

Relationship Between Well Performance and Structural Setting in the Marcellus Shale of Greene County, Pennsylvania*

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Abstract

Analysis of horizontal Marcellus Shale wells in Greene County, Pennsylvania suggests a correlation between estimated ultimate recovery per thousand feet of lateral (EUR/1,000 ft) and structural setting. Basement-generated anticlines and synclines of Greene County seem to have a direct effect on well performance. To test the relationship between EUR/1,000 ft and structural setting in the Marcellus Shale, 730 wells with adequate production, completion, and location information were categorized into four structural settings based on shallow residual mapping the base of the Big Injun Sand. The structural settings refer to the relative height above or below the residual trend surface of the Big Injun at a given location. The structural settings, from low to high, are (1) Below Trend (2) At or Near Trend (3) Above Trend, and (4) Well Above Trend. The Below Trend structural setting has the highest average EUR/1,000 ft and outperforms the worst structural setting, Well Above Trend, by 25%. The average EUR/1,000' decreases with each progressively shallower structural setting. A similar relationship between horizontal well performance and structural setting has been observed in the Utica-Point Pleasant Shale (Utica Shale) in Ohio. In the Utica Shale, structurally low settings show higher total organic carbon (TOC) compared to structurally high settings. It is hypothesized that structurally low settings offer a better environment for the deposition and preservation of organics. The relationship between well performance and structural setting in the Marcellus Shale will be explored and compared to what has been observed in the Utica Shale. Further, the importance of filtering wells by structural setting prior to analyzing completion methods will be emphasized.

Reference Cited

Fitzgerald, D.R., M.W. Casto, and R.B. Thomas, Sr., 2017, Structural Control of the Point Pleasant Formation Deposition and Production: Search and Discovery Article # 51434, Web Accessed May 5, 2019,
http://www.searchanddiscovery.com/documents/2017/51434fitzgerald/ndx_fitzgerald.pdf

RELATIONSHIP BETWEEN WELL PERFORMANCE AND STRUCTURAL SETTING IN THE MARCELLUS SHALE OF GREENE COUNTY, PENNSYLVANIA

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Agenda

- Overview of Residual Mapping
- Recap of Utica-Point Pleasant Shale observations presented at 2017 AAPG Eastern Section Conference
- New observations in the Marcellus Shale of Greene County
- Comparing and contrasting the Utica-Point Pleasant and Marcellus
- Possible explanations for differences
- Practical application of these observations
- Future work

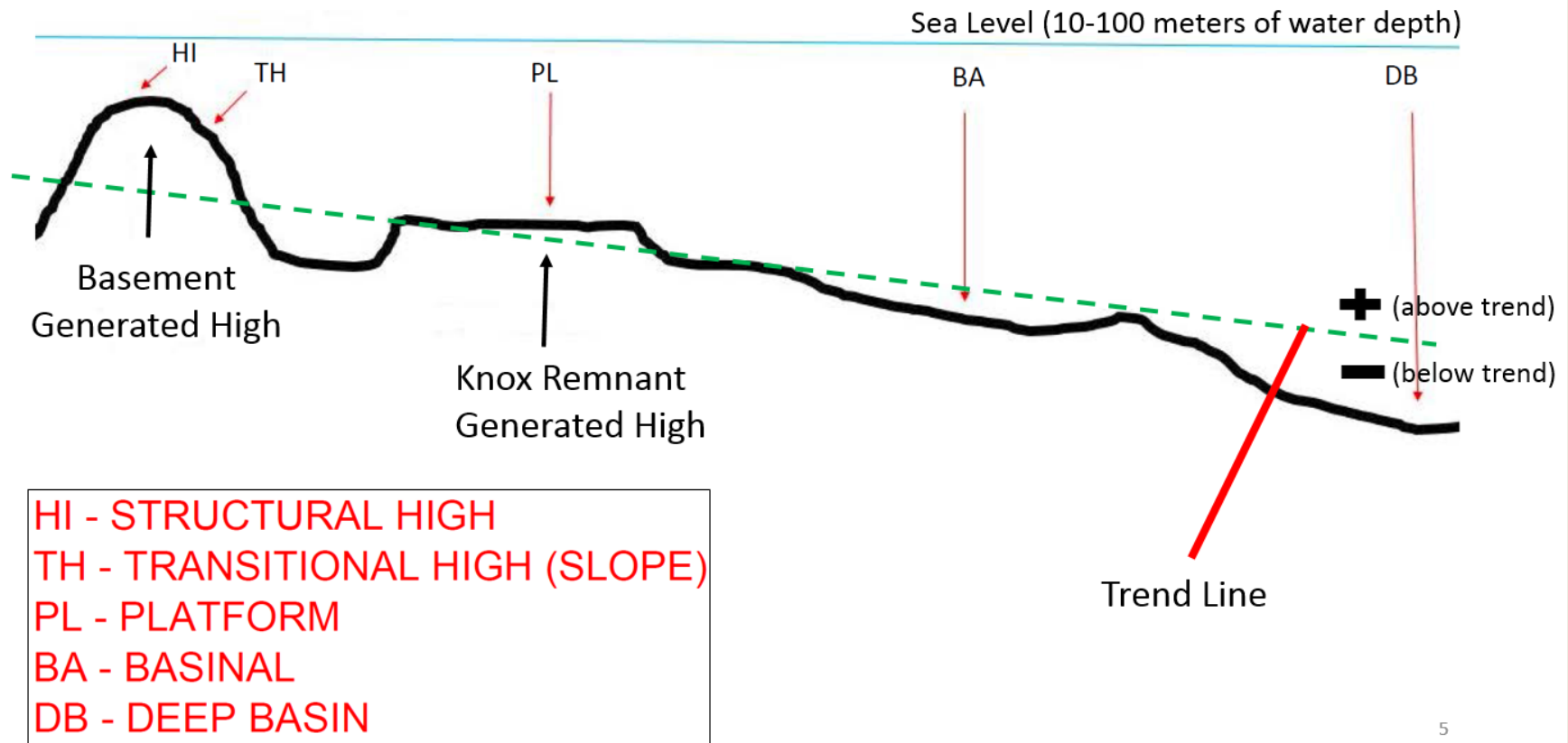
Residual Mapping

Layman's Description:

Approximating the surface topography at the time of deposition by canceling out regional dip, which was largely influenced by post-depositional tectonics

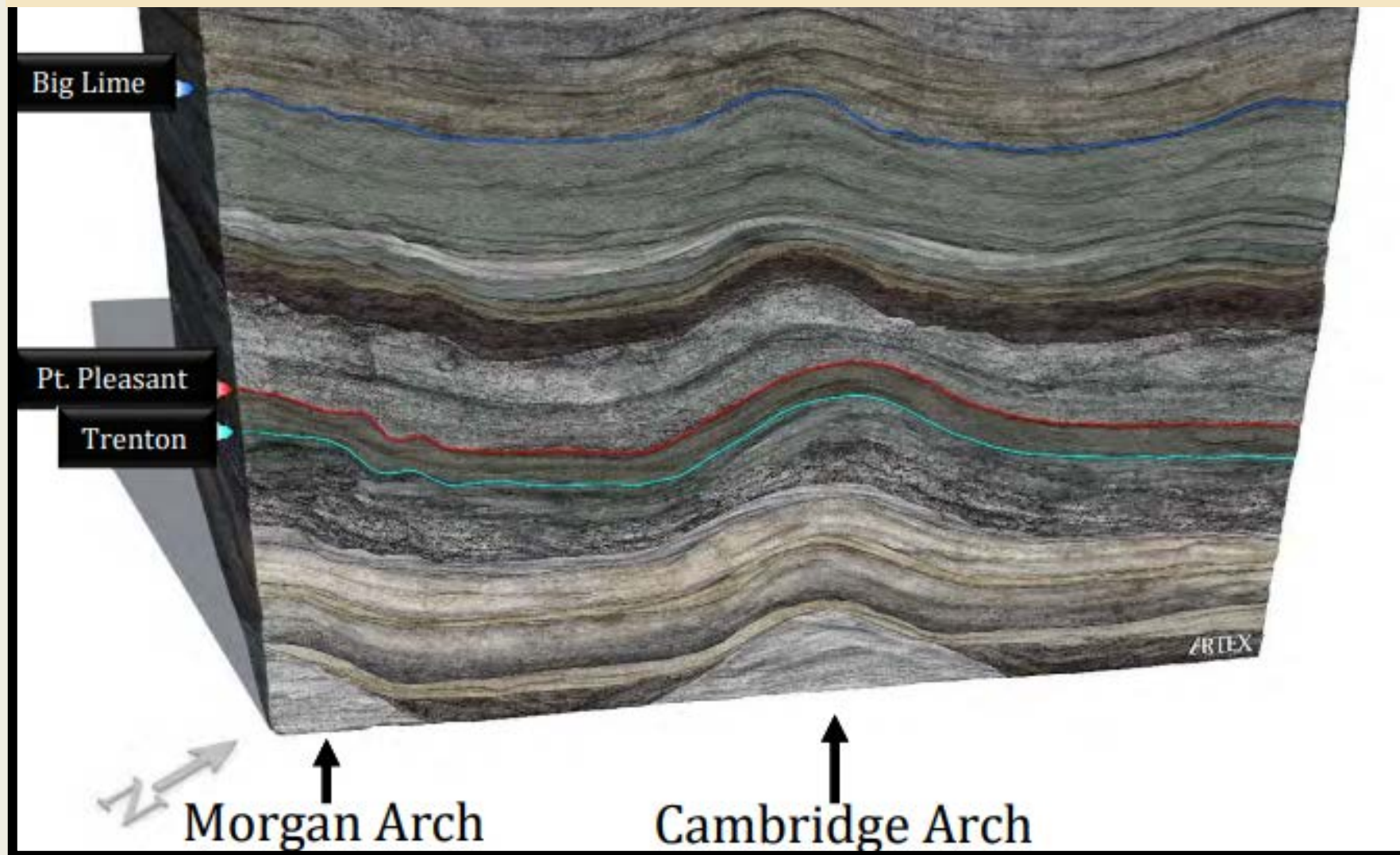
Residual Mapping

Utica-Point Pleasant Example (from 2017 presentation)



Source: "Structural Control of the Point Pleasant Formation Deposition and Production"; Fitzgerald, Casto, Thomas; AAPG Eastern Section Conference 2017; Morgantown, WV

Example of basement structures translating all the way up to shallower formations with many more penetrations. Using shallower zones allows us to create a residual map with much higher resolution than if we only used wells penetrating the zone of interest.

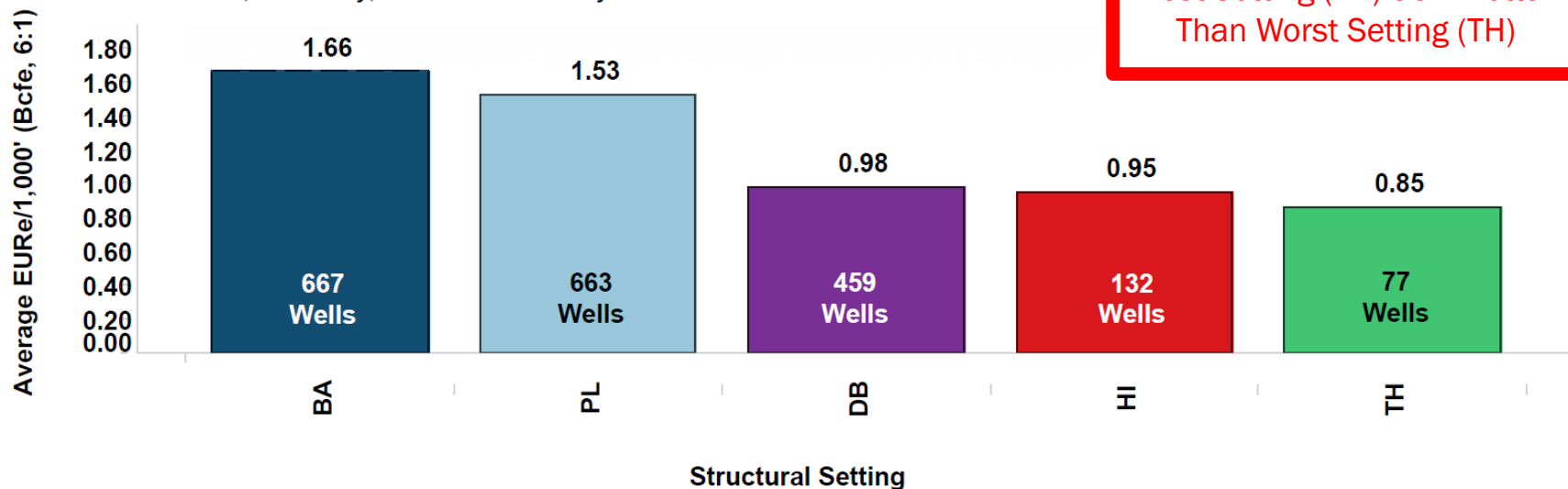


Performance vs. Structural Setting

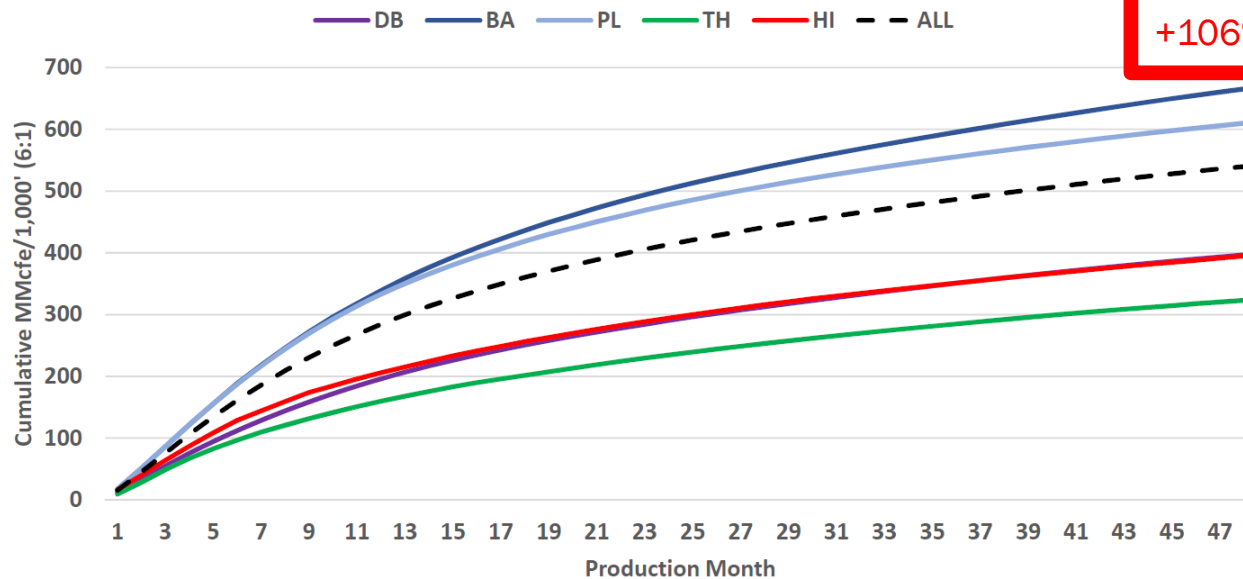
Ohio Utica-Point Pleasant Example

Average EURE/1,000' (Bcfe, 6:1) vs Structural Setting

Utica-Point Pleasant, Ohio Only, All Thermal Maturity Windows



Cumulative MMcfe/1,000' (6:1) by Structural Setting Utica-PP Shale, Ohio, All Windows



Basinal Setting

- Best producing setting
- Lower oxygen levels
- Most organic preservation

- Low energy environment
- Continuity of organic beds
- Highest TOC

HI

TH

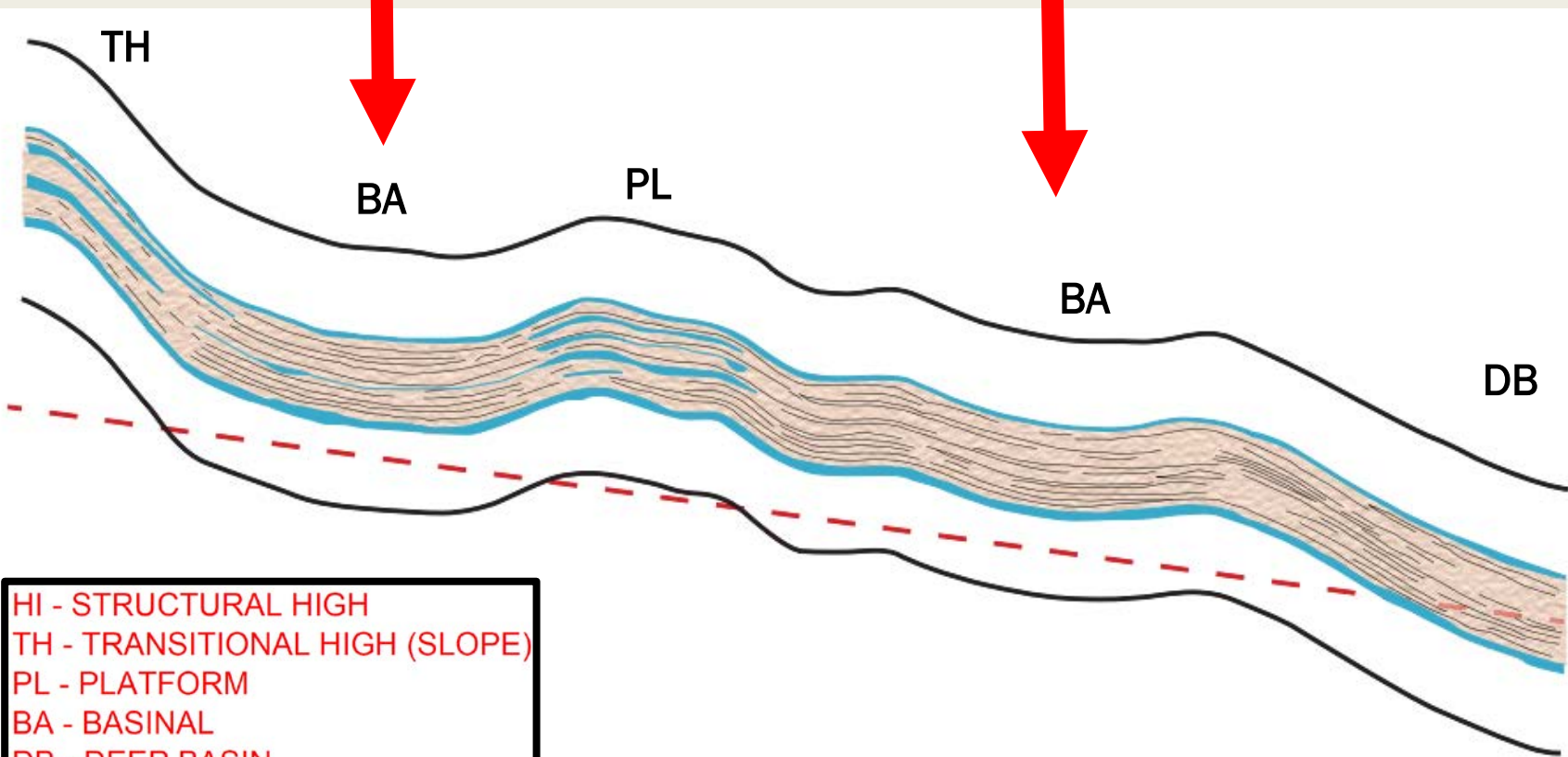
BA

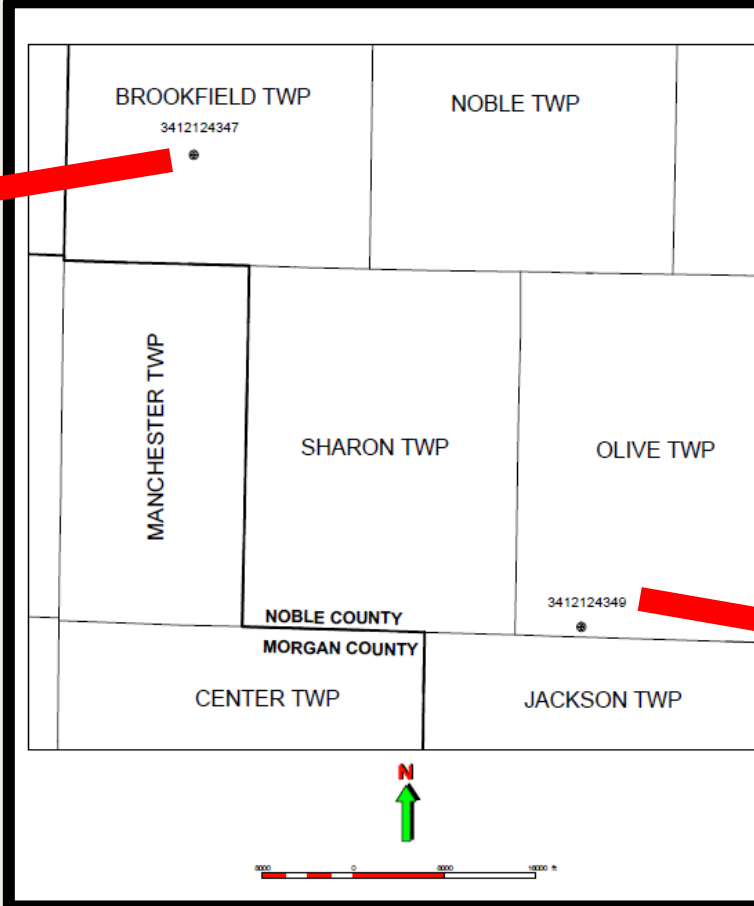
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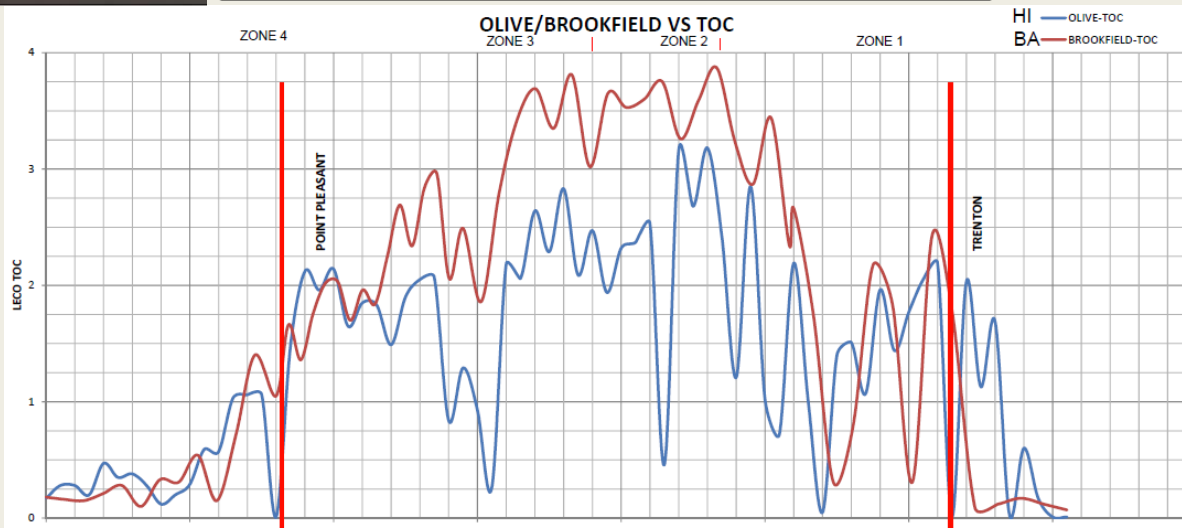
DB

HI - STRUCTURAL HIGH
TH - TRANSITIONAL HIGH (SLOPE)
PL - PLATFORM
BA - BASINAL
DB - DEEP BASIN





BA: Max
TOC 4%



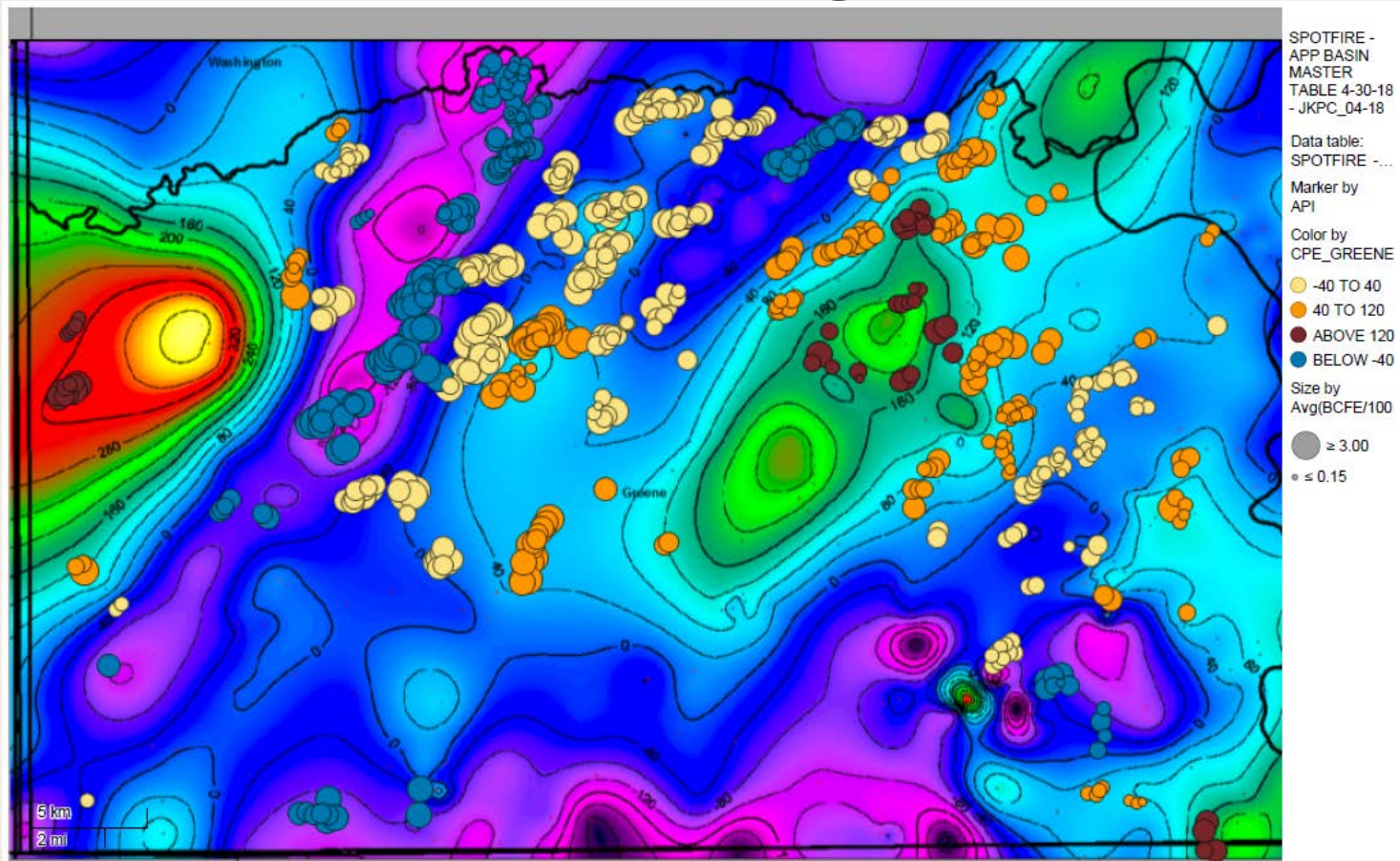
HI: Max
TOC 3%

What We Learned in the Utica-PP

- There is a correlation between well performance and structural setting
- There is a correlation between TOC and structural setting
- Therefore, one of the reasons we observe poorer well performance in certain structural settings is likely because of diminished preservation of organics in those environments
- Another reason performance suffers in certain structural settings is that staying in zone is much more difficult when starting on a high or transitional high. This is partly due to the lack of distinction in the gamma ray log due the Utica-Point Pleasant's unique minerology.

Residual Mapping

Greene County – Base of Big Injun



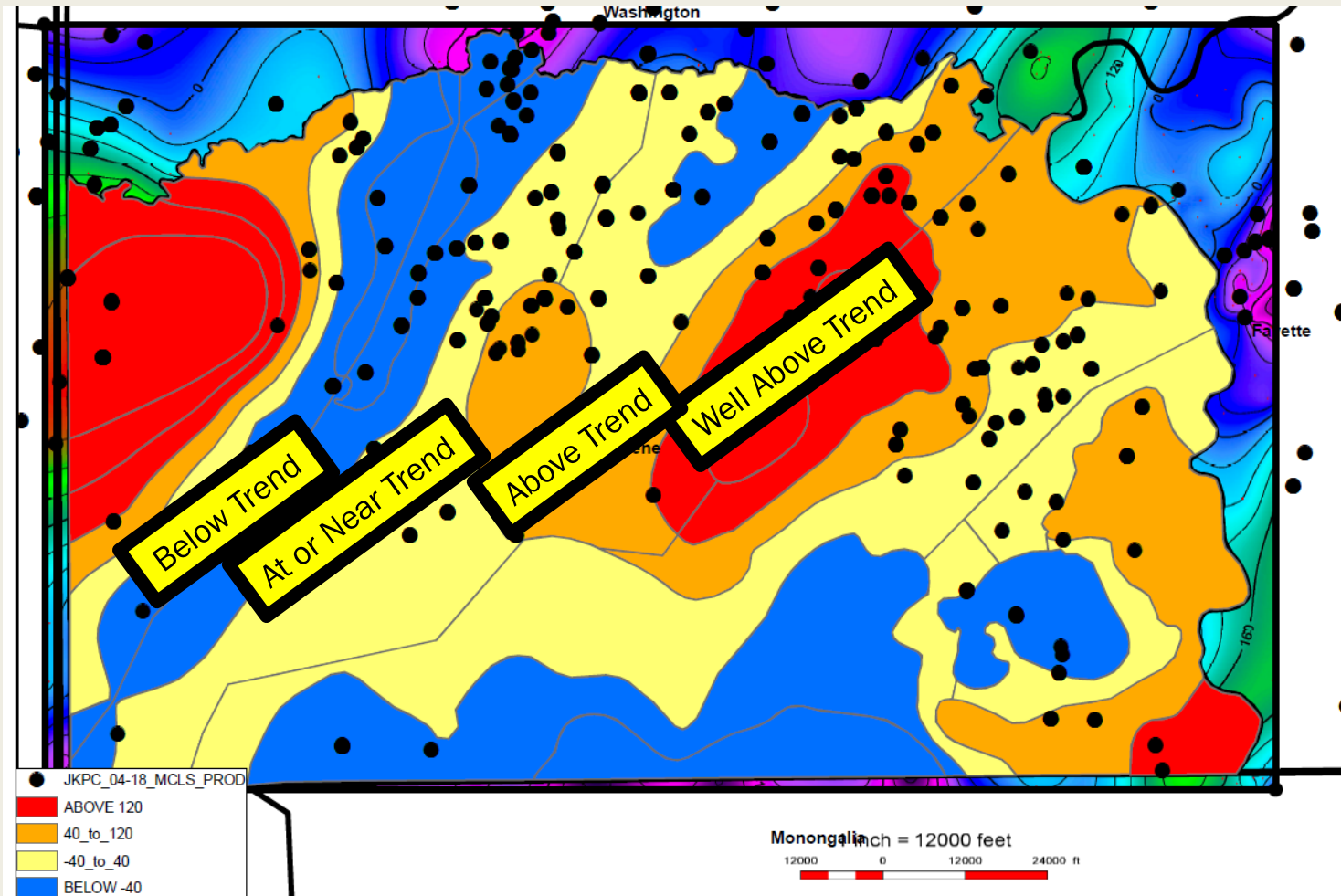
Divided into Four Structural Settings:

(Height above or below trend surface)

1. Below Trend (Below -40 meters)
2. At or Near Trend (-40 to 40 meters)
3. Above Trend (40 to 120 meters)
4. Well Above Trend (Above 120 meters)

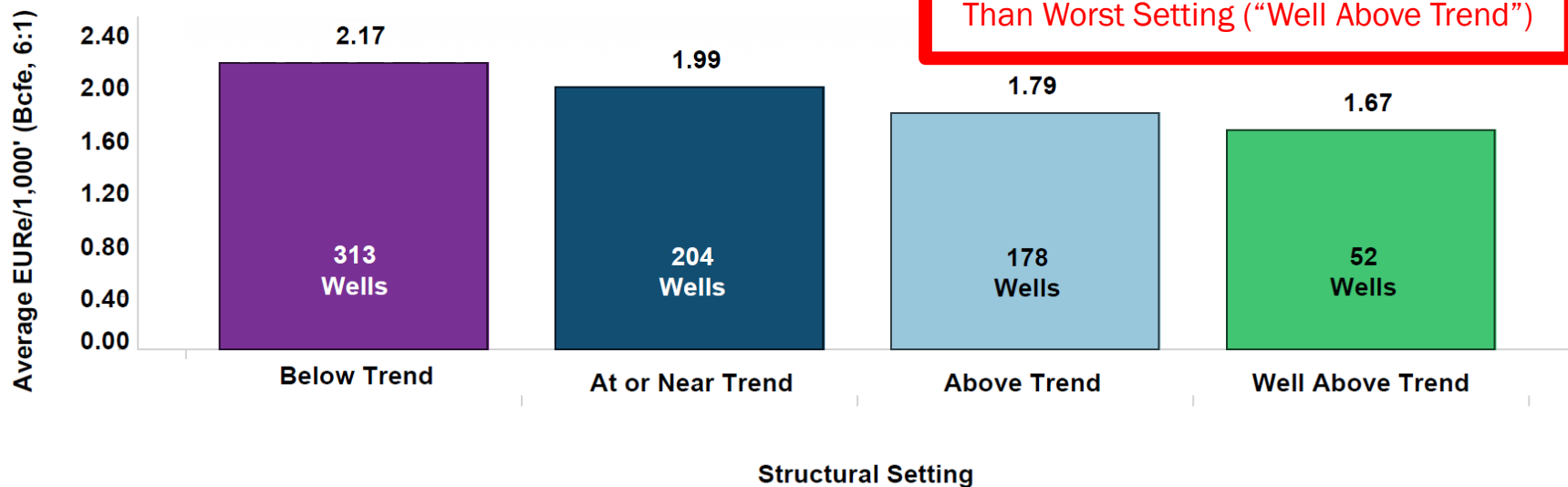
Residual Mapping

Greene County – Base of Big Injun



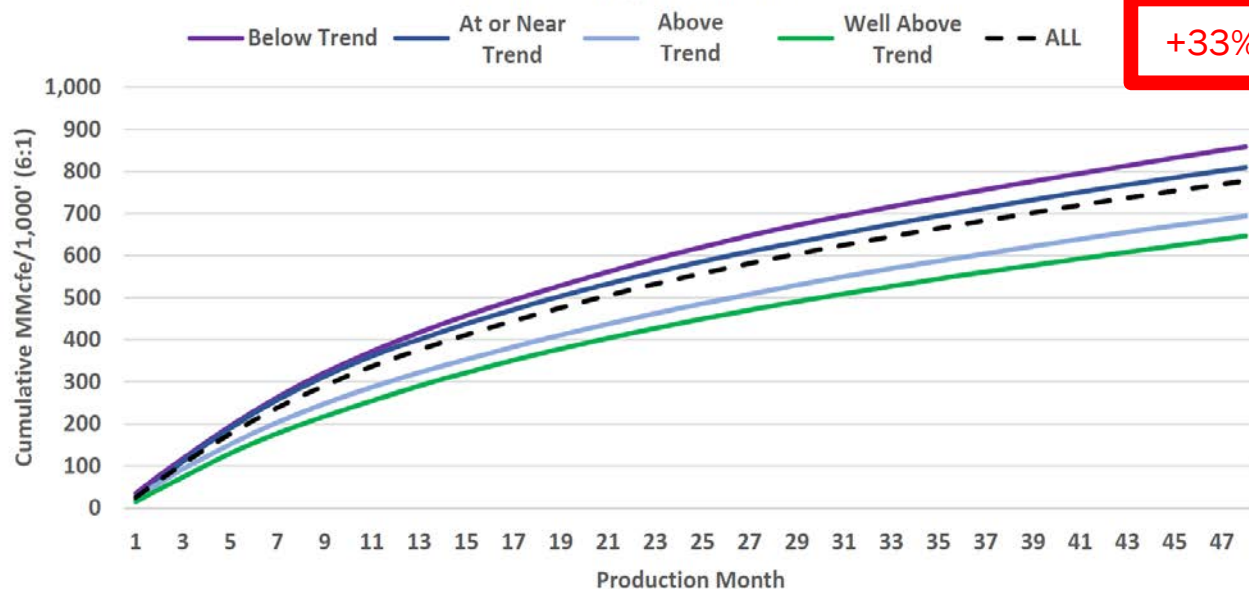
Average EURE/1,000' (Bcfe, 6:1) vs Structural Setting

Marcellus Shale, Greene County, Pennsylvania



Cumulative MMcf/1,000' (6:1) by Structural Setting

Greene County, PA Marcellus



Performance vs. Structural Setting

Greene County Marcellus Shale Observations

- The “Below Trend” setting has the highest average EUR/1,000 ft
- The “Well Above Trend” setting has the lowest average EUR/1,000’ ft
- The average EUR/1,000’ decreases with each progressively shallower structural setting
- The difference between the best and worst settings is 30%

Comparing/Contrasting Observations in Utica-PP and Marcellus Shale

- Both show that performance is worse in highest structural settings
- The difference in average performance between best and worst setting is greater in the Utica-PP (95%) versus the Marcellus (30%)

Possible Explanations for Differences in Utica-PP and Marcellus Shale Observations

- Water depth for Utica-PP ranges from 30 to 300 ft (low oxygen)
- Water depth for Marcellus Shale greater than 350 ft (dominantly anoxic)
- Therefore, decomposition of organics due to wave action, sunlight, oxygen, etc. not likely an issue in Marcellus
- Theory: this implies that differences in organics accumulation and preservation may be a function of the actual topography on which the organics came to rest (flat, sloping, etc.) and that organics slumped to lowest point
- Another issue effecting well performance: geosteering with gamma ray is much easier in Marcellus compared to Utica-PP, so out-of-zone percentage not expected to be as much of an issue in Marcellus

Practical Application of These Observations

- It is often difficult or impossible to account for the differences in performance (per 1,000 ft) between groups of horizontal wells in the same formation
- The differences are often attributed to: hydrocarbons-in-place, reservoir pressure, thermal maturity, target zone selection, geosteering (in-zone percentage), completion design, and other factors
- ALL OF THESE can have an effect on performance
- The work presented here allows one to “normalize” a data set by structural setting in order to make other correlations more meaningful

Practical Application of These Observations (continued)

- For example:

- *If you are going to correlate performance vs. proppant loading (lbs/ft) for a group of wells, you may want to normalize by structural setting first so you are not studying ‘apples and oranges’*
 - Or else, you may ascribe certain performance trends to proppant loading, when they are really a function of structural setting, or a combination of both

Future Work

- Compare Marcellus Shale TOCs in different structural settings to see if trend follows $\text{EURE}/1,000'$ vs structural setting (as in Utica-PP)