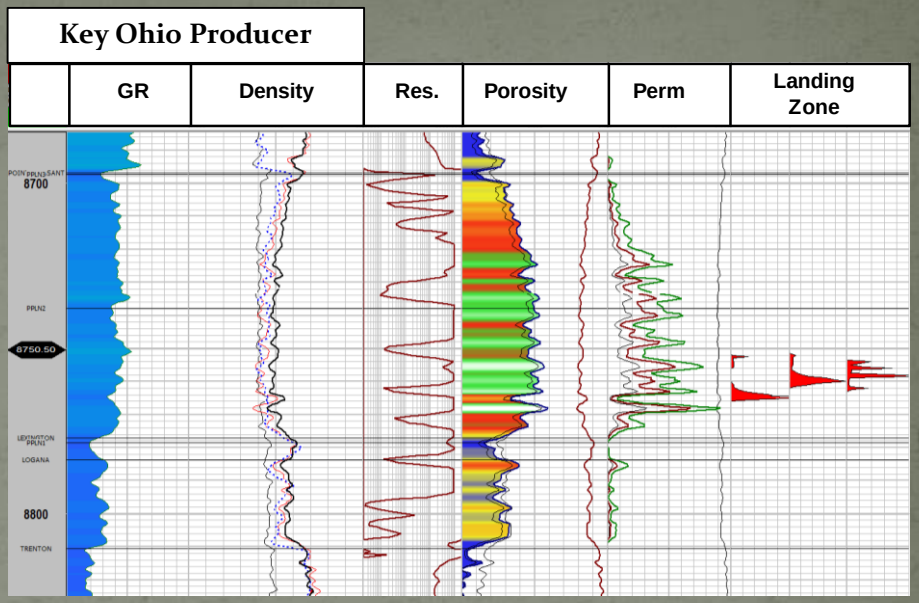


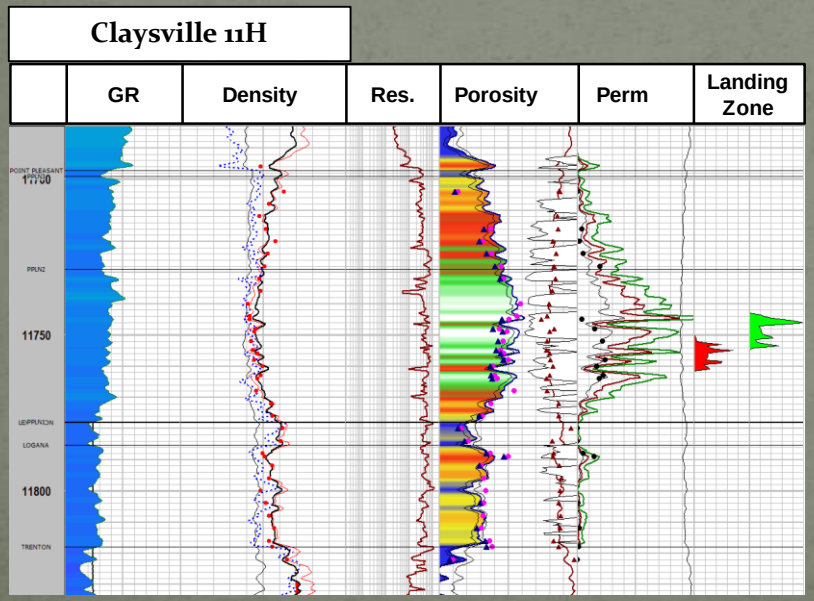
FIB SEM examples from lateral target interval.

Note TOC content and well developed pore network.

Selection of Point Pleasant Lateral Target



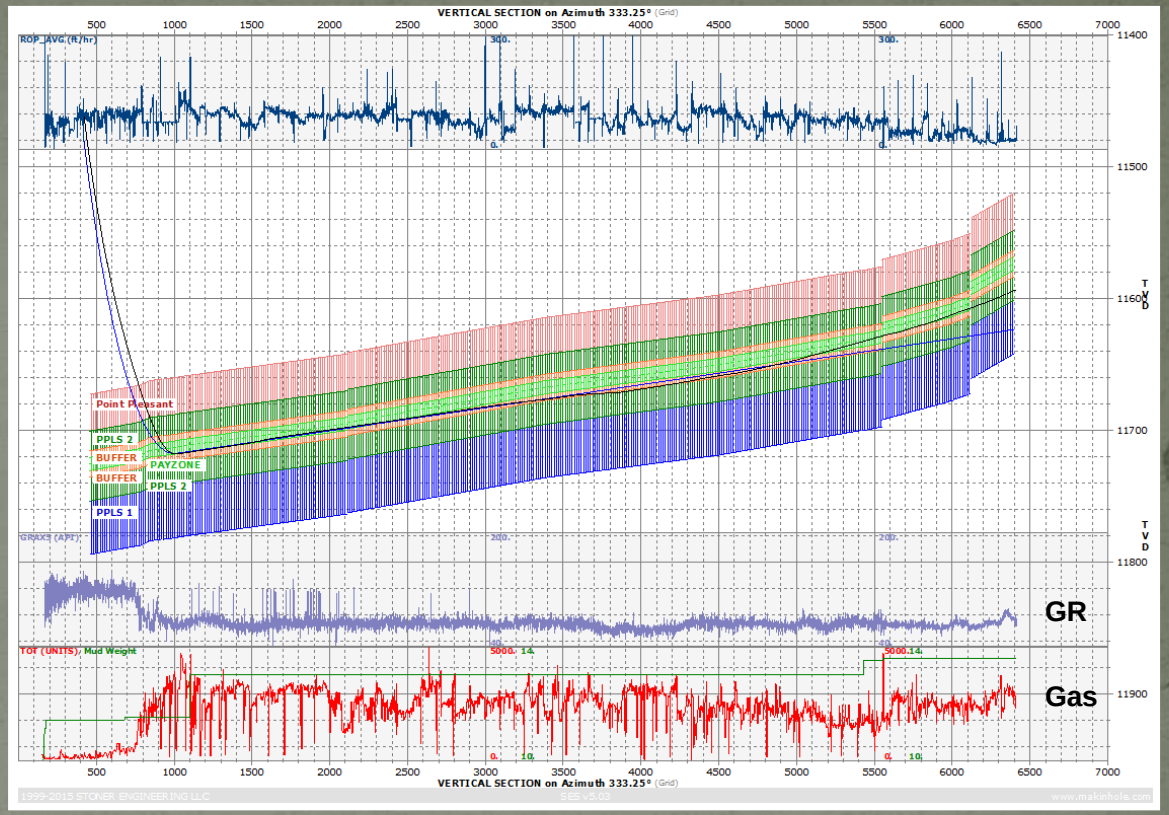




- Re-interpreted offsetting well MWD data to evaluate landing target.
- Compared lateral target to production data and EUR/1000 metrics.
- Observed correlation between highest production and targeting highest porosity zone.

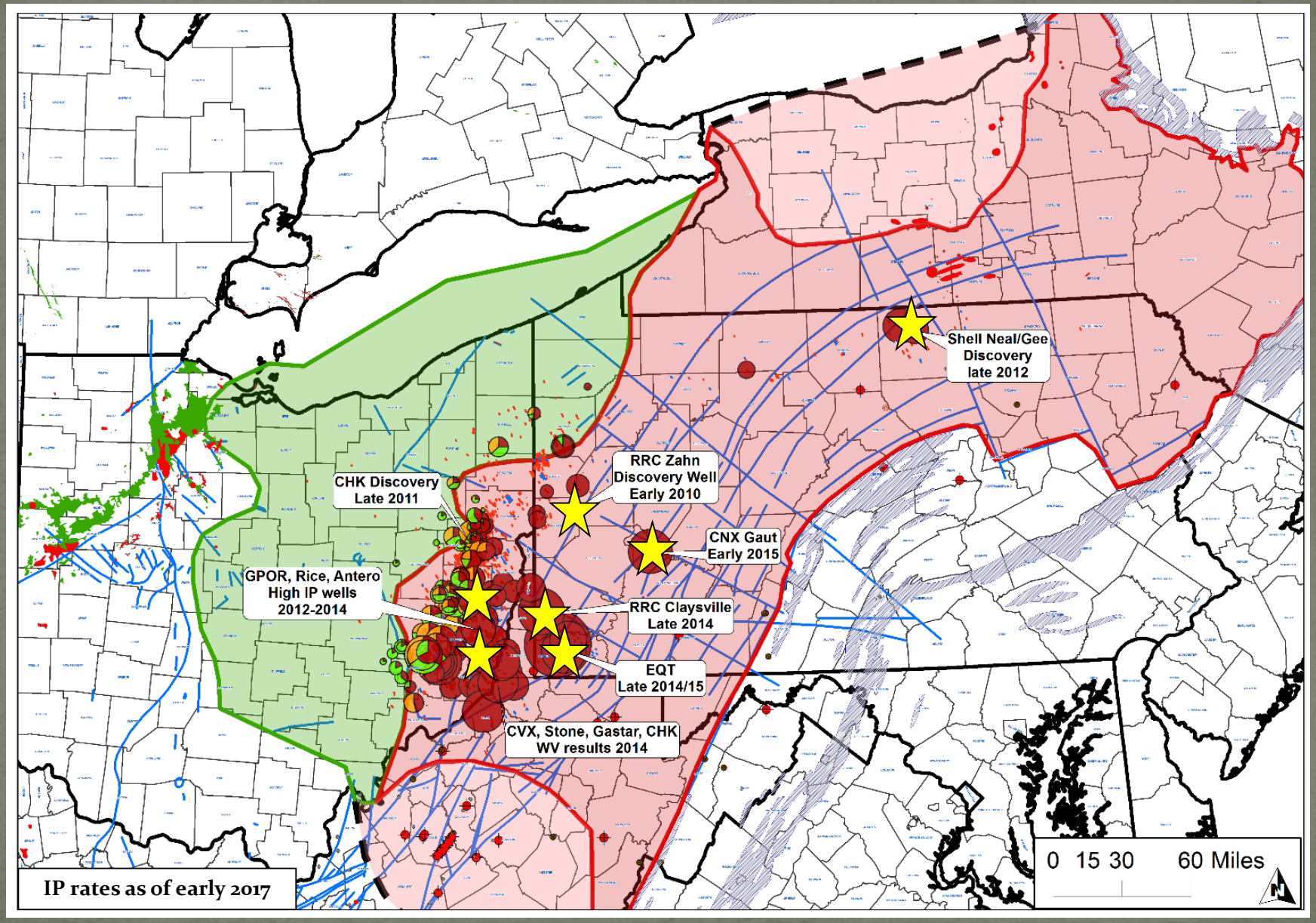
1st High-Volume Horizontal in Southwest Pennsylvania

2014 Claysville 11H Flowback – tested 59 Mmcf/d and 5,800 psi initial pressure.



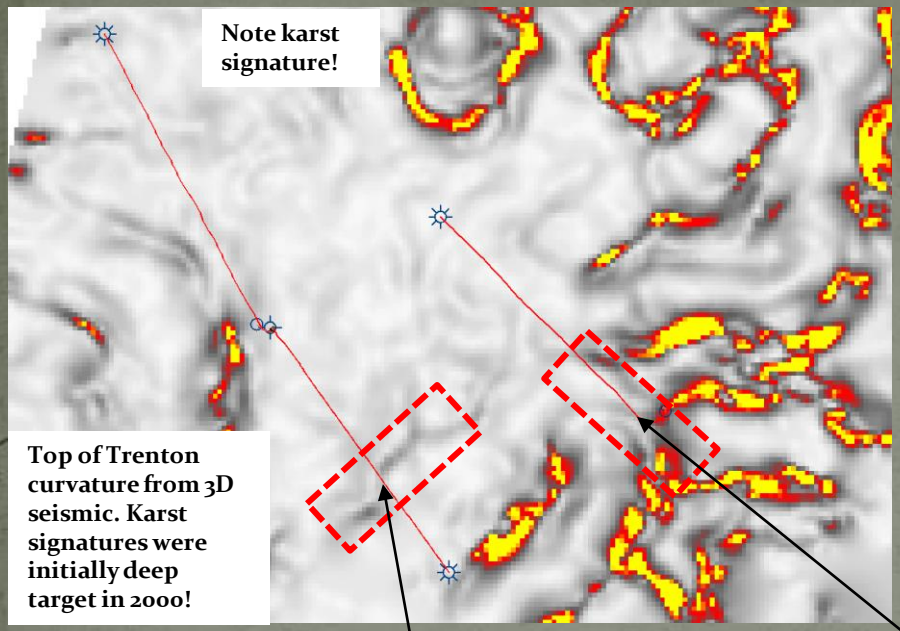
- Drilled pilot hole and horizontal in Q3 2014.
- Maintained strong gas shows throughout lateral.
- No significant well control issues.
- Key horizontal well establishing commerciality of the Point Pleasant dry gas play in SWPA.

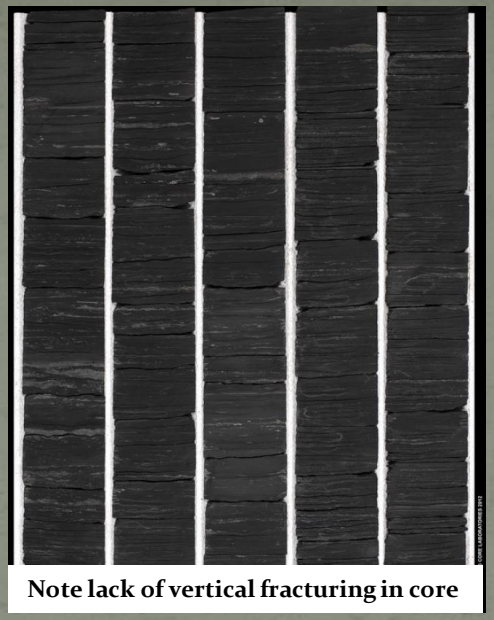
Utica - Point Pleasant Play – Present Day



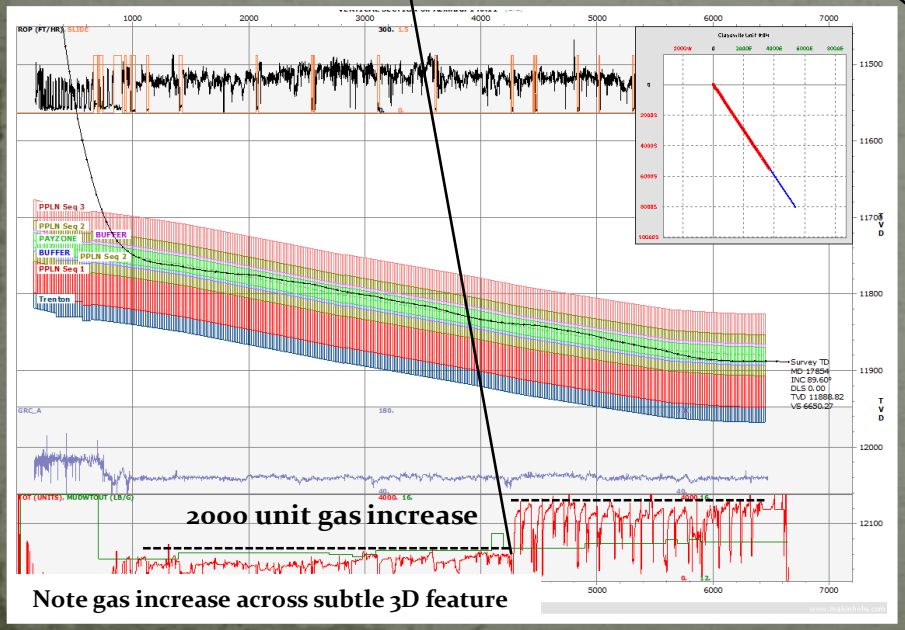
Since 2013 there has been significant expansion of play into Pennsylvania, Northeast Pennsylvania, and West Virginia.

What Is The Role of Natural Fracturing?

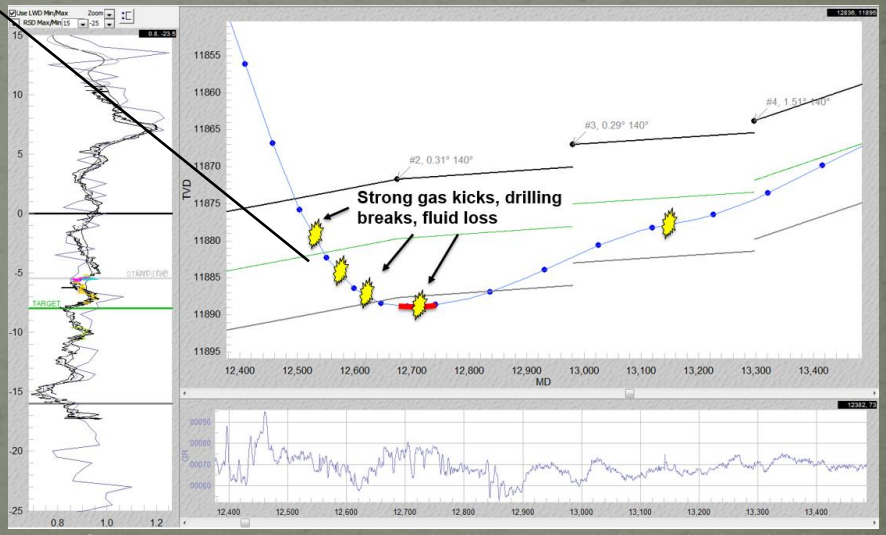



Note lack of vertical fracturing in core

- Fractures rare in core and vertical FMI but observed in seismic, drilling, and production.
- Level of fracturing significantly less than that observed in Marcellus.



Note gas increase across subtle 3D feature



Significant gas shows and drilling breaks while drilling through fractured interval identified on seismic.

Future Considerations, Concepts, Ideas

- What is the influence of fracturing and faulting?
- Have the core areas been fully established and defined?
- What other play concepts need to be tested?
- What about the Utica Interval?
- Can the oil window be commercialized?
- What is the eastern thermal maturity limit of play?
- Are there any technological limitations?
- Should we be looking at old areas with new approaches?
- Lots of exploration challenges and opportunities to cover in the future.

- Thank you!!!

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