

LITHOSTRATIGRAPHY AND PETROPHYSICS OF THE DEVONIAN MARCELLUS INTERVAL IN WEST VIRGINIA AND SOUTHWESTERN PENNSYLVANIA

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Outline

- ❑ Goals
- ❑ Purpose
- ❑ Study Area
- ❑ Lithostratigraphy and Depositional Environments
- ❑ Regional Relationships
- ❑ Petrophysical Problems
- ❑ Derived Curves
- ❑ Gas Identification
- ❑ Water Saturation
- ❑ Lithological Analysis
- ❑ Pay Identification
- ❑ Pay Maps
- ❑ Conclusions

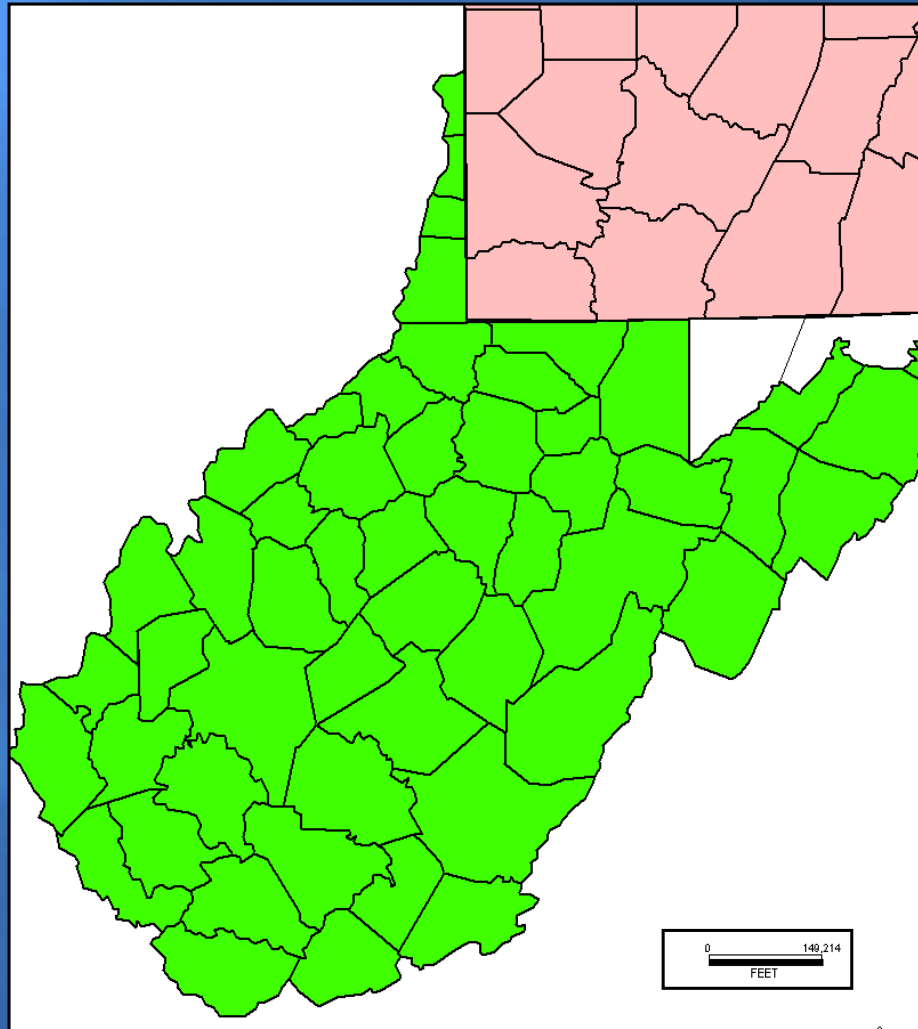
Goals

- ❑ Improve Subsurface Studies of the Middle Devonian
- ❑ Better Define Middle Devonian Stratigraphic relationships
- ❑ Document Middle Devonian Petrophysics
- ❑ Clarify Middle Devonian Economic Potential and its relation to stratigraphy

Purpose

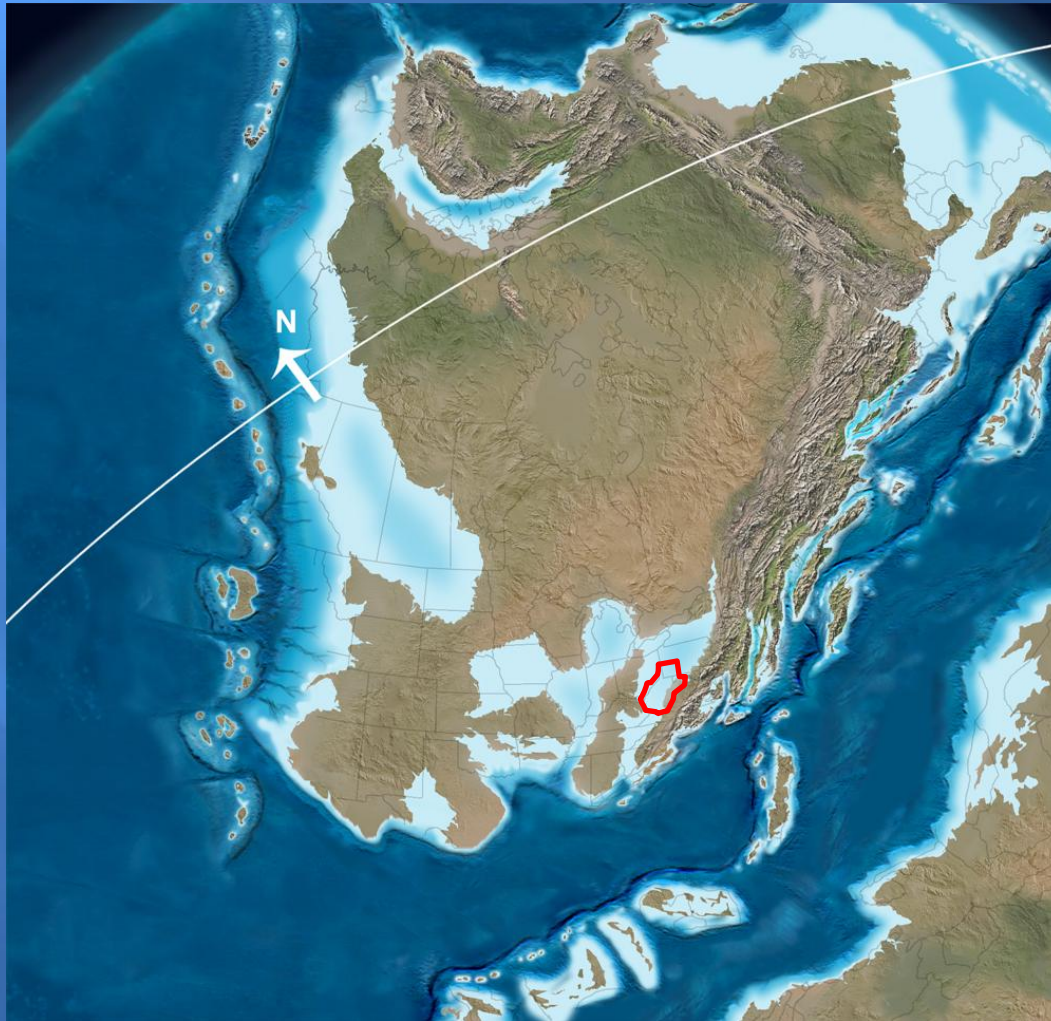
- ❑ Comprehensive stratigraphic analysis of the Middle Devonian
 - Maps
 - Cross-sections
- ❑ Comprehensive petrophysical analysis of the Middle Devonian
 - Log & Core
- ❑ Refine petrophysical parameters that influence economic potential in the Middle Devonian
 - Predictive petrophysical model

Study Area



**23500 mi² (60865 km²)

Regional Geology



Middle Devonian (385 Ma)

(Modified from Blakey, Ron: <http://jan.ucc.nau.edu/~rcb7/namD385.jpg>)

Regional Geology

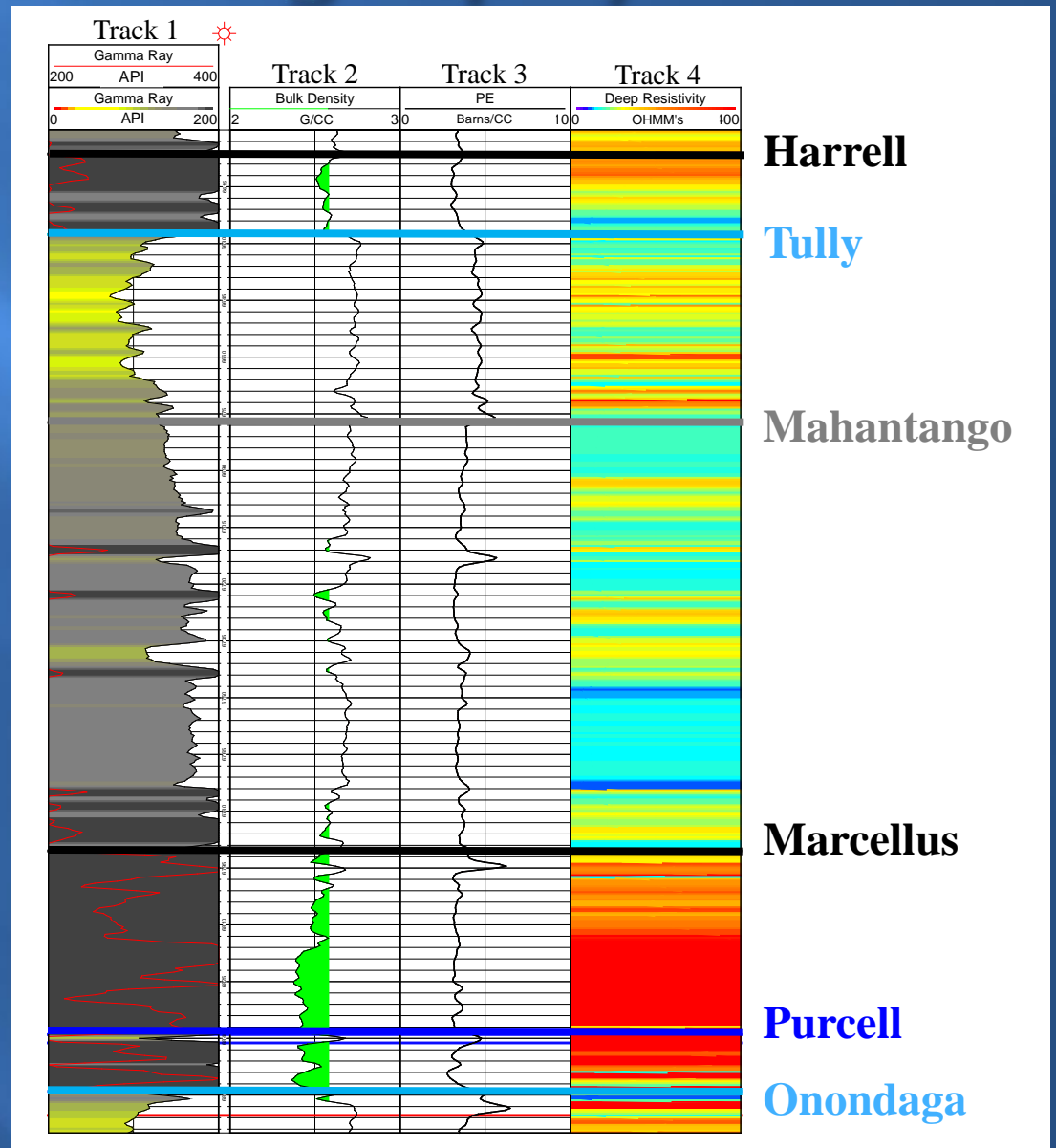


Middle Devonian (385 Ma)

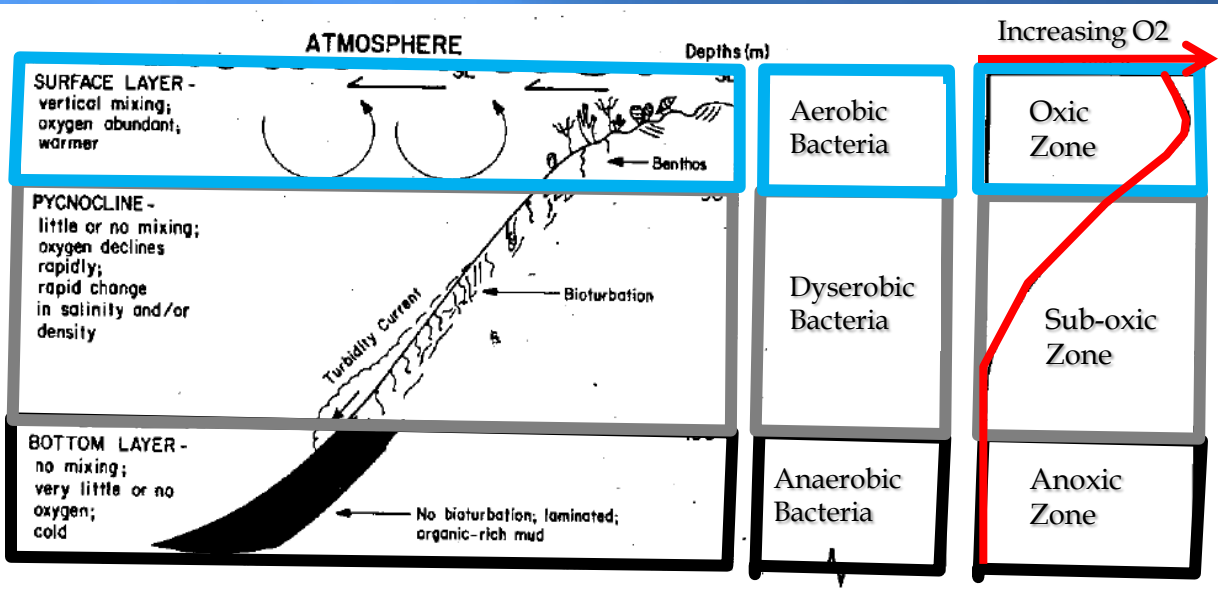
(Modified from Blakey, Ron: <http://jan.ucc.nau.edu/~rcb7/namD385.jpg>)

Lithostratigraphy

Devonian	Upper	Gordon
		Alexander
		Huron
		Rhinstreet Shale
	Middle	Harrell Shale
		Tully Limestone
		Mahantango Shale
		Marcellus Shale
		Onondaga Limestone
		Huntersville Chert
		Needmore Shale
		Oriskany Sandstone



Depositional Environments



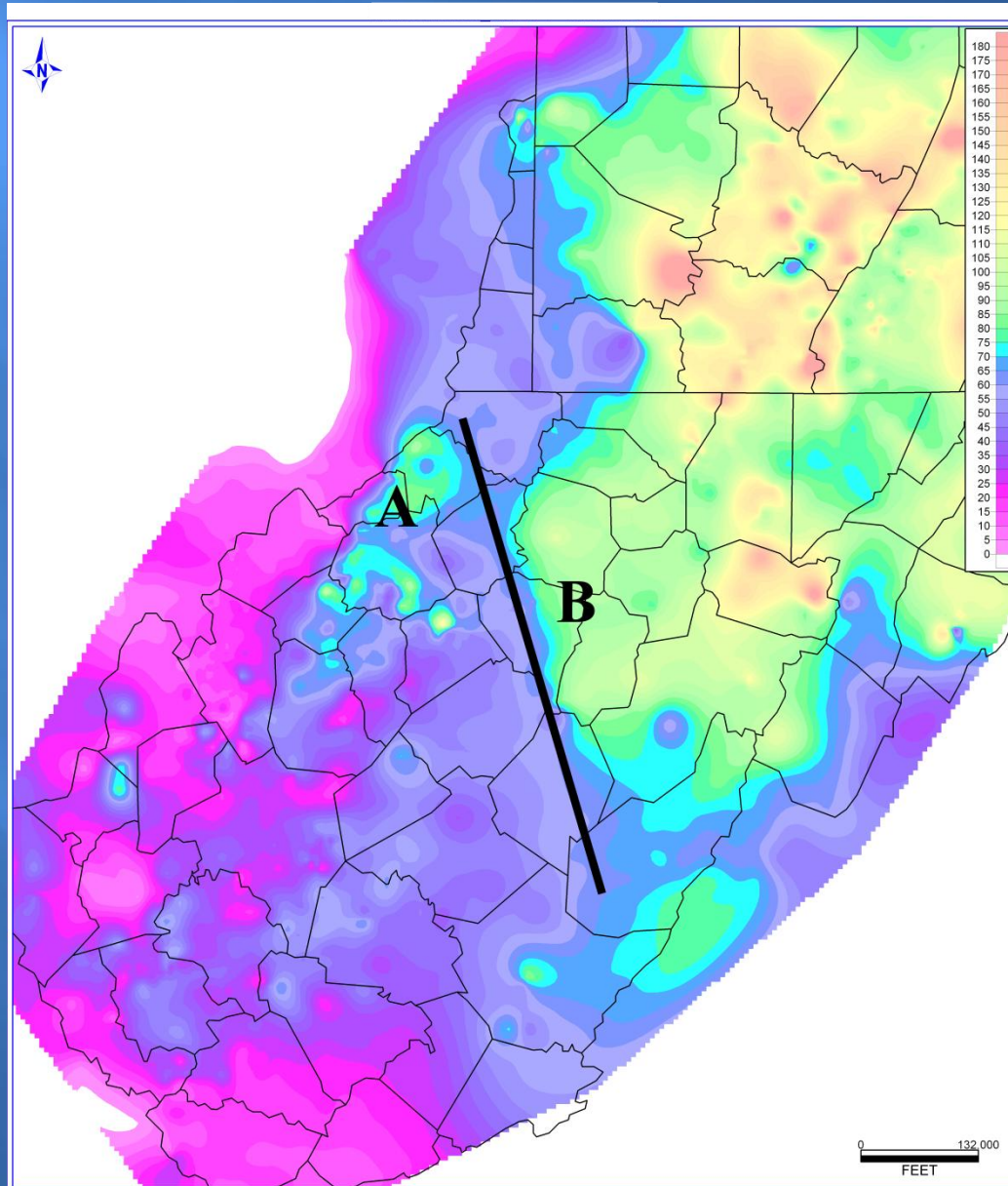
Altered from Ettensohn and Barron 1981

Overall oxidation process by aerobic bacteria.

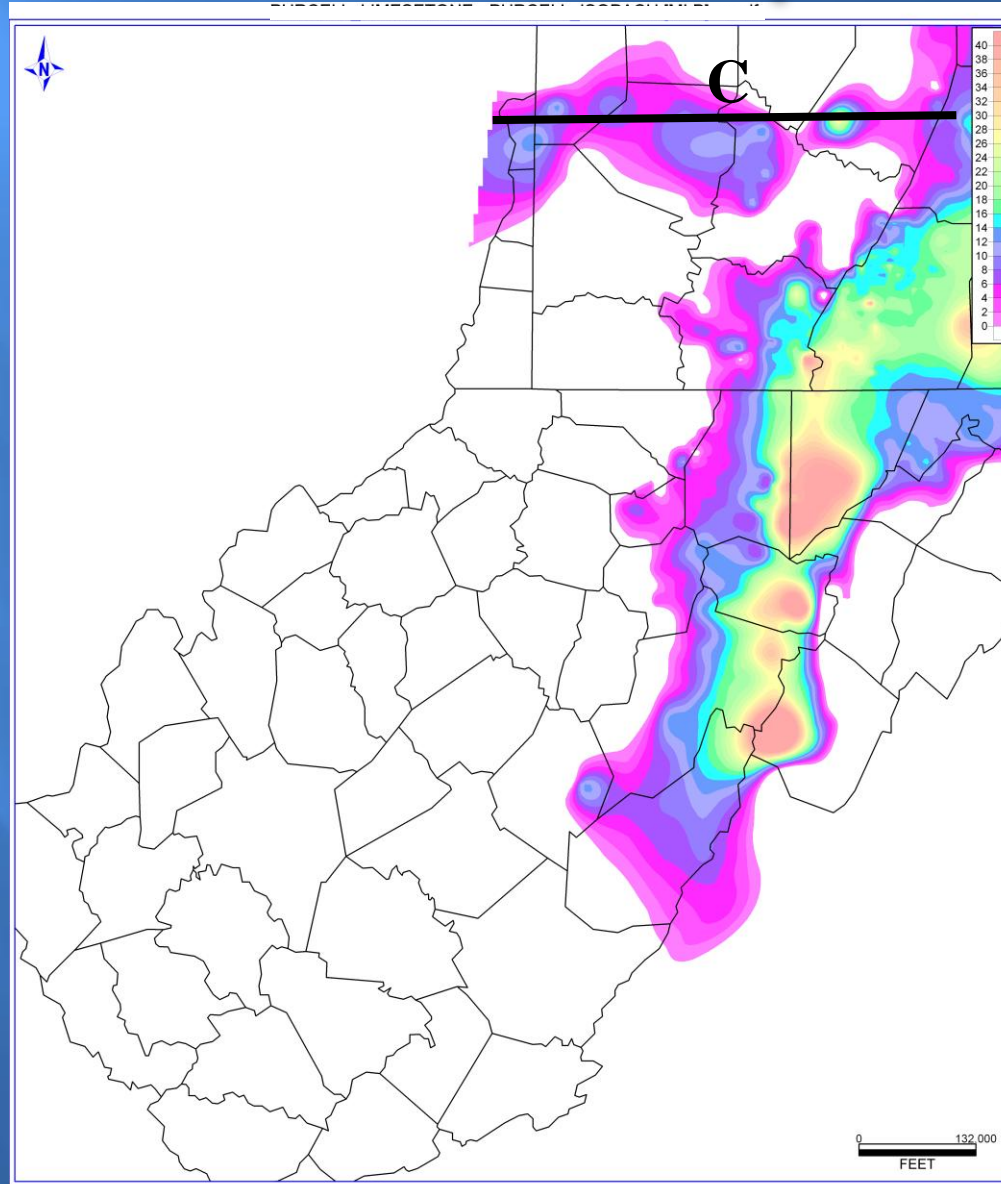
Exhaustion of Oxygen anaerobic bacteria use Nitrates as a source of Oxygen.

Once Nitrates are exhausted anaerobic bacteria use sulfates as the oxidant.

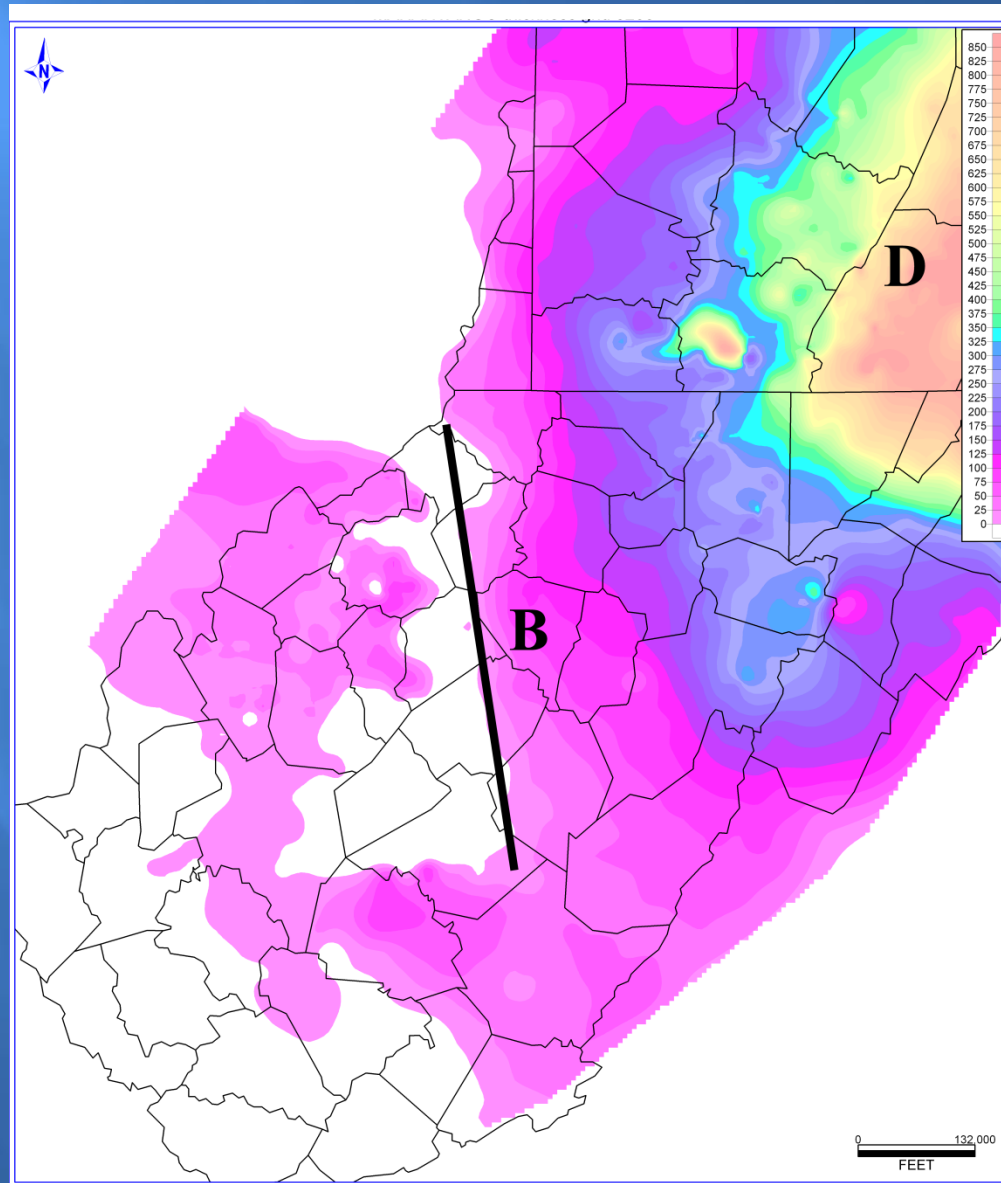
Regional Relationships: Marcellus Isopach



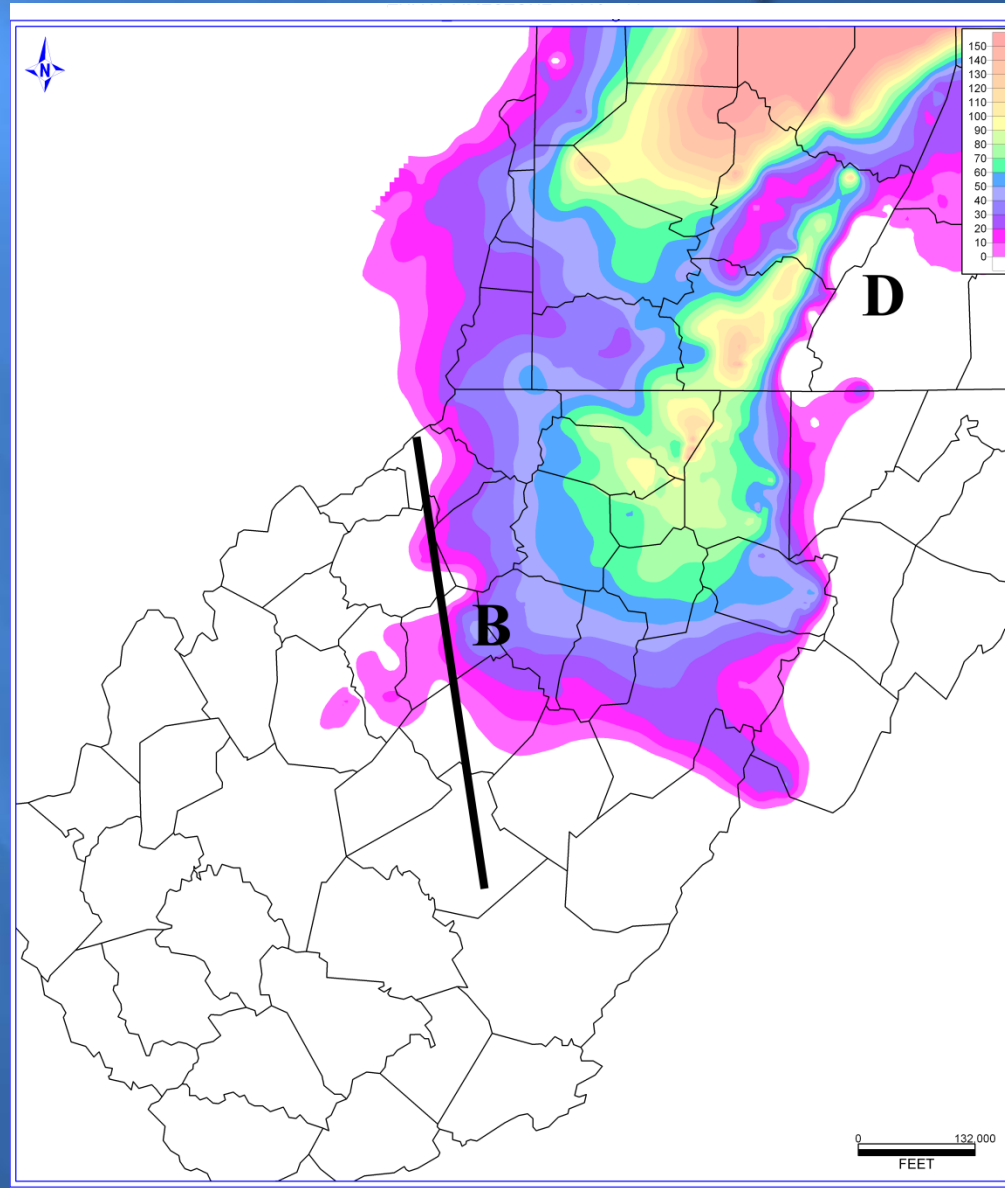
Regional Relationships: Purcell Limestone Isopach



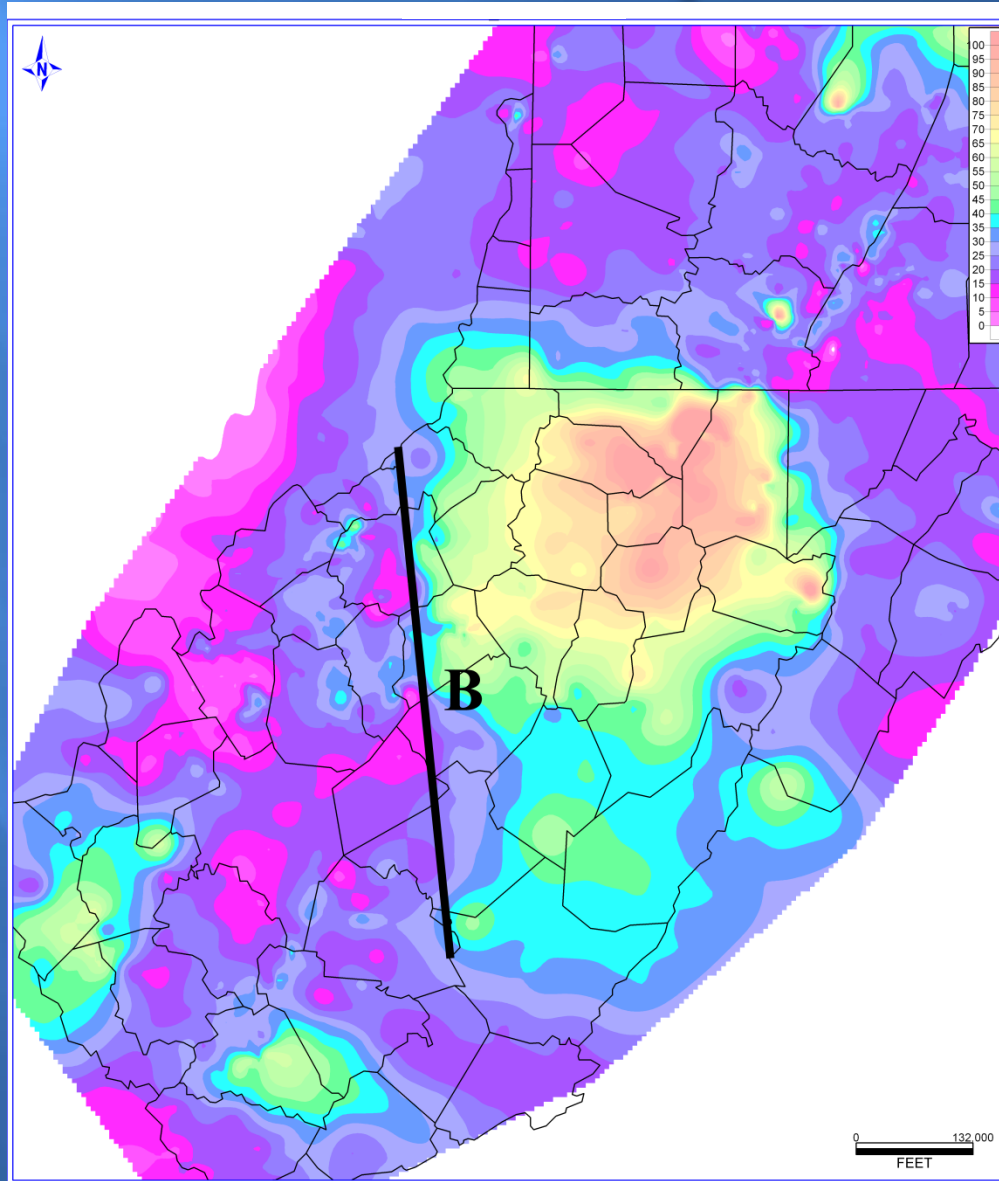
Regional Relationships: Mahantango Isopach



Regional Relationships: Tully Limestone Isopach

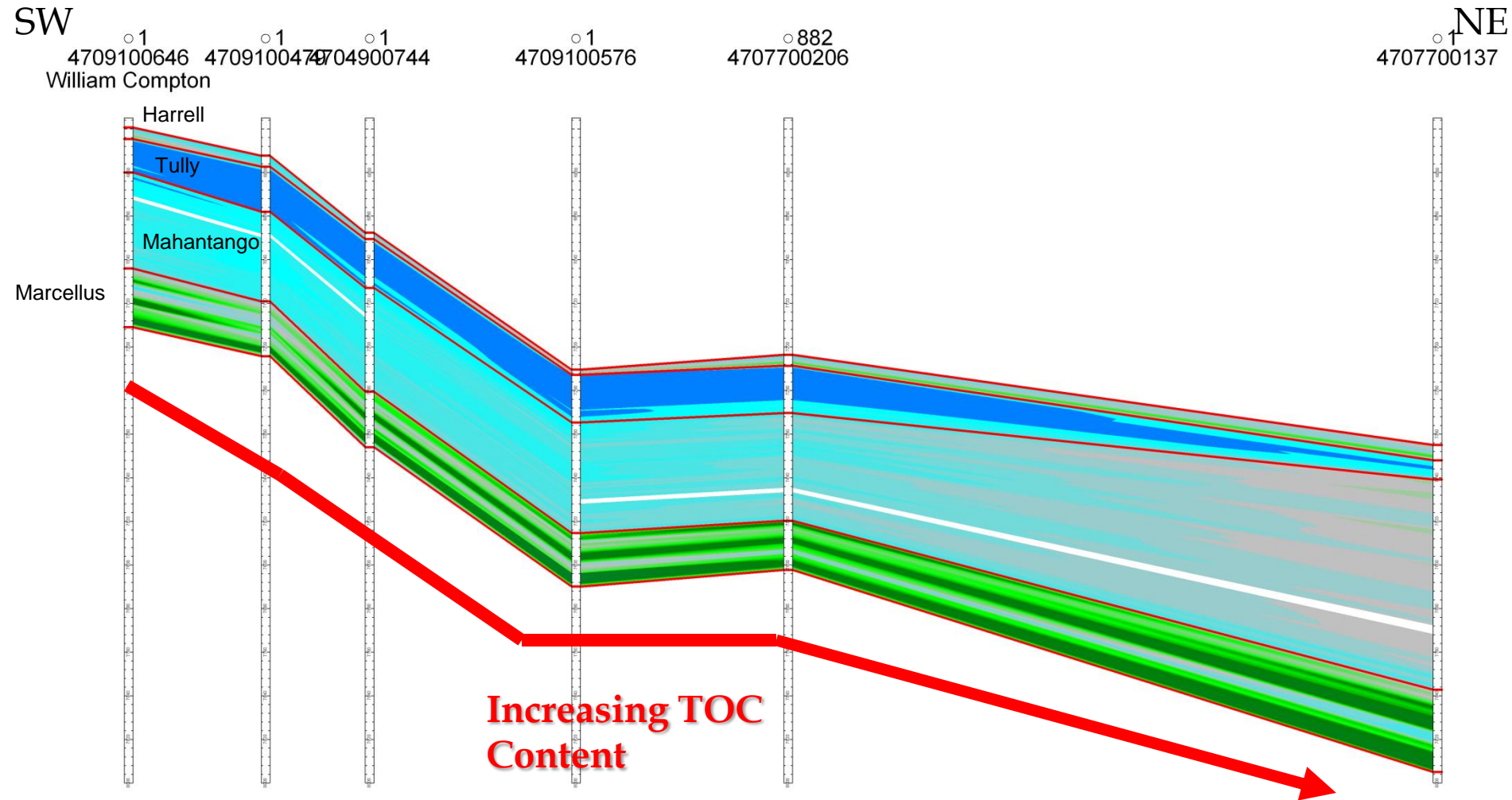


Regional Relationships: Harrell Isopach



Regional Relationships

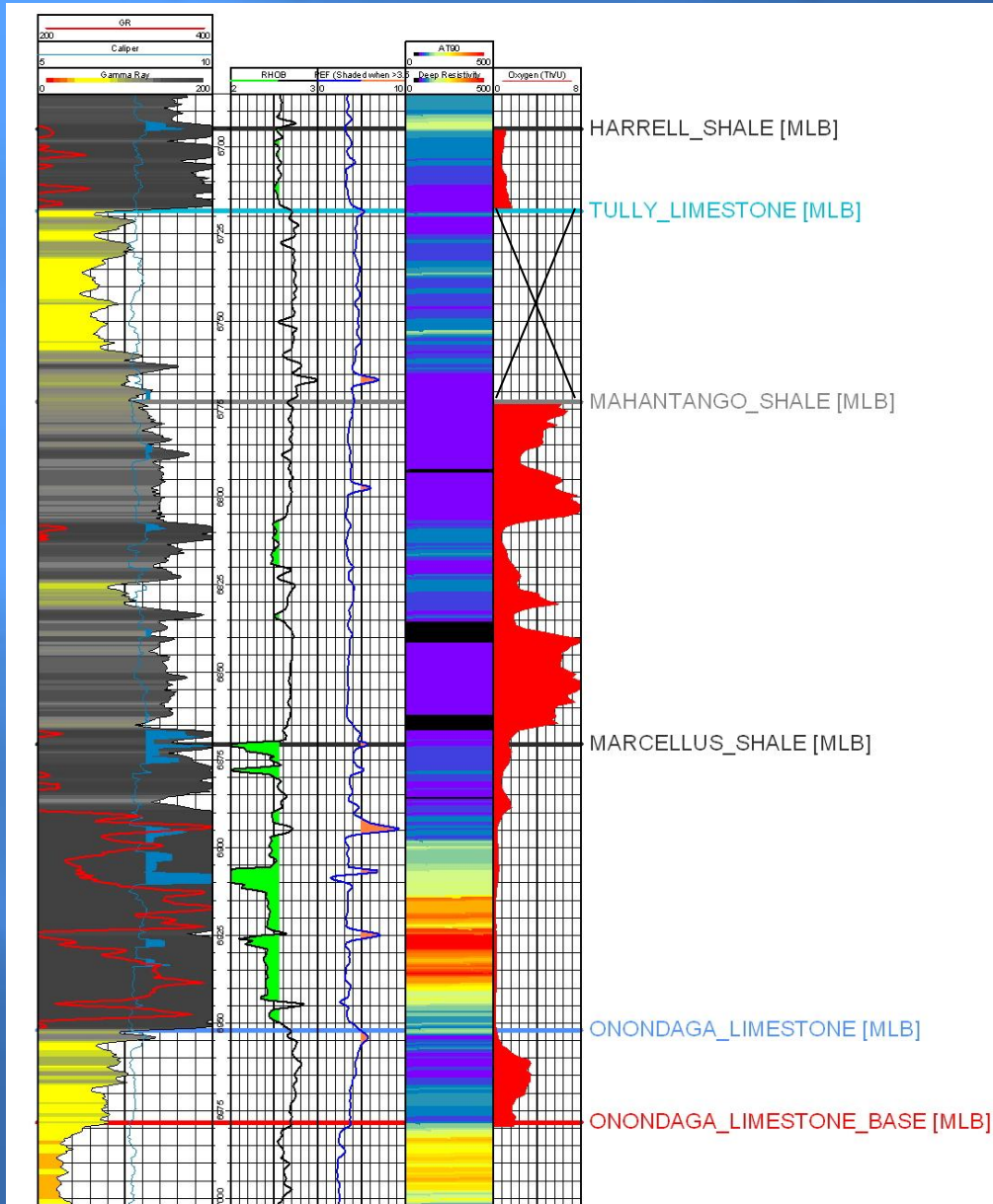
Structural X-Section Near Chestnut Ridge Anticline (NW West Virginia)



Petrophysical Problems

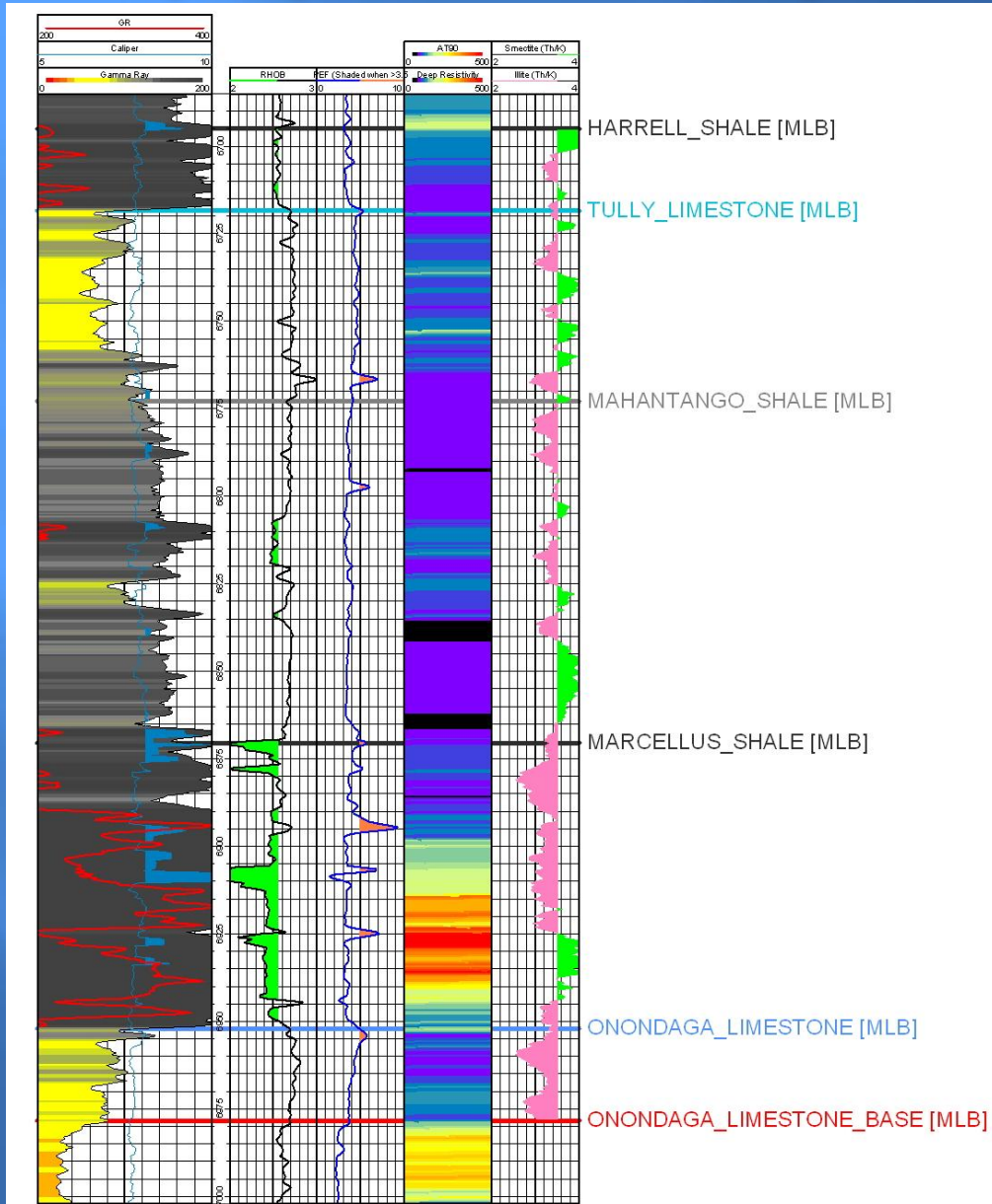
- ❑ Sw affected by bound water on clays
- ❑ Lithologic analysis affected by pyrite
- ❑ Tool readings and pay identification effected by washout

Petrophysical Analysis: Derived Curves



- Reducing Vs. Oxidizing conditions determined by Th/U
- Works in Shales

Petrophysical Analysis: Derived Curves

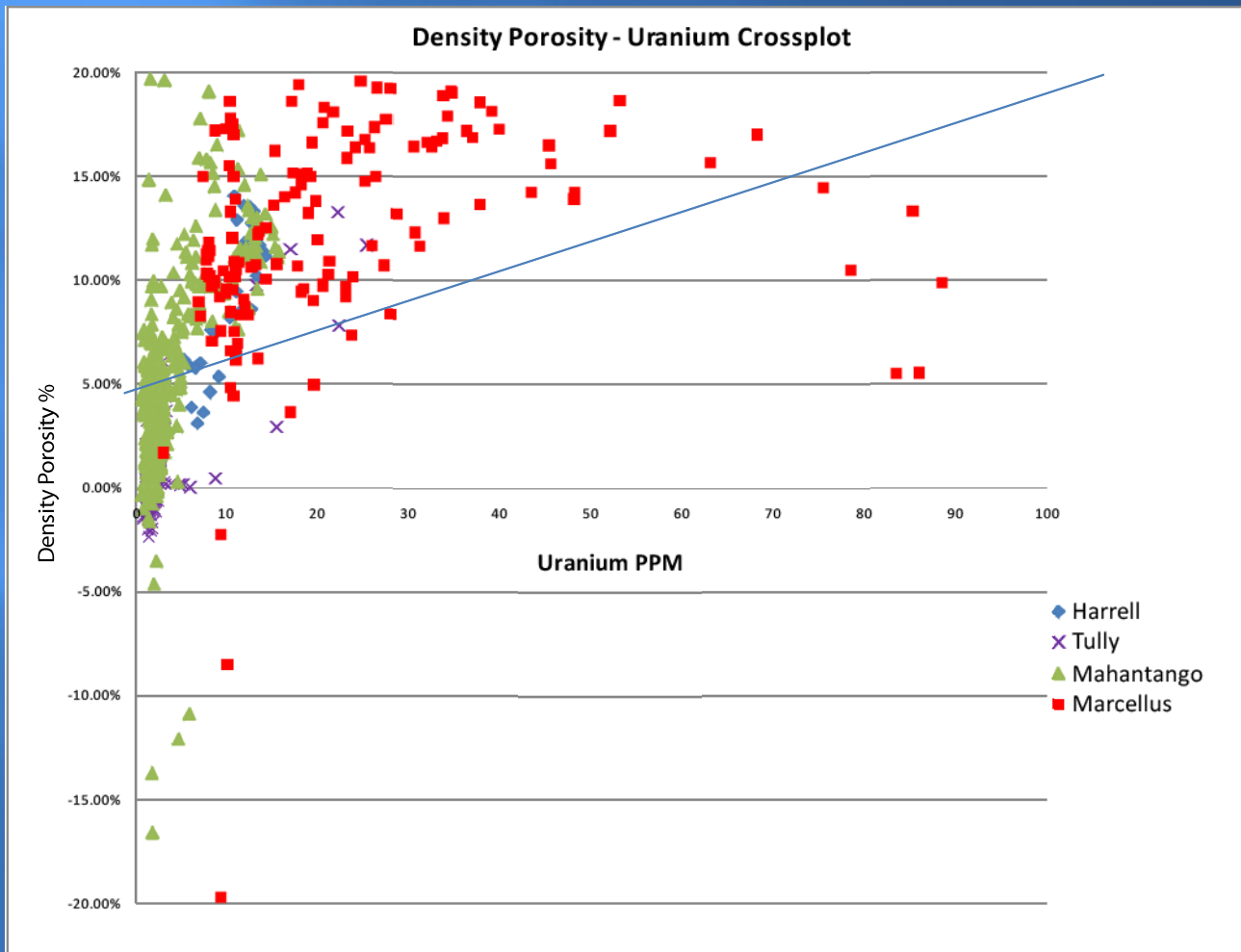


- Clay type can be determined from Th/K

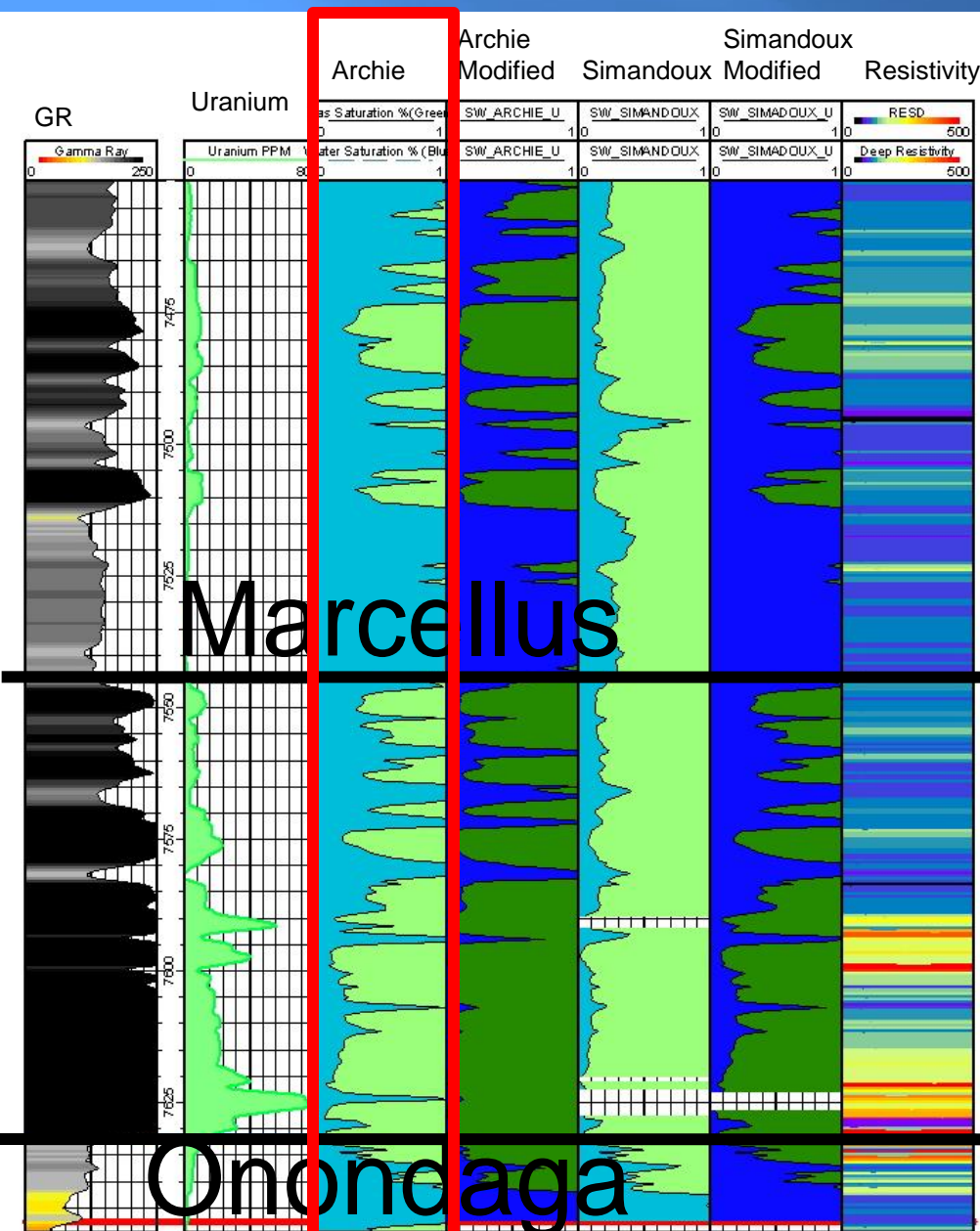
- Illite-Pink
- Smectite-Green

- Illite can increase porosity by 4%

Petrophysical Analysis: Gas Identification



Water Saturations

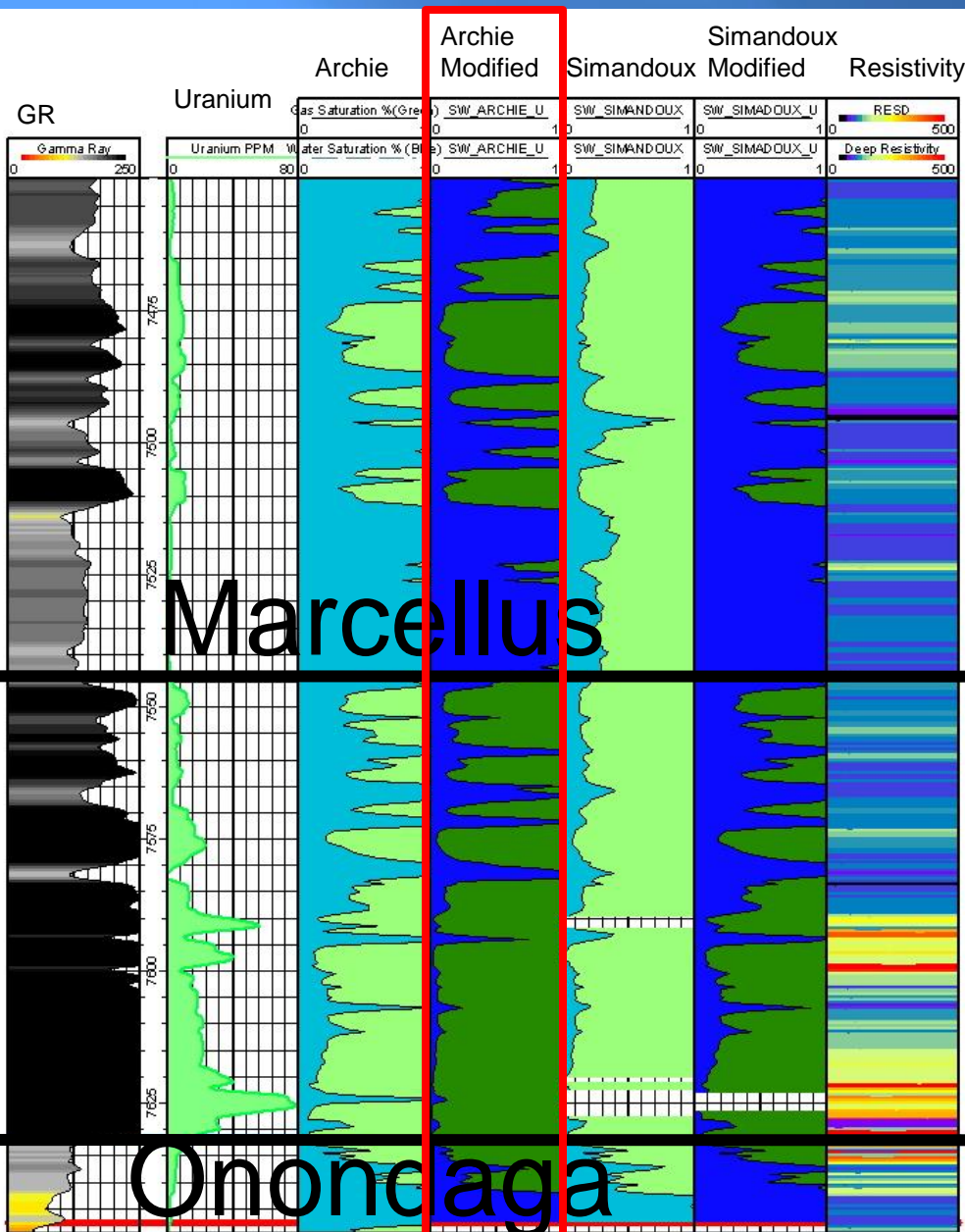


Archie

$$S_w = \left(\frac{R_w * a}{\Phi^m * R_t} \right)^{\frac{1}{n}}$$

- Over estimates water saturation
- Under estimates gas saturation
- Originally derived for sandstones

Water Saturations

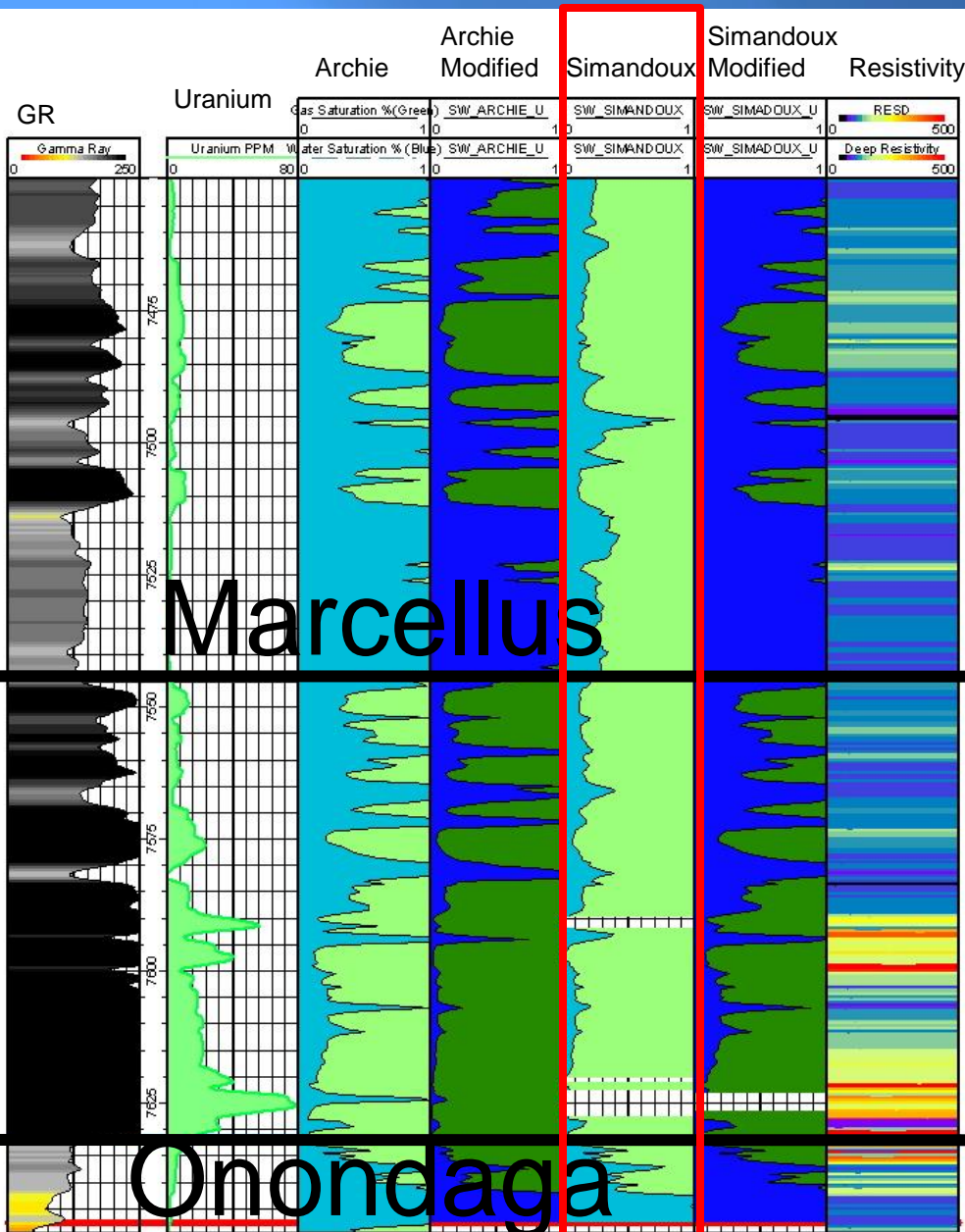


Archie Modified

$$S_{wu} = \left(\frac{R_w * a}{\Phi^m * U * R_t} \right)^{\frac{1}{n}}$$

- Incorporates Uranium
- Pay outside of Marcellus proper

Water Saturations



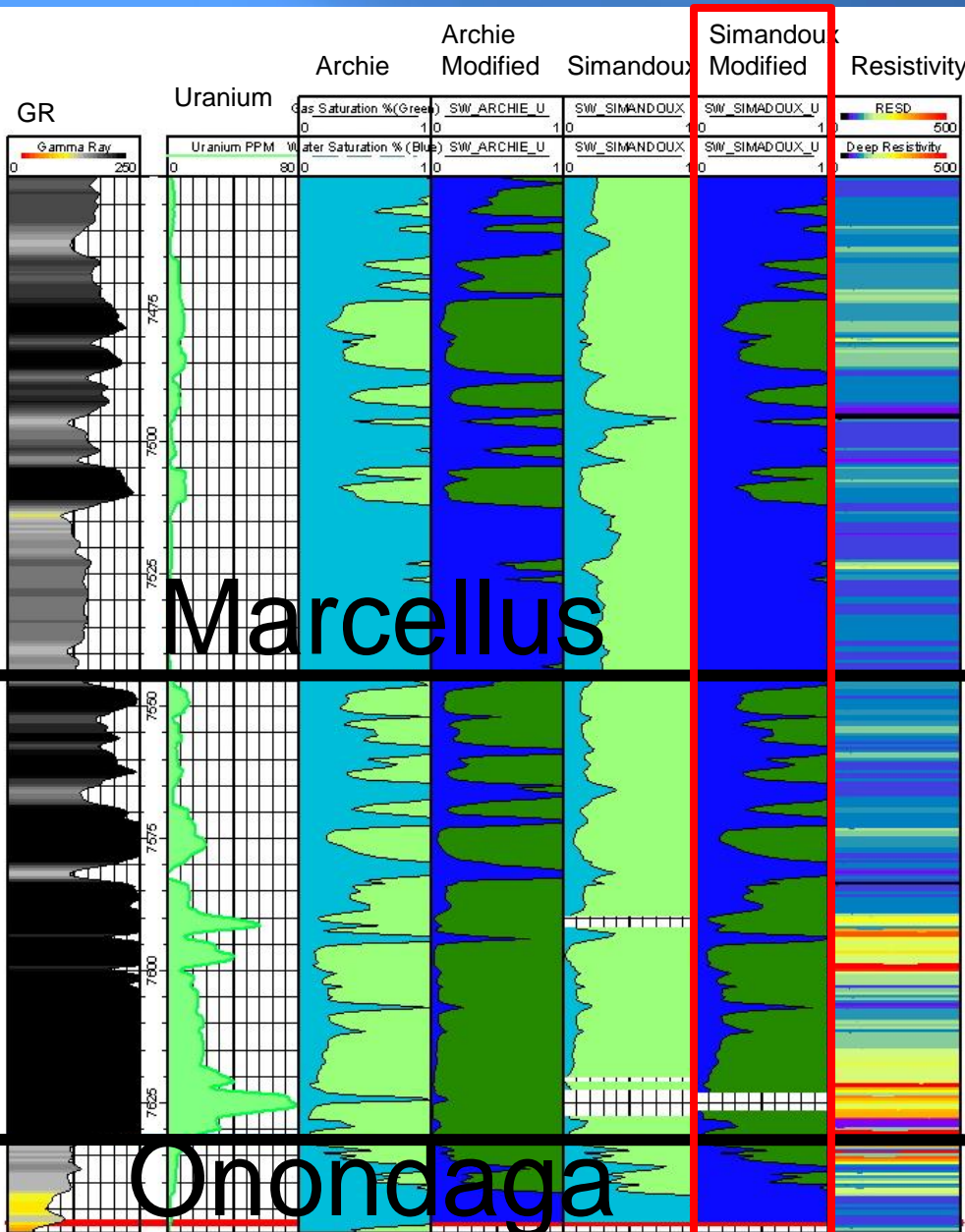
Simandoux

$$S_w = \frac{\sqrt{\left(\frac{V_{sh}}{R_{sh}}\right)^2 + 4 * \left(\frac{\Phi^m}{a * R_w(1 - V_{sh})}\right) * \frac{1}{R_t} - \frac{V_{sh}}{R_{sh}}}}{2 * \frac{\Phi^m}{a * R_w(1 - V_{sh})}}$$

$$V_{sh} = \frac{Gr - Sand}{Shale - Sand}$$

- Over estimates gas saturation
- Derived for shaly sands

Water Saturations



Simandoux Modified

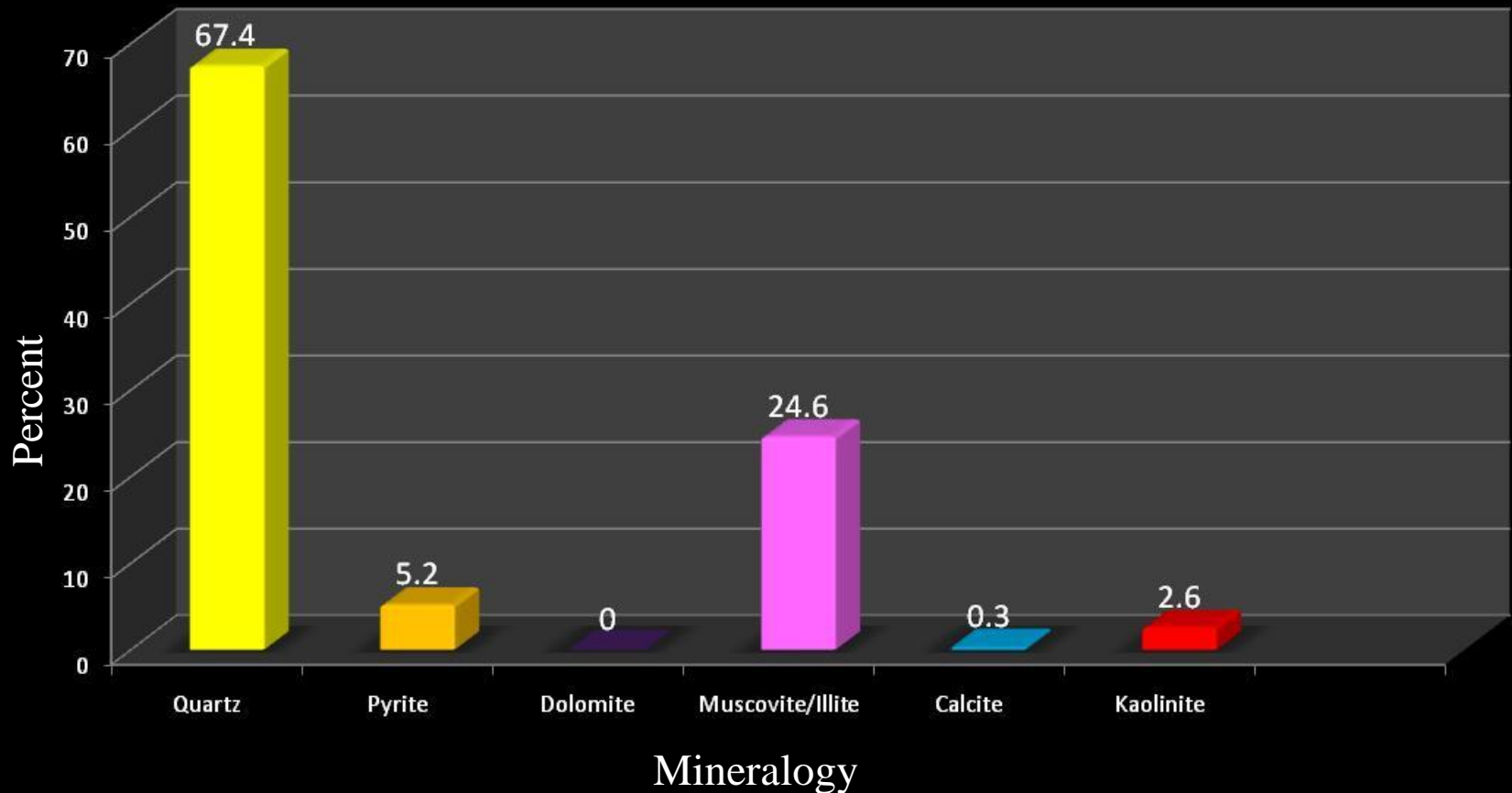
$$S_{wu} = \frac{\sqrt{\left(\frac{V_{uran}}{R_{sh}}\right)^2 + 4 * \left(\frac{\Phi^m}{a * R_w (1 - V_{uran})}\right) * \frac{1}{R_t} - \frac{V_{uran}}{R_{sh}}}}{2 * \frac{\Phi^m}{a * R_w (1 - V_{uran})}}$$

$$V_{uran} = \frac{U - \text{Shale}}{\text{Shale} - \text{Sand}}$$

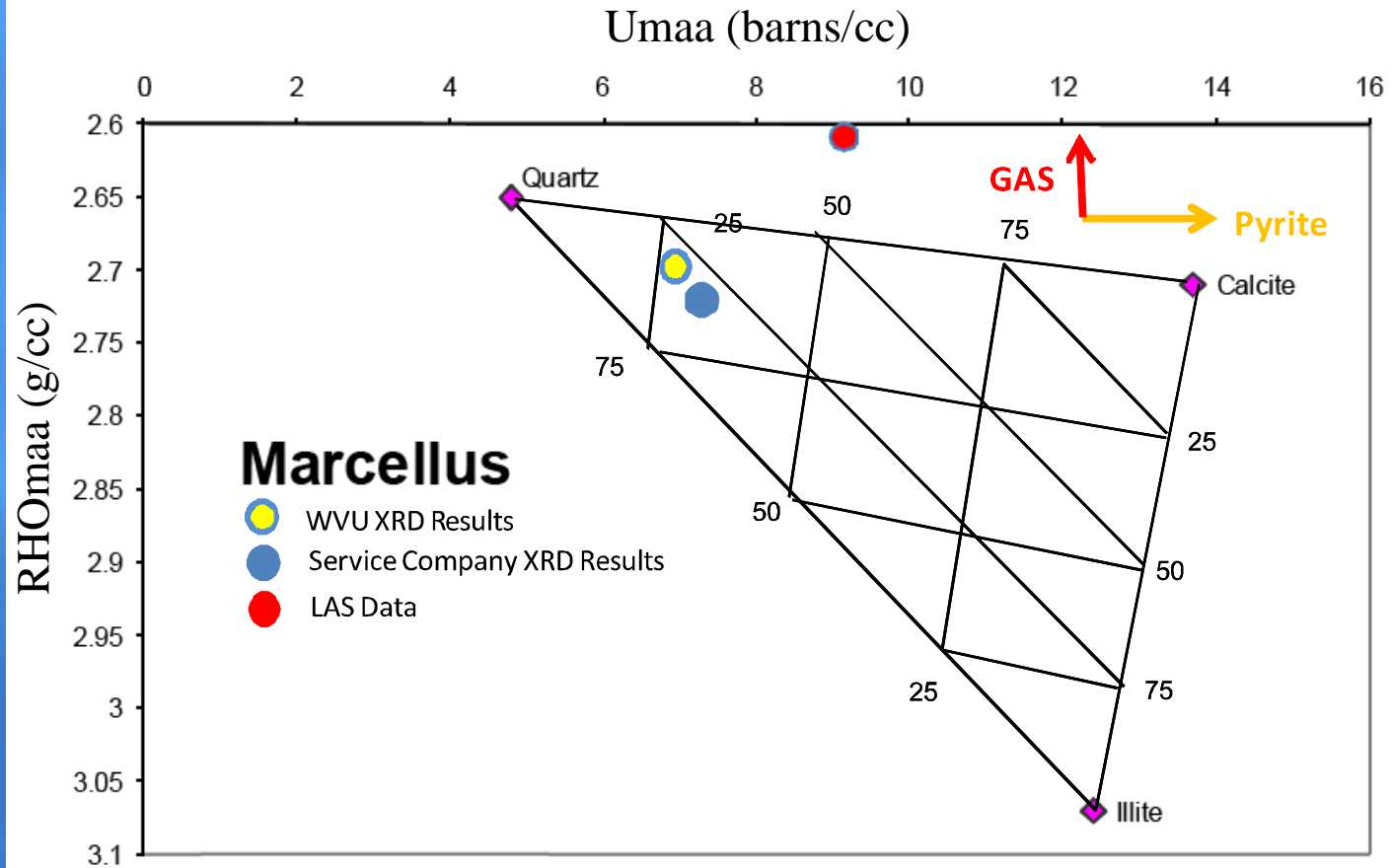
- Incorporates Uranium in V_{uran}
- Shows pay outside of Marcellus proper

Lithological Analysis

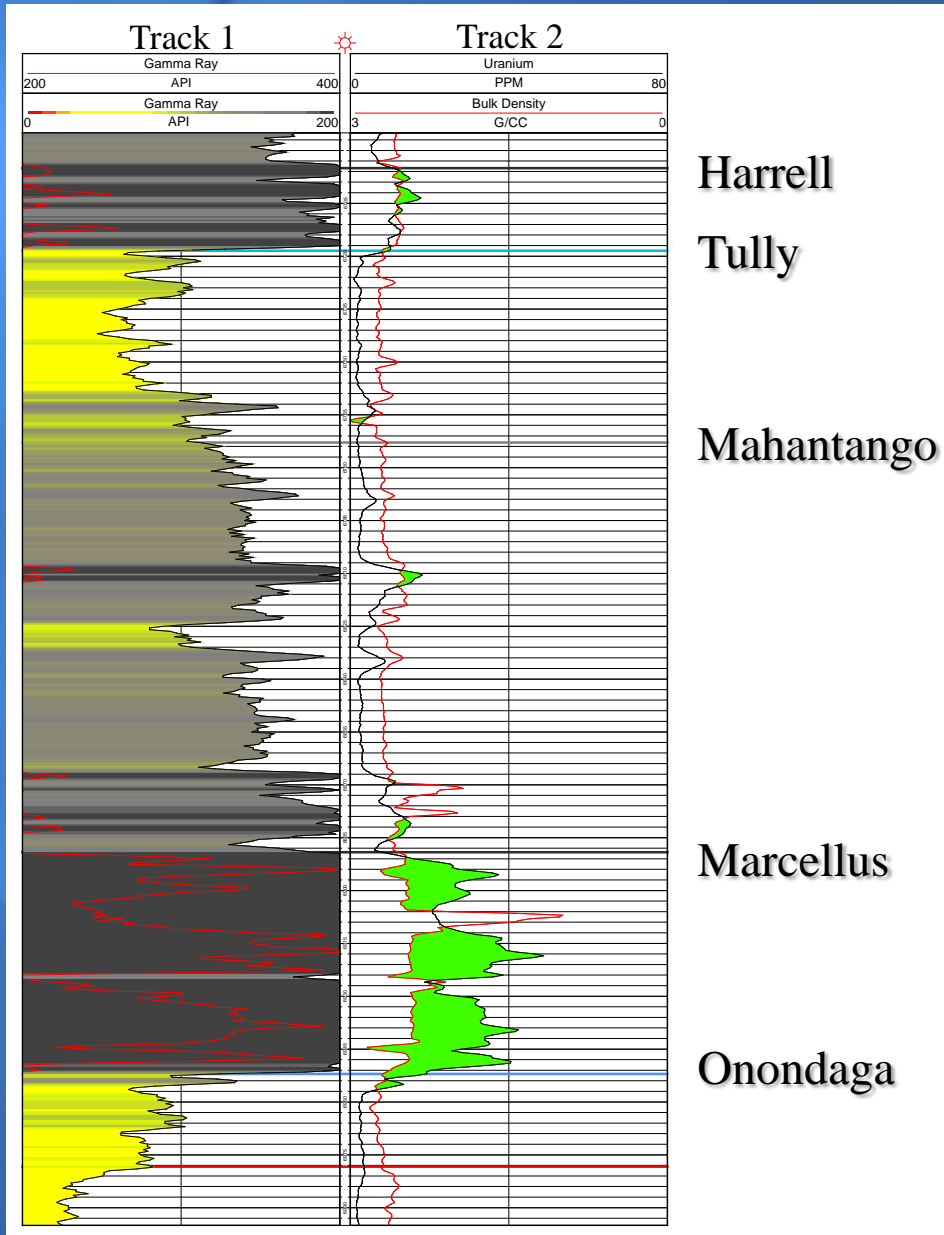
XRD Marcellus Lithology



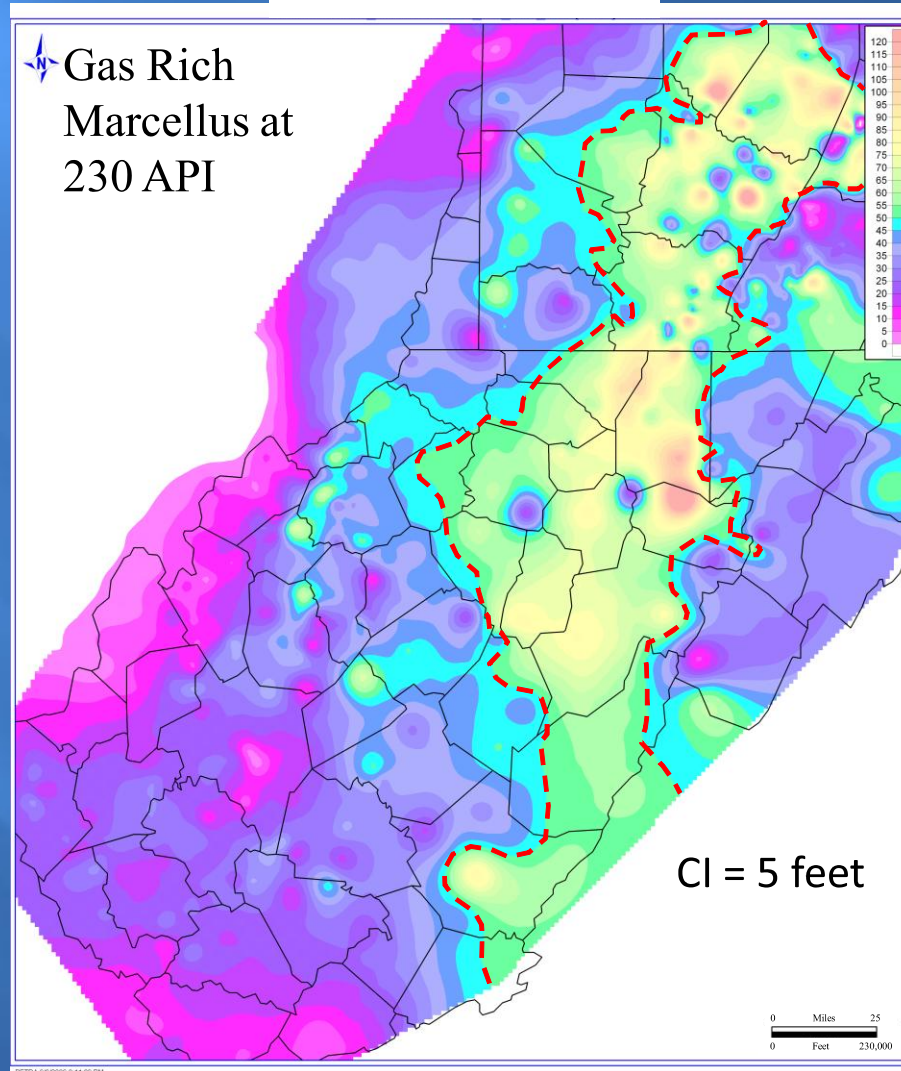
Lithological Analysis



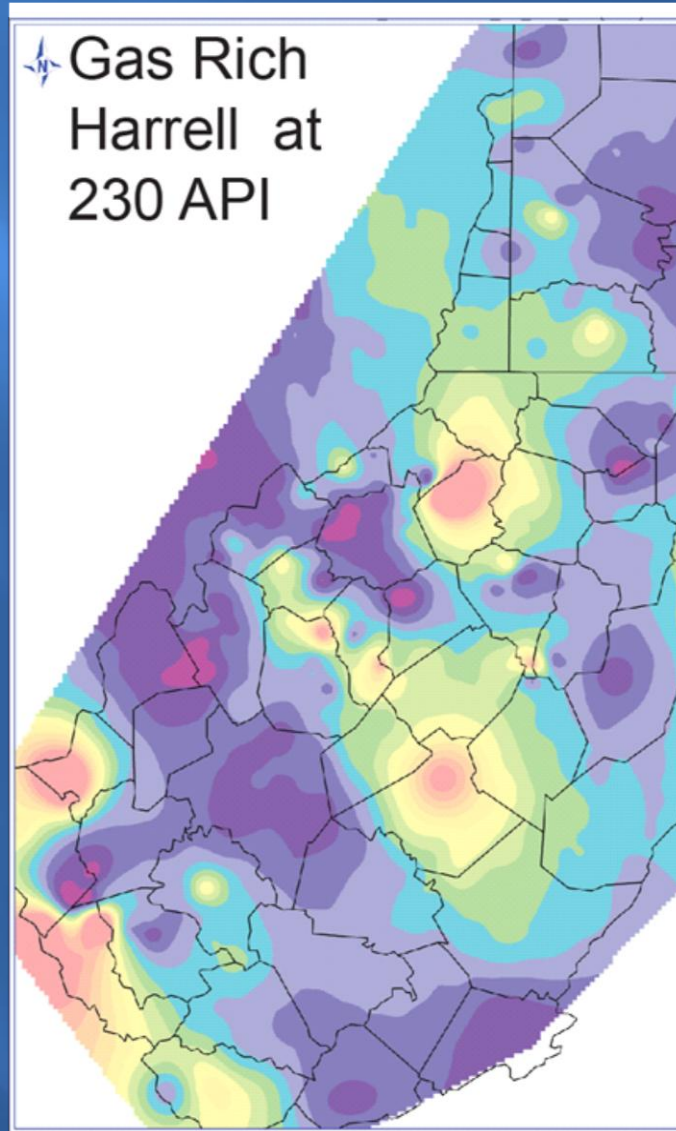
Pay Identification



Pay Maps: Net Pay of Marcellus above 230 api



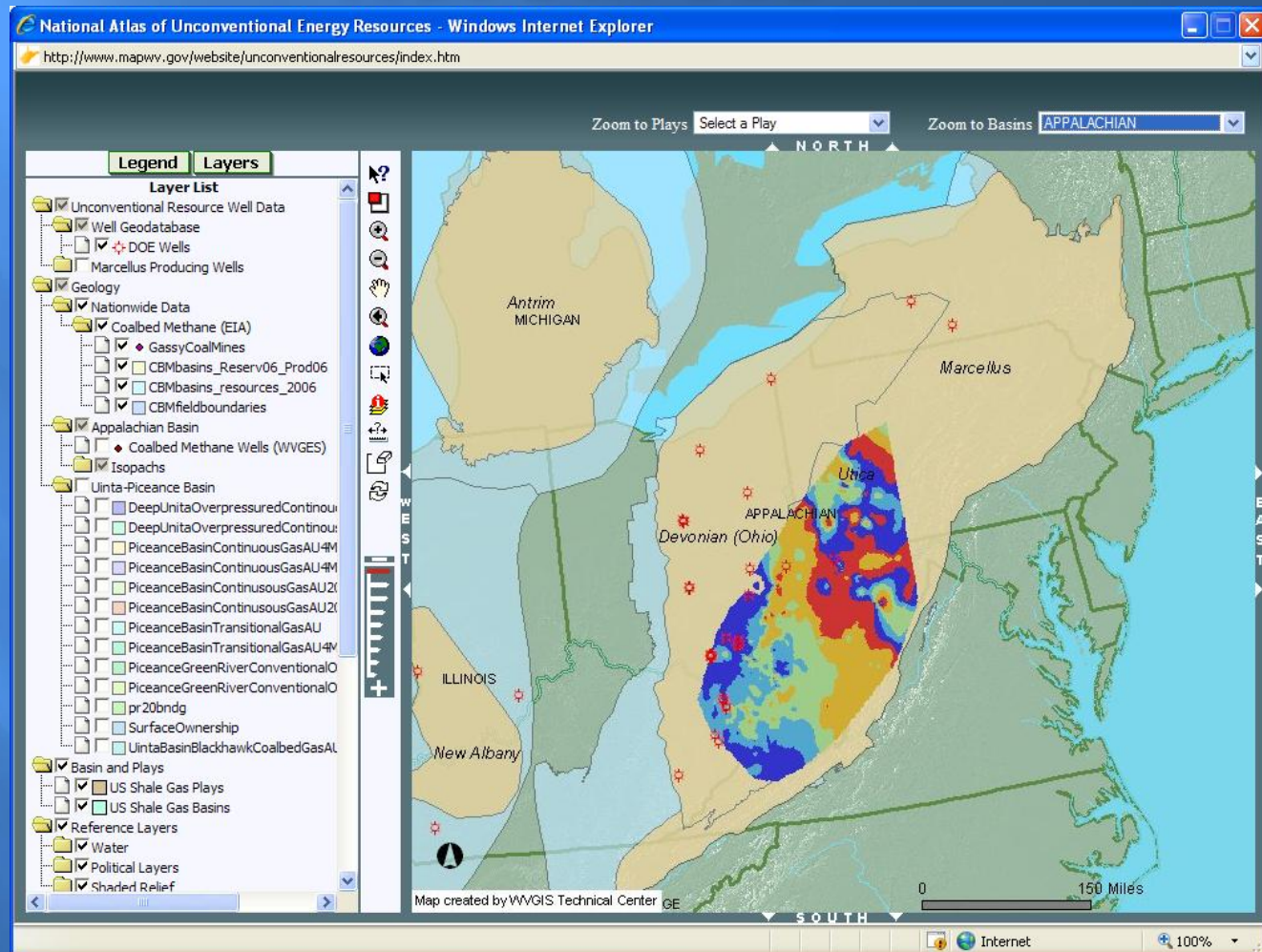
Pay Maps: Net Pay of Harrell above 230 api



Conclusions and Future Work

- ❑ Definition of stratigraphic units
 - Marcellus < 2.55 g/cc density, high resistivity, and GR > 200 API.
- ❑ Depositional relationships
 - Trend A, B, and C
- ❑ Pyrite and gas affect
 - Rhoma Umma
 - Density-Uranium
- ❑ The Marcellus is not a true “shale”
- ❑ Spectral Gamma Ray tool is extremely useful
- ❑ New method of recognition of pay
- ❑ Pay appears to exist outside of Marcellus proper.
- ❑ Modified Archie equations
- ❑ Initial results on pay maps
- ❑ Continue to calibrate derived curves

Atlas of Unconventional Energy Resources



<http://www.mapwv.gov/unconventionalresources/>

Acknowledgments



QUESTIONS?