Integrated Characterization of Utica and Marcellus Black Shale Gas Plays, New York State*

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Abstract

The Ordovician Utica and Devonian Marcellus Shales have the potential to produce economic quantities of gas across much of south central New York State. The Marcellus Shale unconformably overlies the Onondaga Limestone and is composed of a basal black shale member called the Union Springs, a widespread limestone unit called the Cherry Valley Limestone and an upper black shale called the Oatka Creek. The Union Springs Shale, Cherry Valley Limestone and basal Oatka Creek Shales onlap and pinch out on a tectonic high to the west. Organic-rich shale thickness increases from 20 feet in the west to 250 feet in the eastern part of the basin. Burial depths range from zero at the outcrop belt to as much as 7,000 feet in the southeastern part of the basin. Thermal maturity ranges from submature in the west, through the oil and gas windows to supermature values in the east. TOC values generally increase from east to west but mostly range from 4-13%.

The Ordovician Utica Shale was deposited in an area of extensive active normal faulting and the most of the organic-rich units are preserved in tectonic lows. The Flat Creek Member of the Utica is an organic-rich calcareous shale that immediately overlies a subaerial unconformity and is time-equivalent to the Trenton Limestone. The upper Flat Creek grades laterally into an interbedded limestone and organic-rich black shale called the Dolgeville Formation that then grades laterally into an organic-rich member of the shallow marine Trenton Limestone. The Trenton and Dolgeville are eroded and capped by an angular unconformity that is overlain by the organic-rich Lower Indian Castle Member of the Utica, which thickens and is best developed in fault-bounded lows. Total thickness of the organic-rich strata ranges from zero in the west to as much as 700 feet in the east with TOC values of 1.5-3.5%. The shales are supermature throughout the fairway. Current burial depths range from zero at the outcrop belt to as much as 9,000 feet.

There are common faults and natural fractures that extend from the basement to the surface that offset both the Utica and Marcellus but the Utica is probably more heavily fractured. The natural faults and fractures may be beneficial or problematic but should be characterized.

References

Algeo, T.J. and B.H. Wilkinson, 1989, Lower-Middle Pennsylvanian Gobbler Formation; isotopic constraints on temperature, water-rock ratio, and timing of burial diagenesis: AAPG Bulletin, v. 73/9, p. 1146.

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Utica and Marcellus Potential in New York State

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Reservoir Characterization Group at the New York State Museum

NEW YORK STATE GEOLOGICAL SURVEY Est. 1836 NEW YORK STATE MUSEUM

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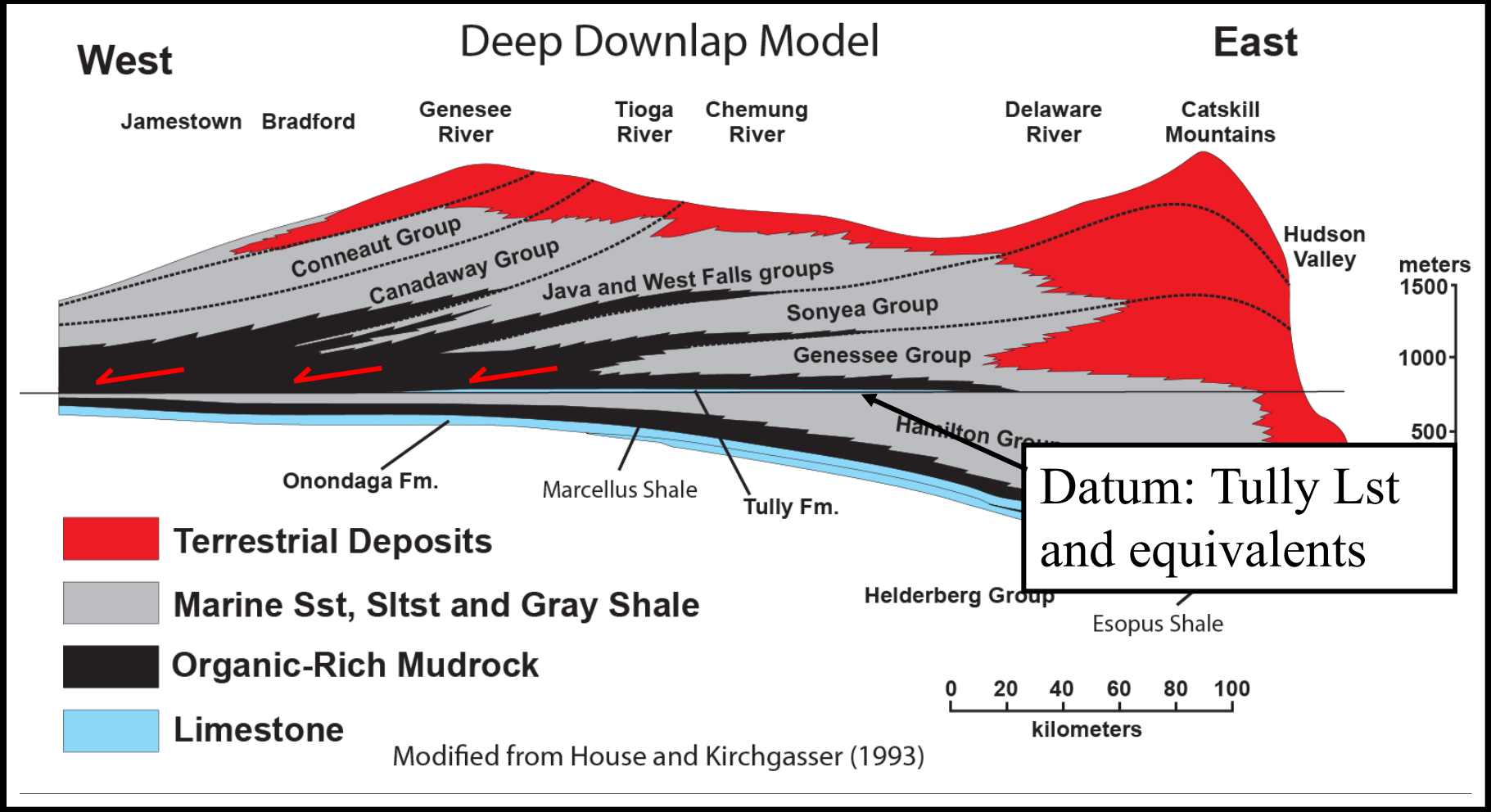
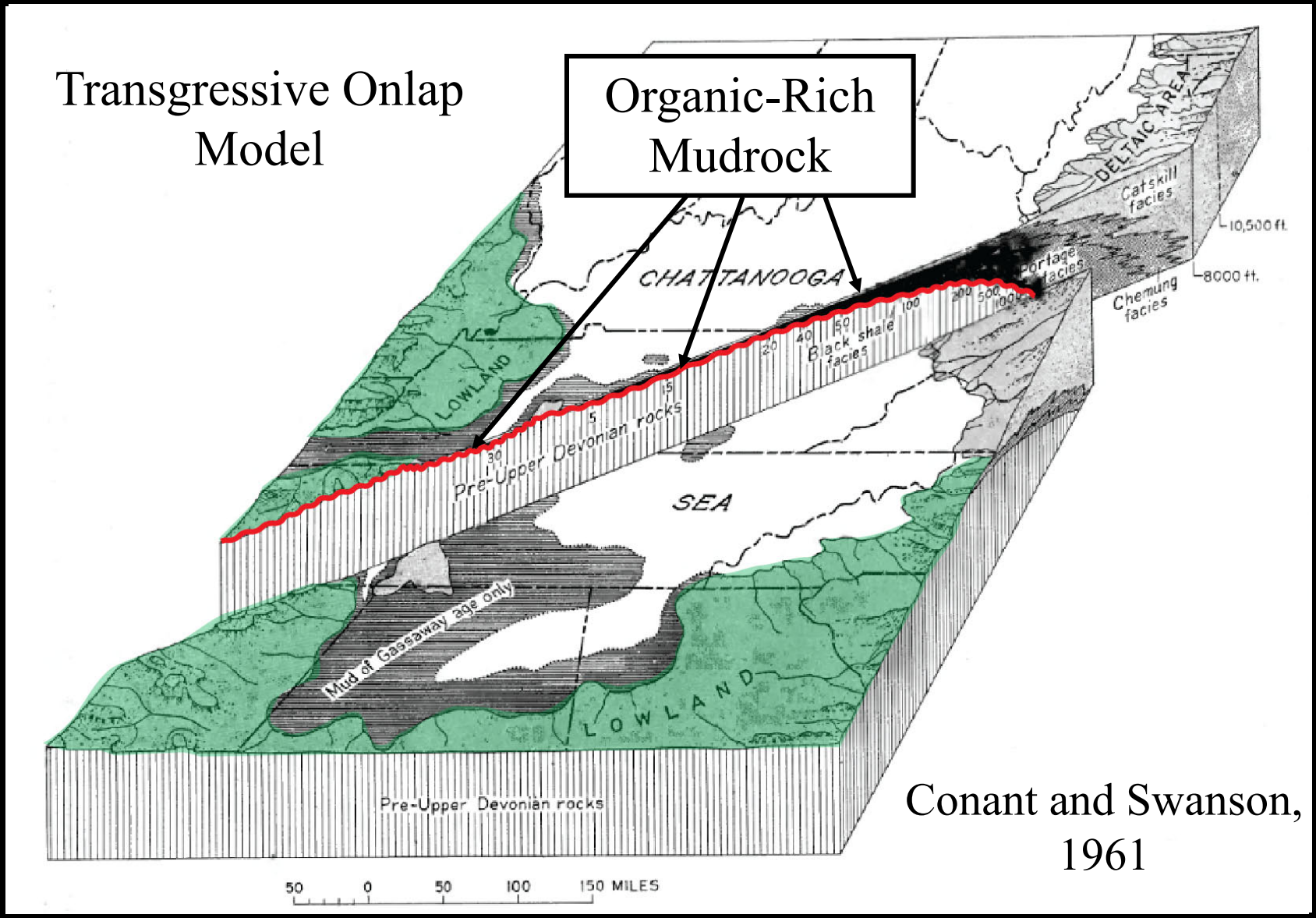
Two Main Goals

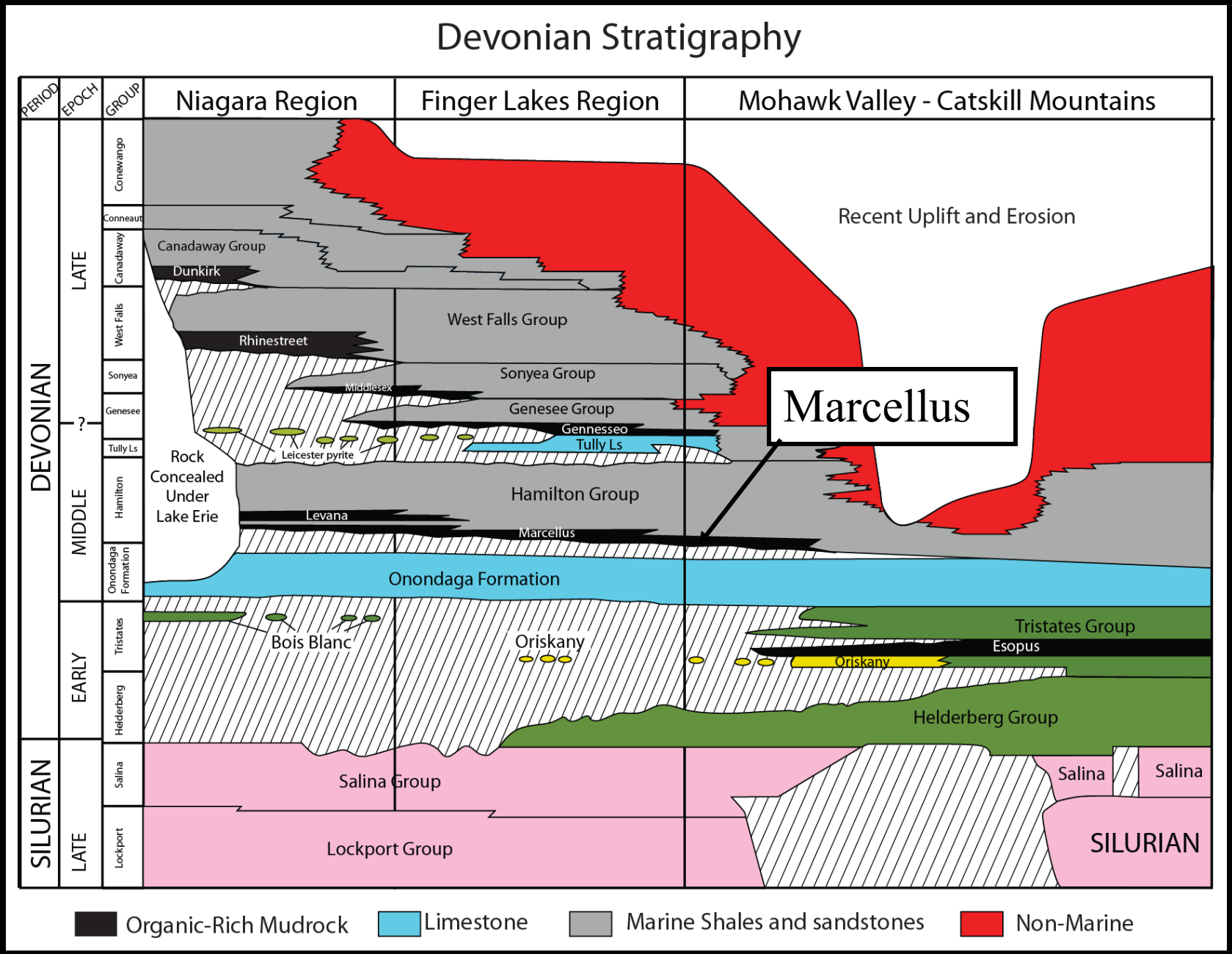
- Will show potential fairways for natural gas production in Utica and Marcellus Shales
- Will show that Marcellus and Utica organic-rich mudrocks formed mainly on western cratonward sides of foreland basins where they onlap unconformities in relatively shallow water – not in the deepest part as has been previously interpreted



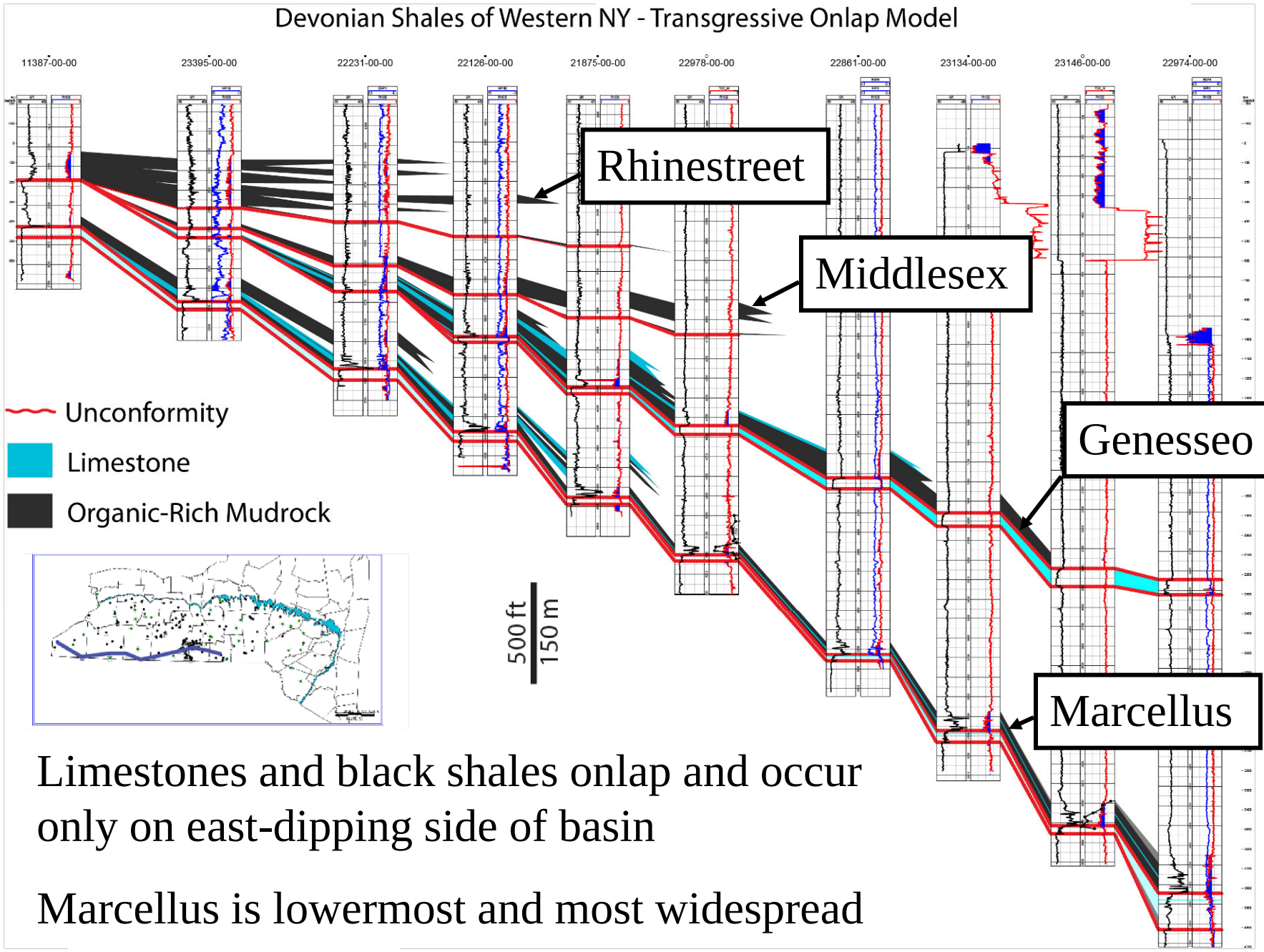
A commonly applied model for the Devonian organic-rich shales in NY is that they were deposited in deep permanently anoxic water (>>100 m) at the toe of the slope and that they downlap on underlying shallow water carbonates onto a drowning unconformity – similar models have been proposed for the Utica



Organic-rich Devonian Chattanooga Shale overlies and onlaps an unconformity and is time-equivalent to exposure nearby – reasoned that water was likely less than 30m (100 feet) deep

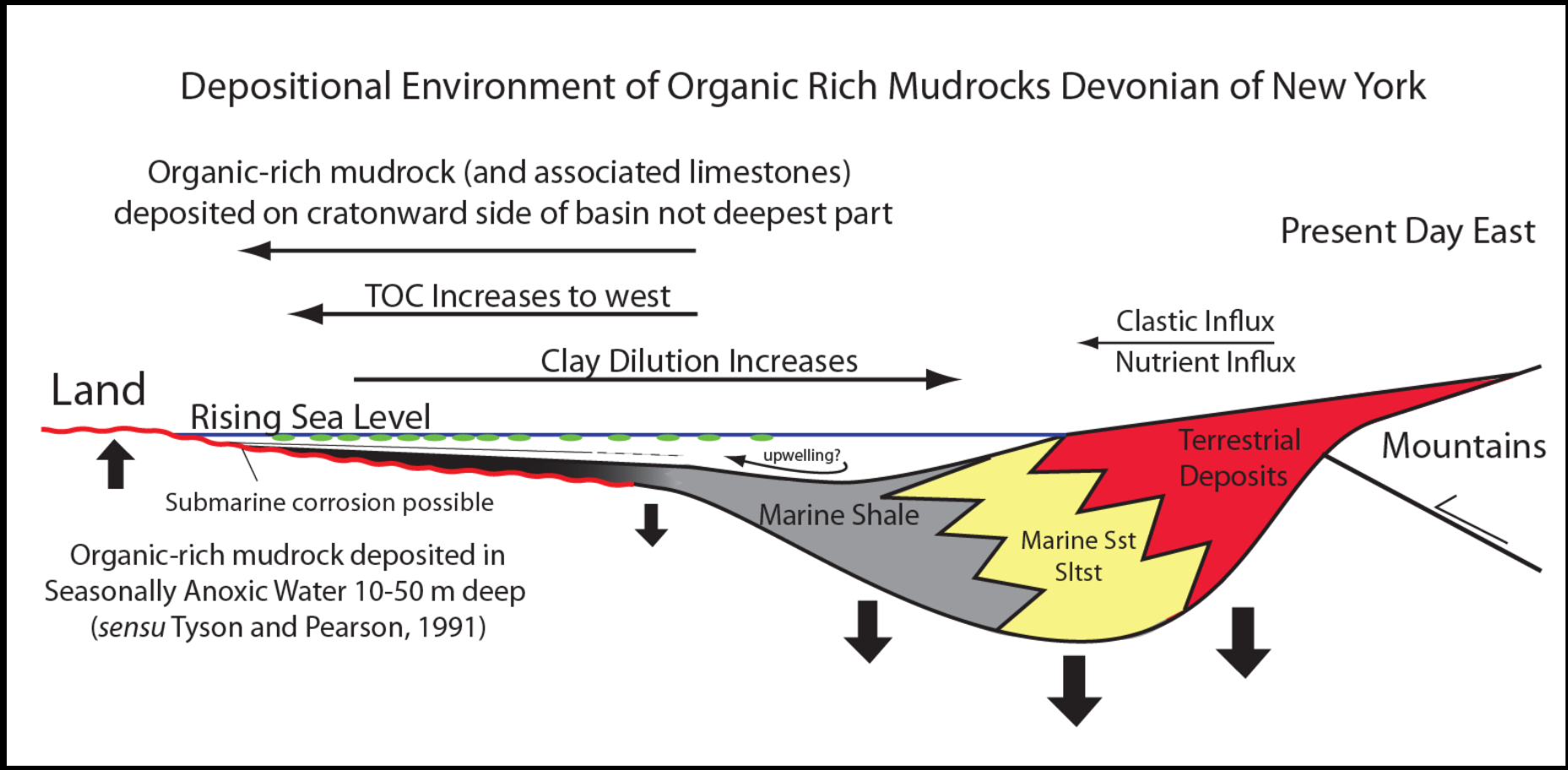


Marcellus is Middle Devonian – overlies and is laterally equivalent to unconformity as are all black shales in NY

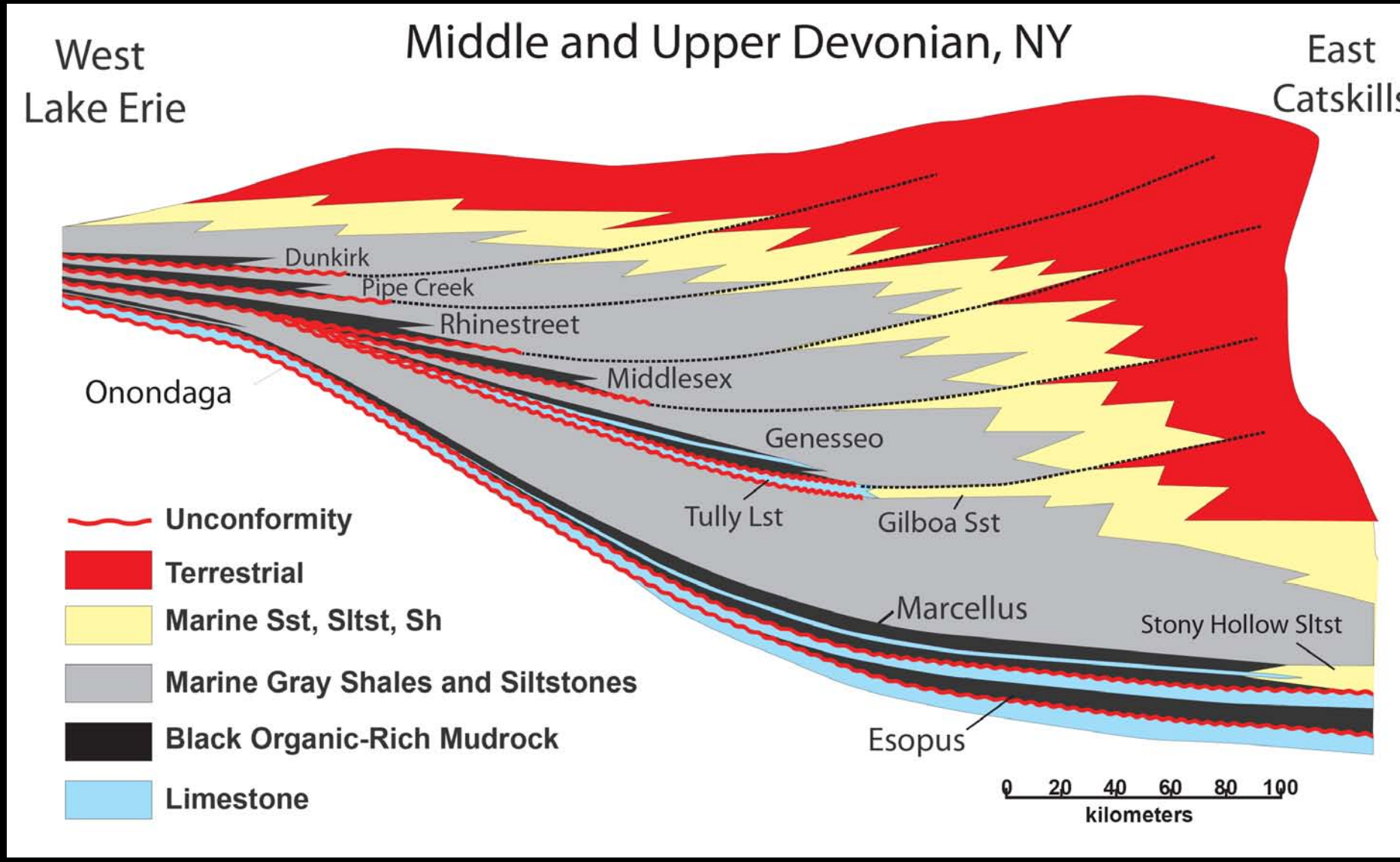


Limestones and black shales onlap and occur only on east-dipping side of basin

Marcellus is lowermost and most widespread



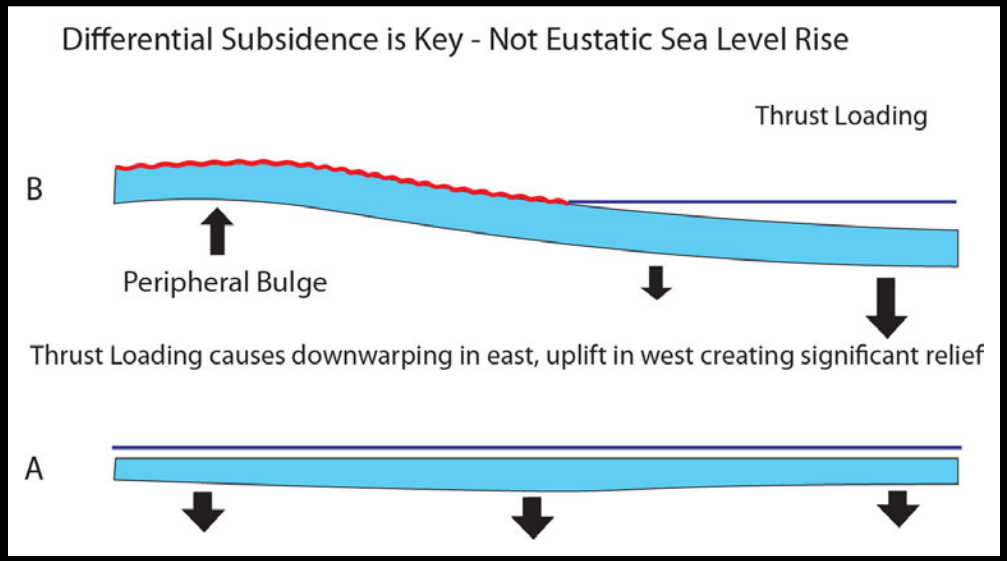
Marcellus and other Devonian organic-rich mudrocks formed primarily on the cratonward side of the basin in relatively shallow water – not in the deepest part – this is mainly a function of dilution – clastics will flow downhill to deepest part but not back up the other side so organic matter can be concentrated



Transgressive Onlap Model – Shales only occur on cratonward side of basin, onlap and are time-equivalent to unconformities

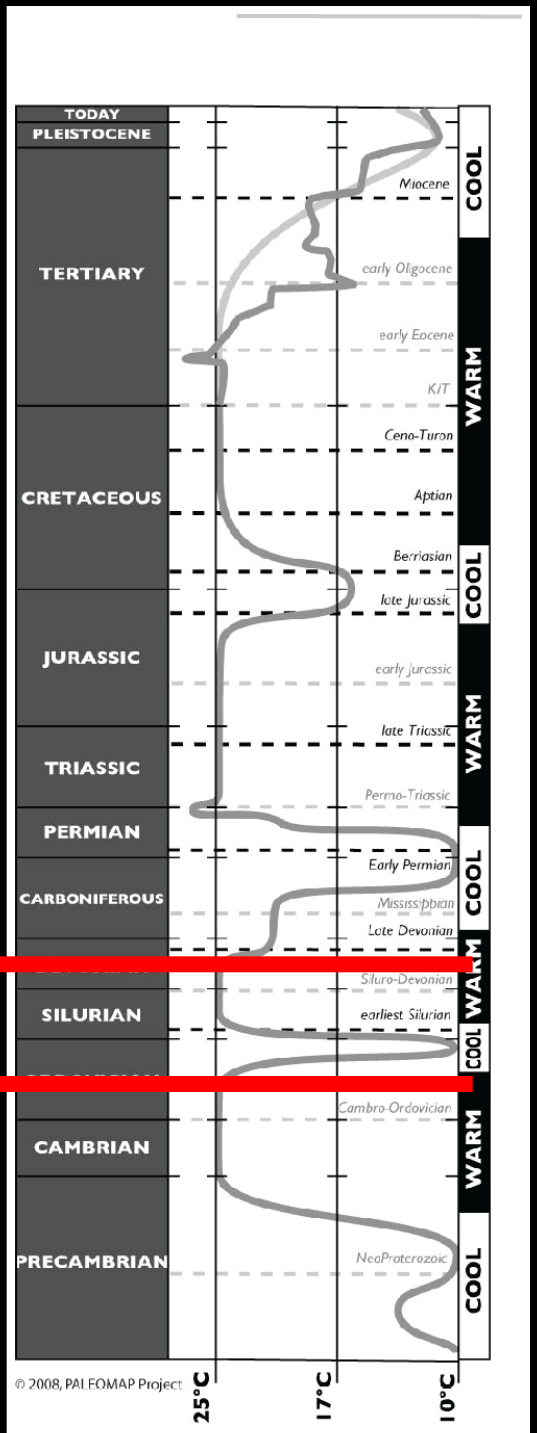
Sea Level Rise

- The transgressions in the cases of both the Utica and Marcellus come more as a result of increased subsidence related to mountain building than of a eustatic sea-level rise – in fact eustatic sea level appears to have been pretty low
- Both deposited during greenhouse times of low amplitude eustatic sea level changes



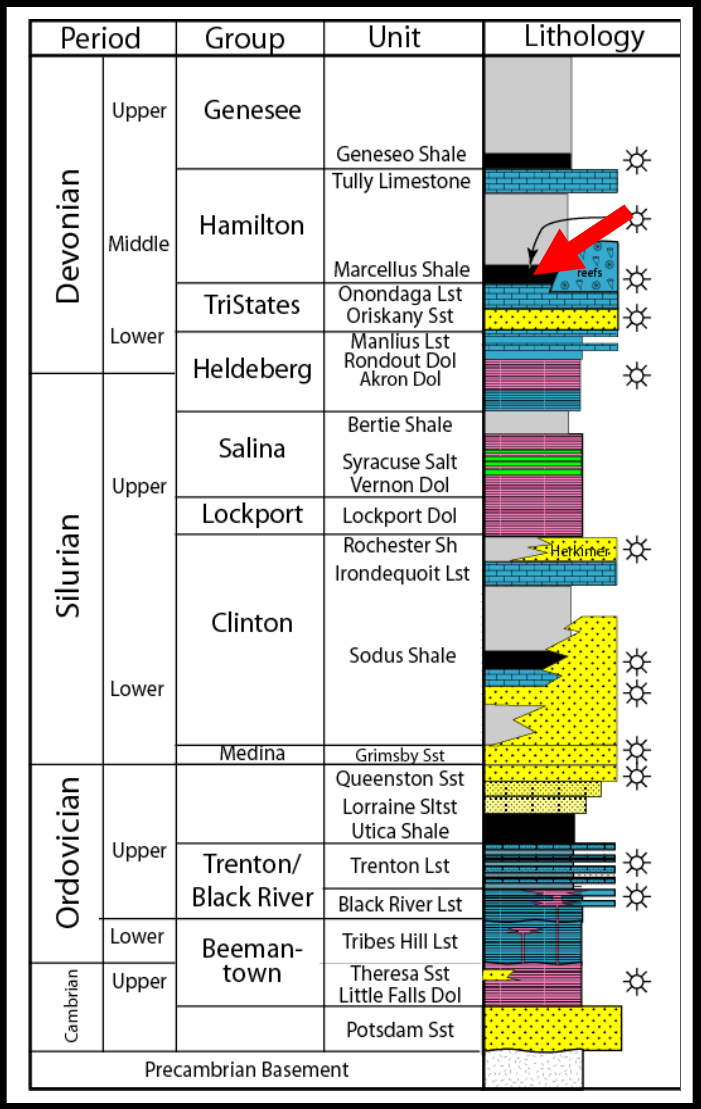
Marcellus

Utica

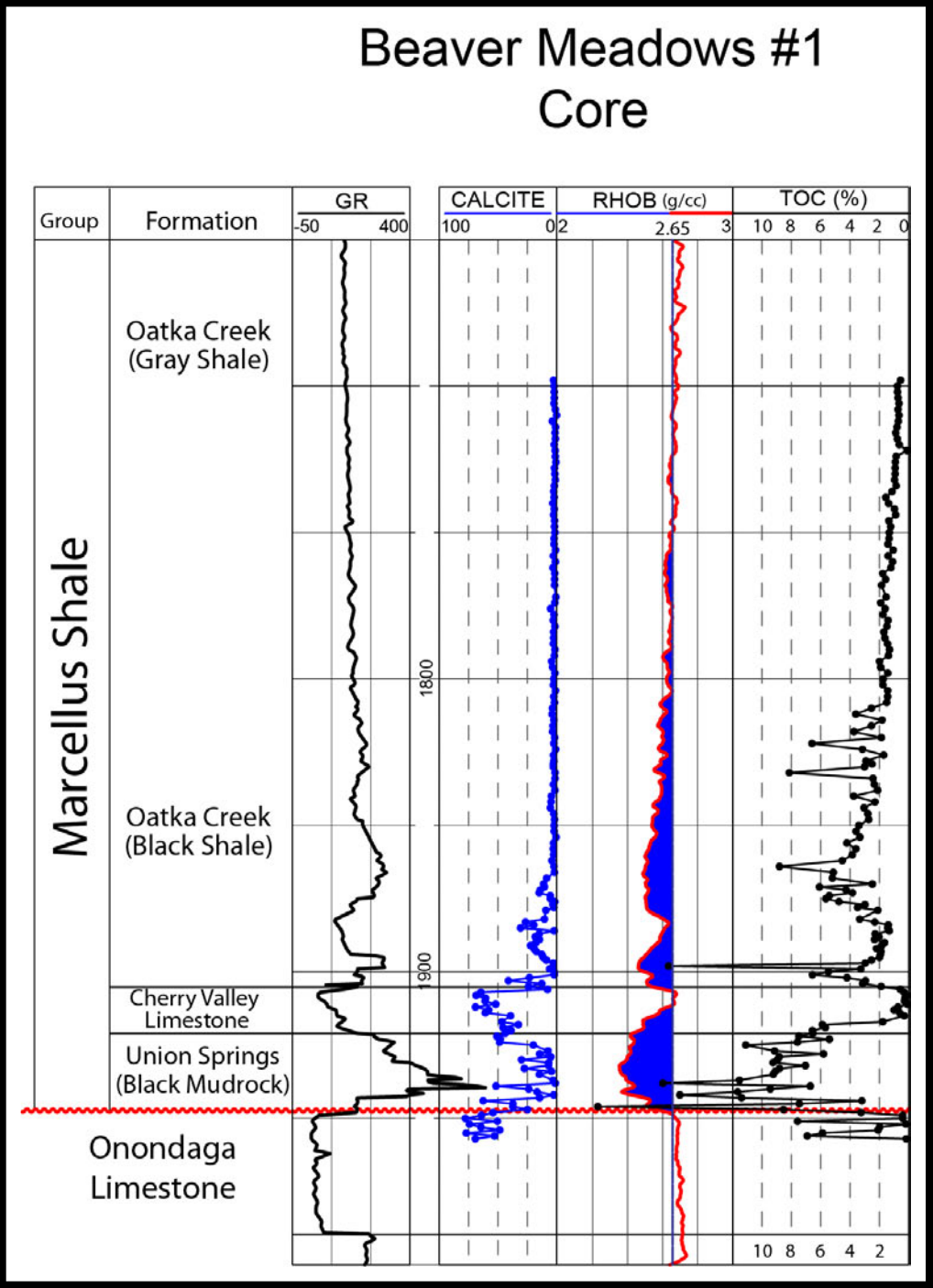


Paleomap project, 2008

Devonian Paleogeography



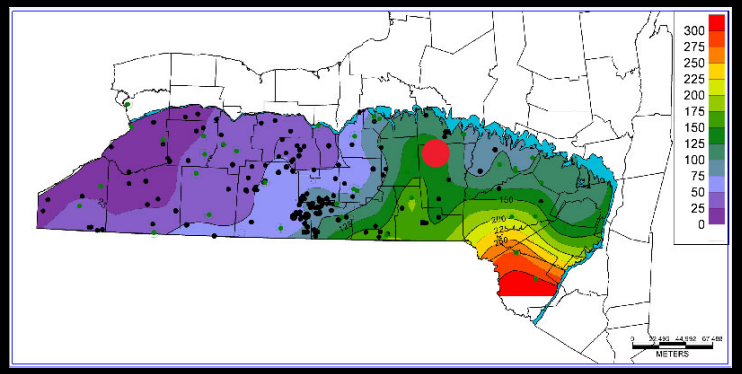
Marcellus deposited during early stages of Acadian Orogeny



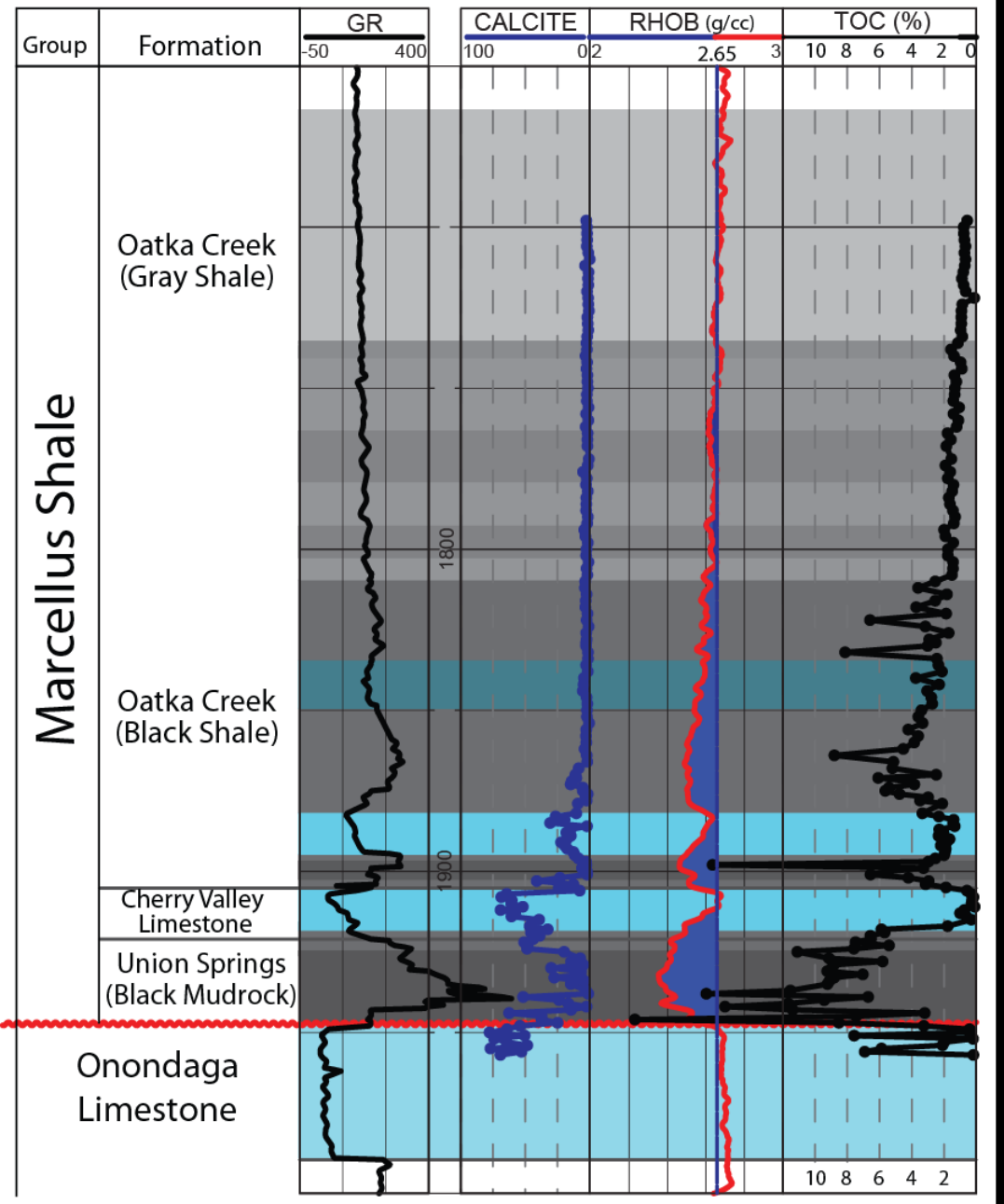
Measured TOC and calcite content on Beaver Meadows core 1 per foot

TOC matches density – shading values below 2.65 g/cc seems to line up well with TOC>1.5%

Calcite percentage also closely tracks GR at base, gray (silty) shale at top



Beaver Meadows #1 Core



Darker gray = more organic rich

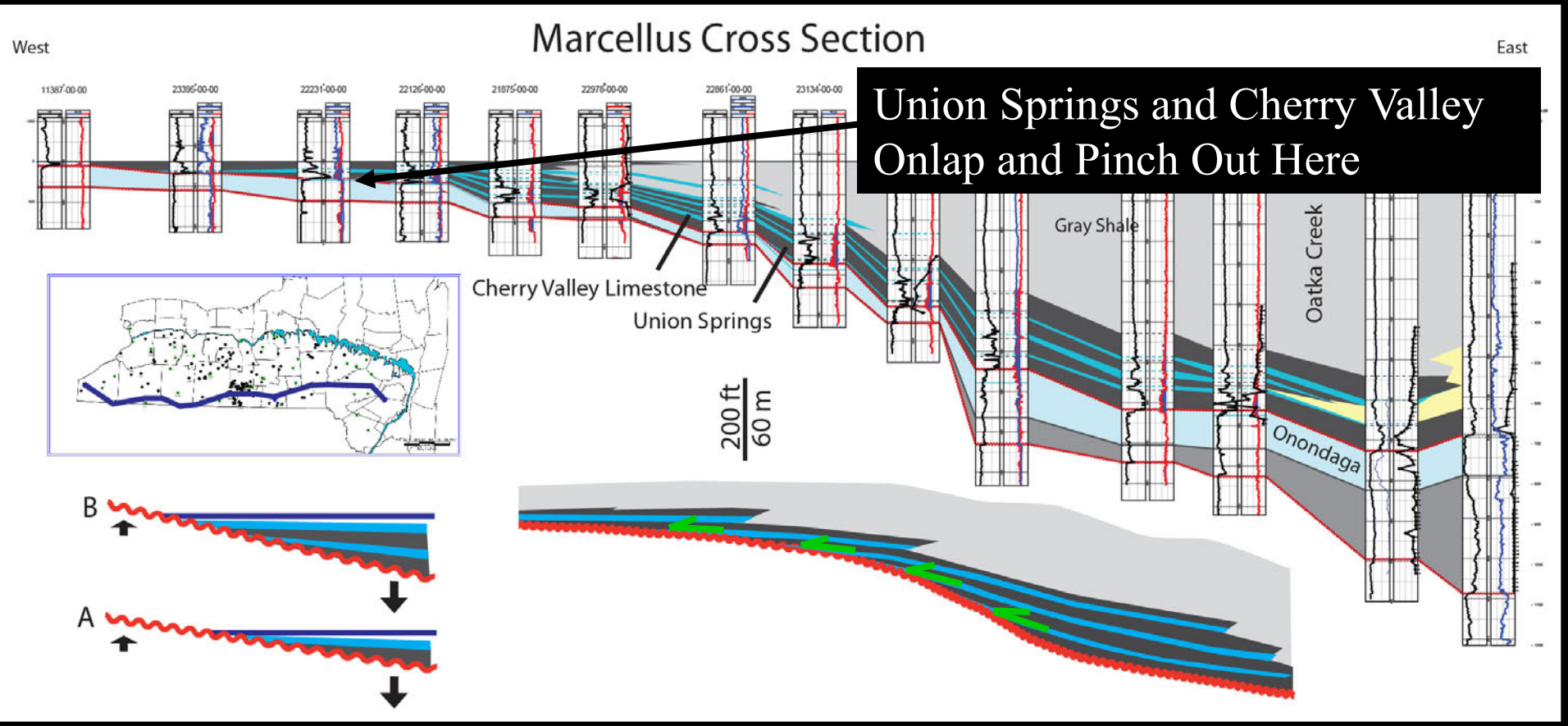
Less Limestone, More Clay

Lower TOC

Very low TOC in limestones

Highest TOC (up to 20%)

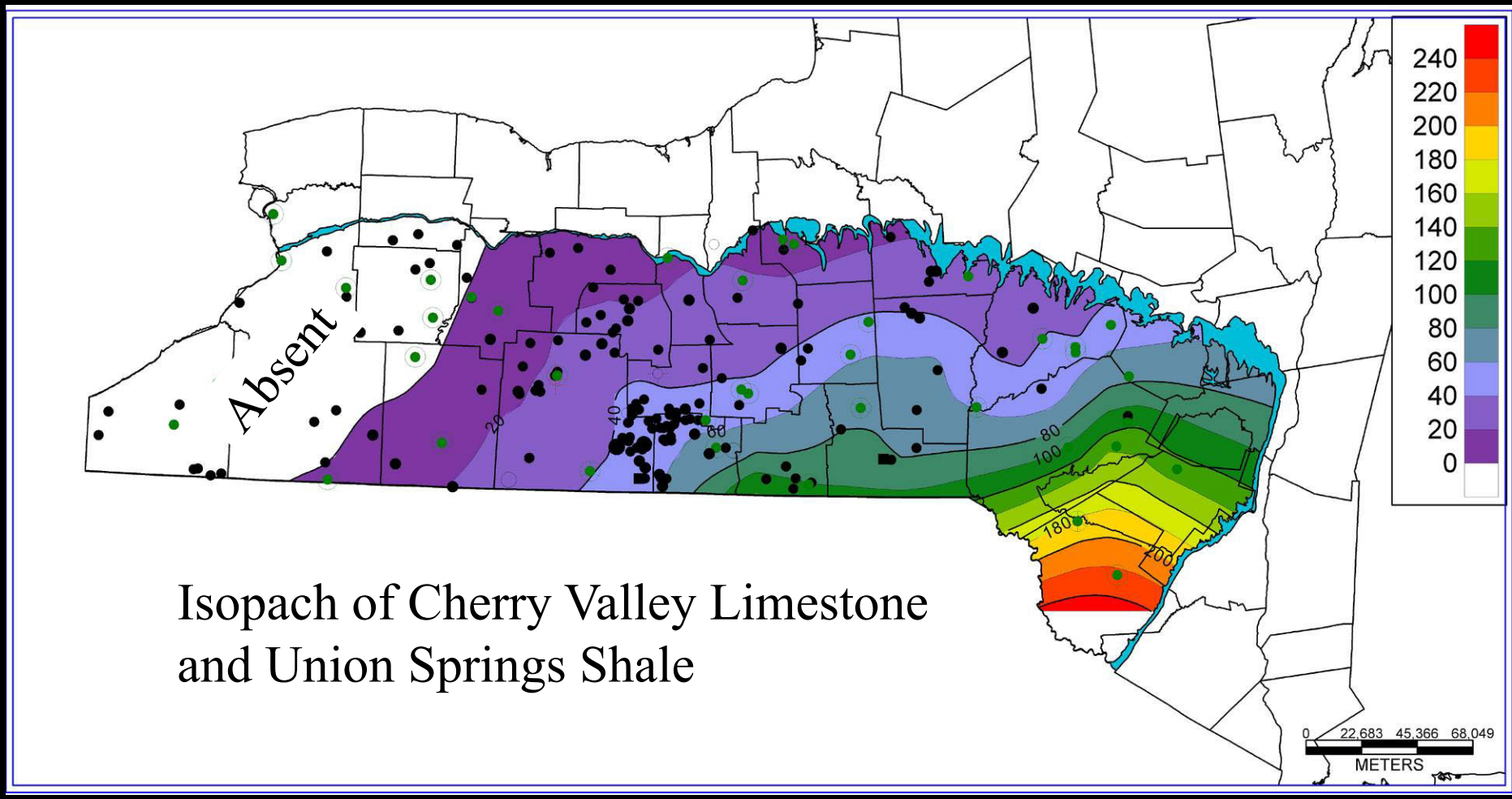
Unconformity at top of Onondaga



Each TOC rich mudrock unit becomes more OC-rich to west until it pinches out and more clay rich and less OC-rich to the east

Limestones onlap and pinch out to west and grade into siltstone to east

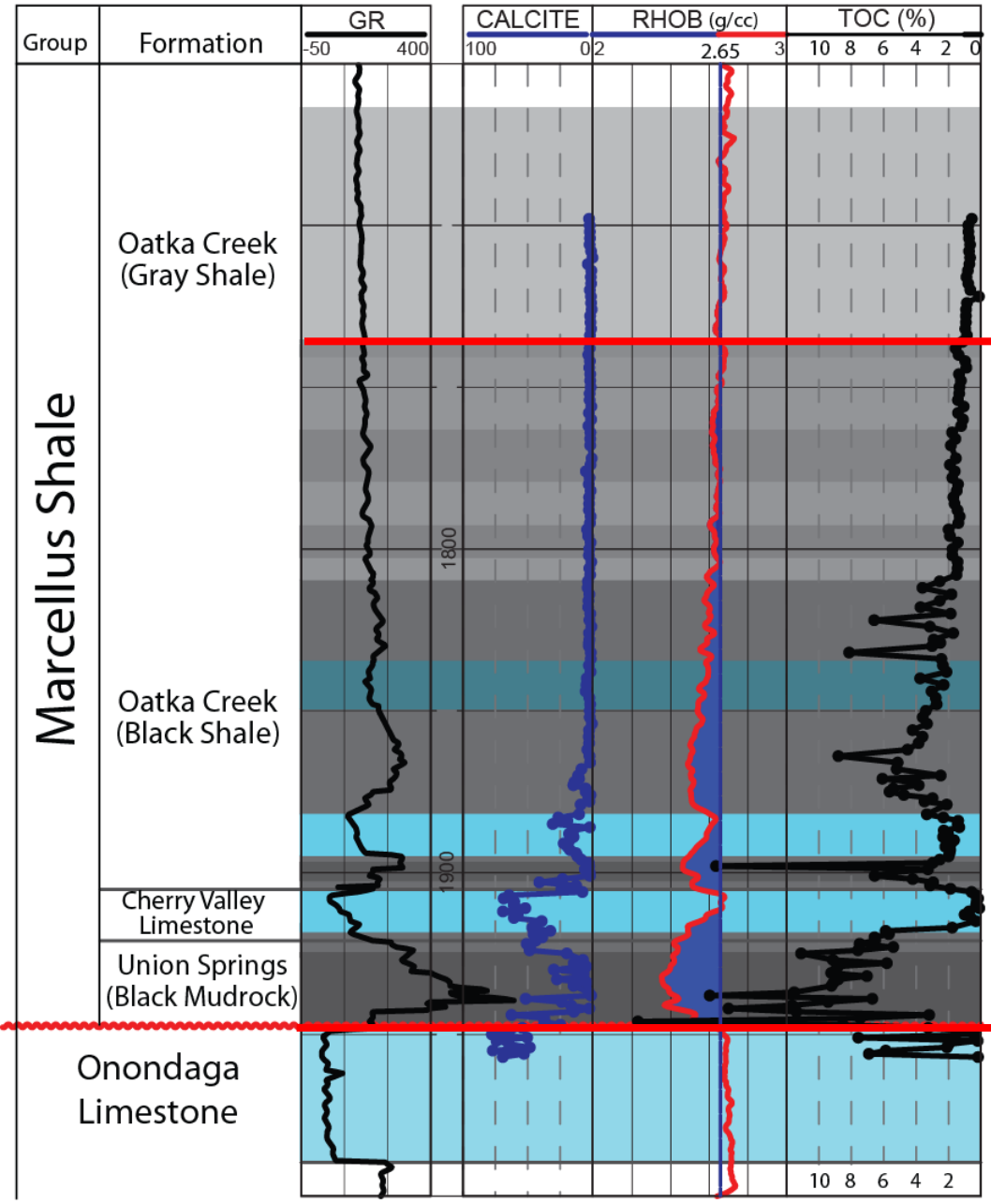
The Union Springs Shale and Cherry Valley Limestone pinch out in western NY, Oatka Creek pinches out under Lake Erie to west



Isopach of Cherry Valley Limestone and Union Springs Shale

The Marcellus Shale is absent from western NY where they onlap and pinch out and thickest in southeast – There is no Marcellus equivalent to the west and this area was probably exposed land - how deep could the water have been during Union Springs deposition?

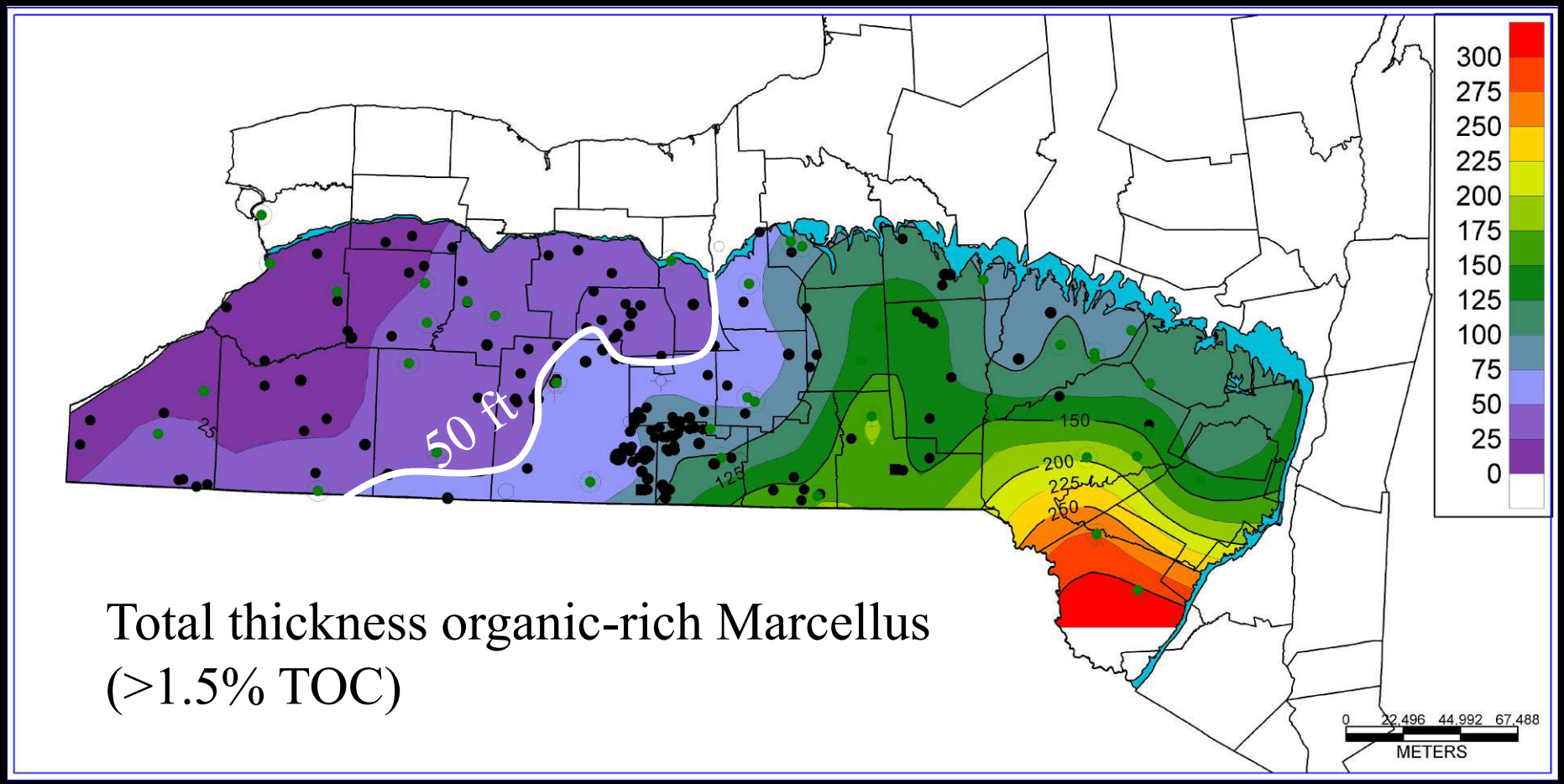
Beaver Meadows #1 Core



Top Organic-Rich Marcellus

Next Map Shows
this total thickness

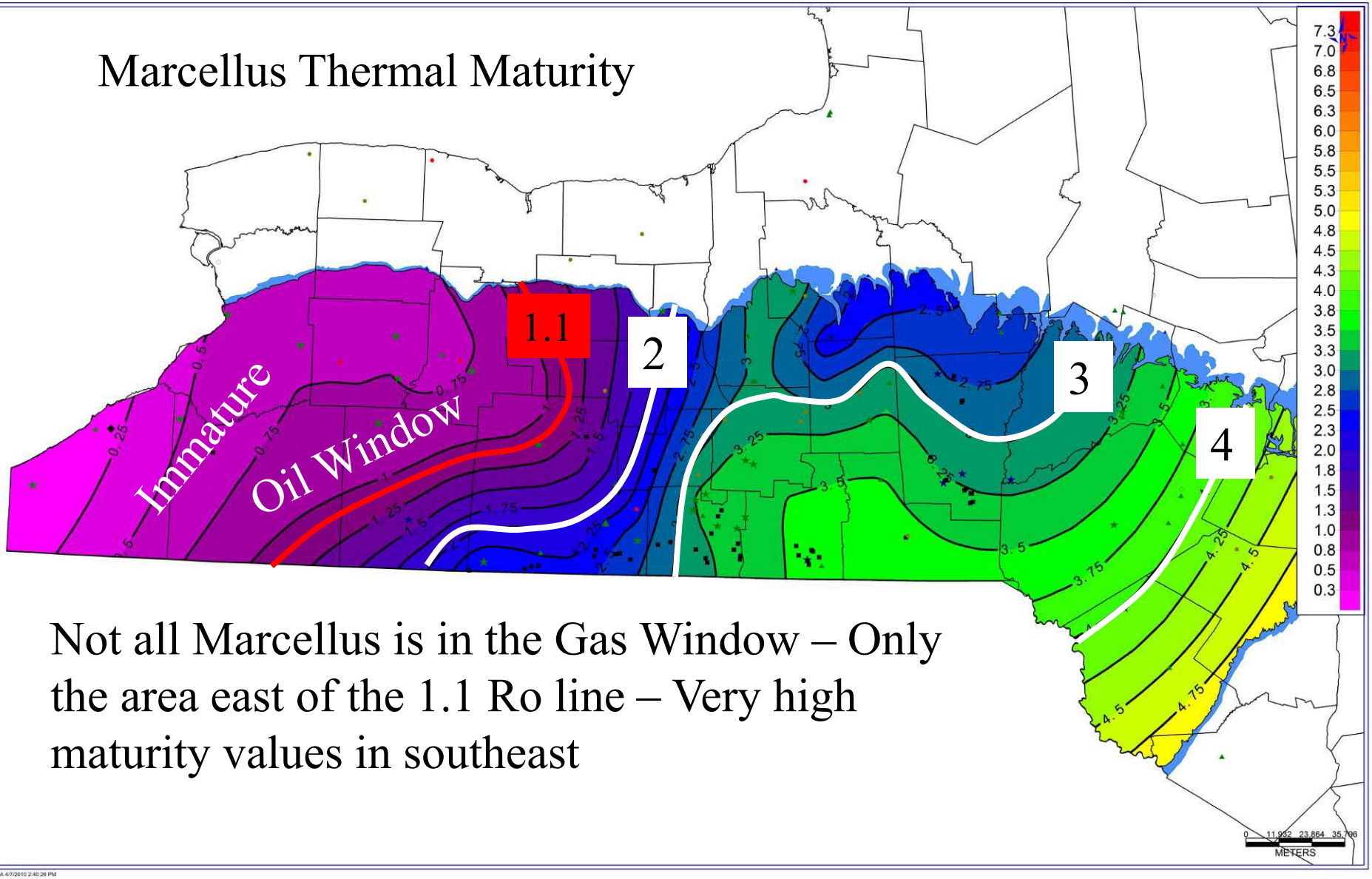
Base Organic-Rich Marcellus



Total thickness organic-rich Marcellus (>1.5% TOC)

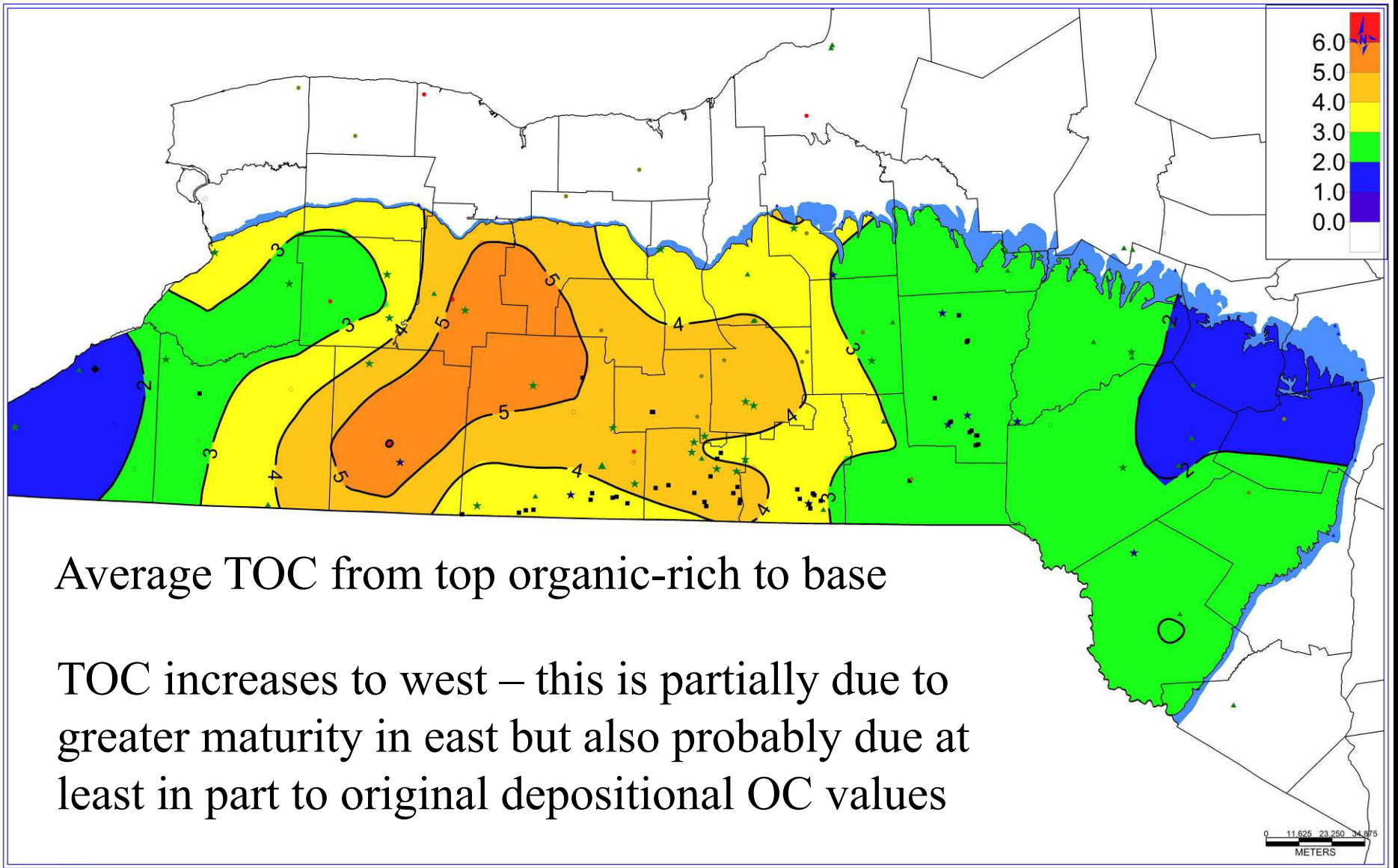
If all the organic-rich beds are summed, the map looks like this – thin to west, much thicker to east – one critical question is how thick does the formation need to be to make economic wells – some have suggested 50 feet – it is a moot point for anything thinner than 50 ft…

Marcellus Thermal Maturity



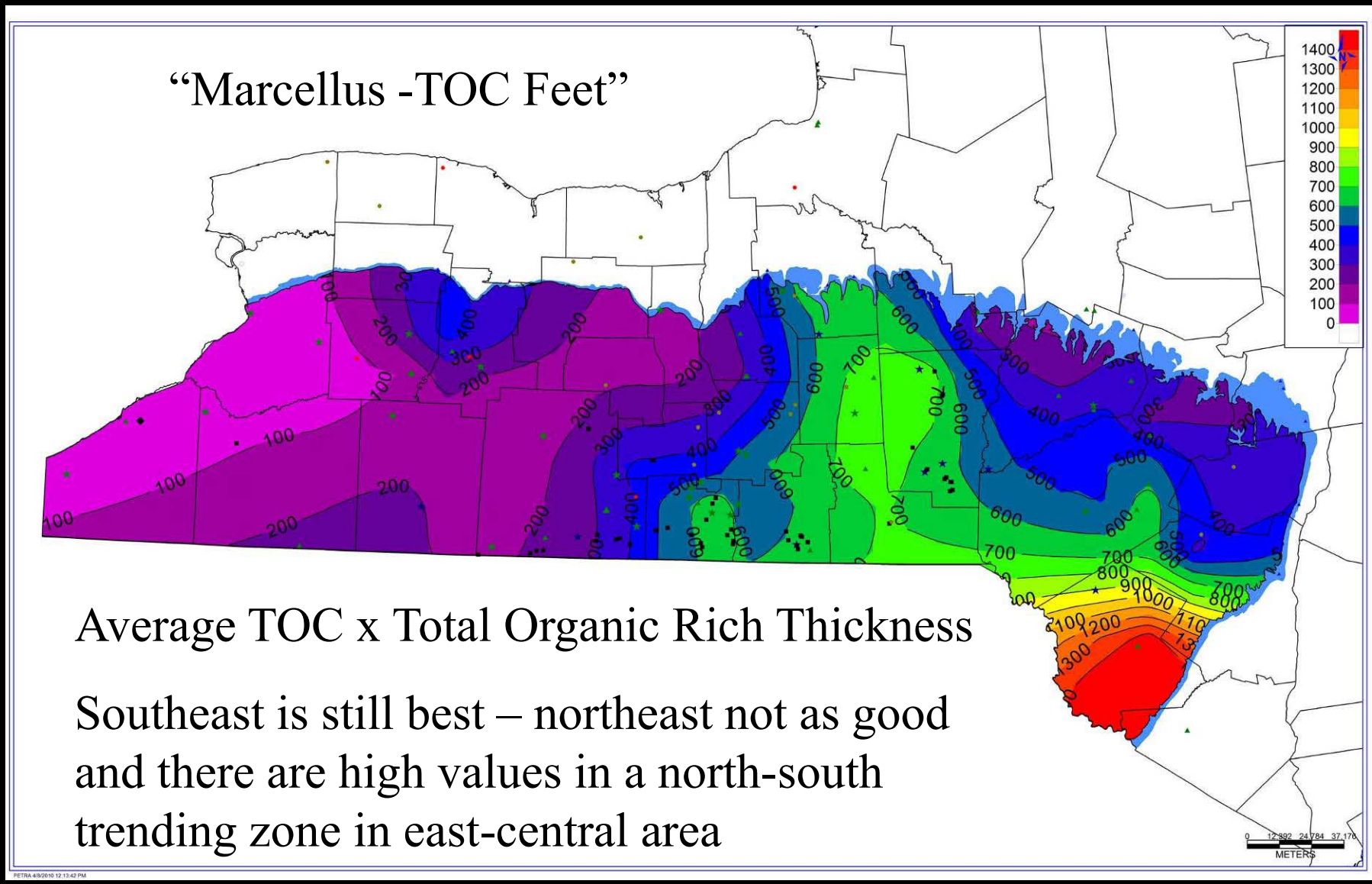
Not all Marcellus is in the Gas Window – Only the area east of the 1.1 Ro line – Very high maturity values in southeast

Western NY is not mature anyway



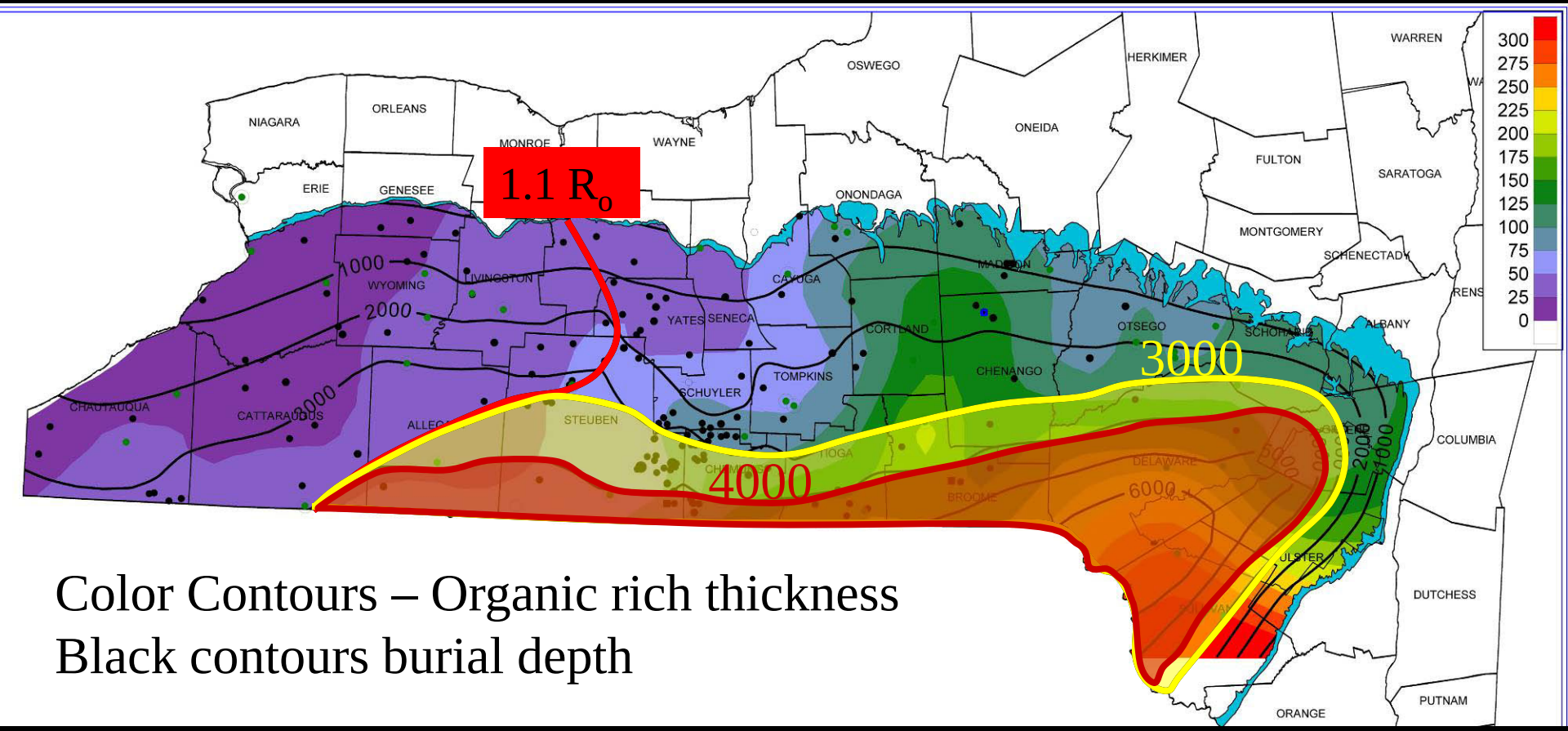
Average TOC from top organic-rich to base

TOC increases to west – this is partially due to greater maturity in east but also probably due at least in part to original depositional OC values



This is an attempt to capture organic richness and thickness – this map will improve with more data

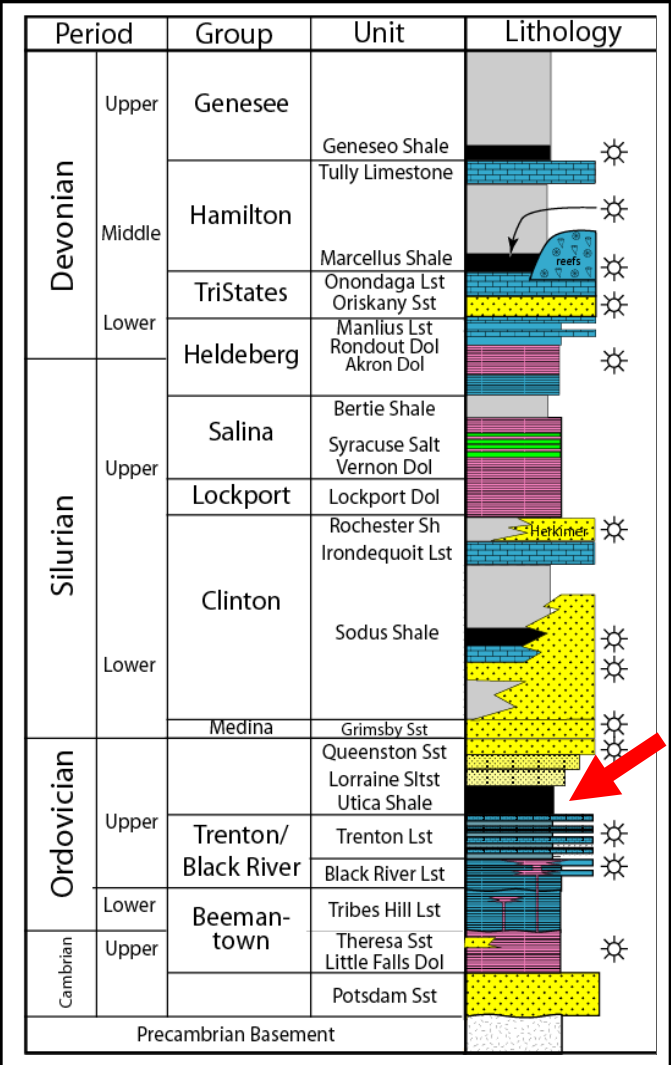
Fairway Map – Marcellus Shale

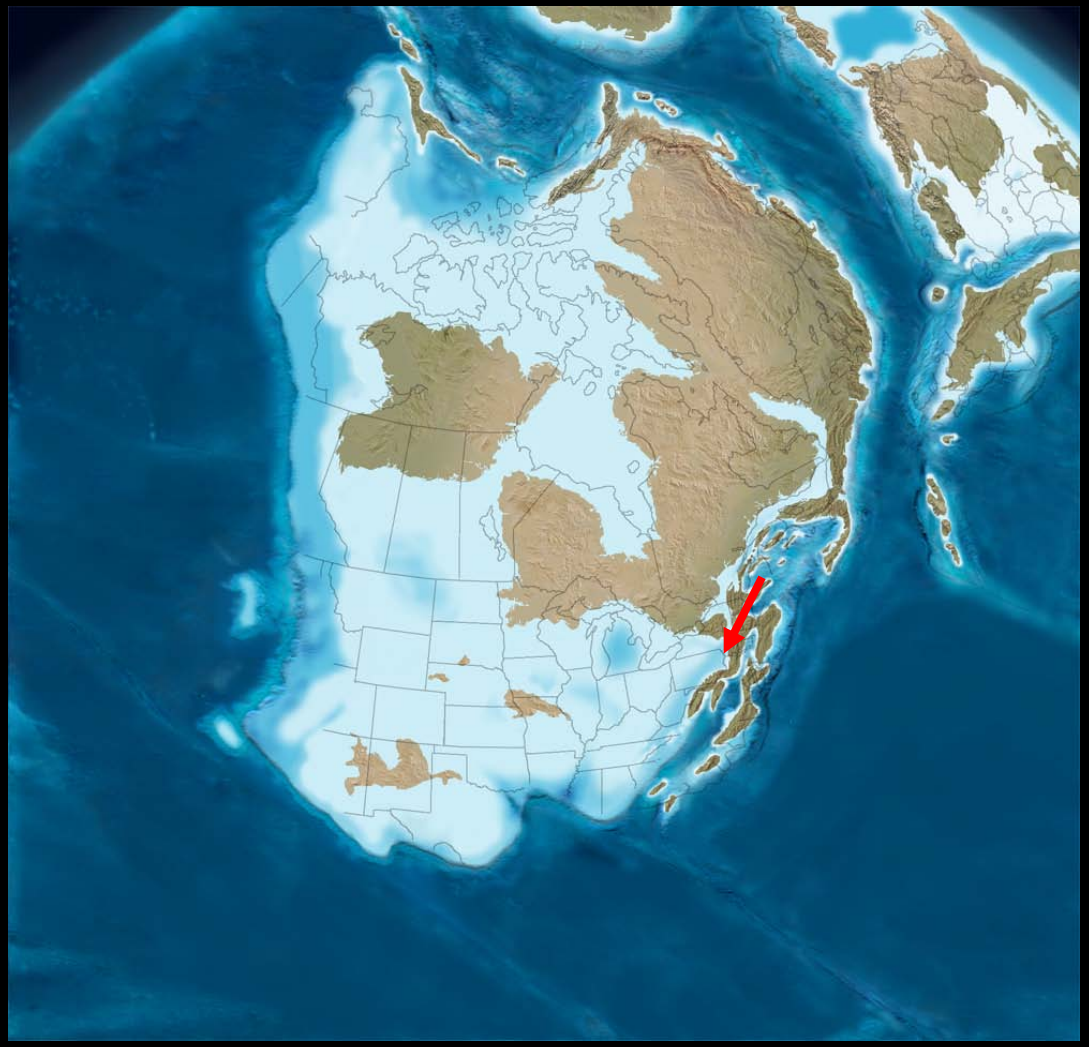


Color Contours – Organic rich thickness
Black contours burial depth

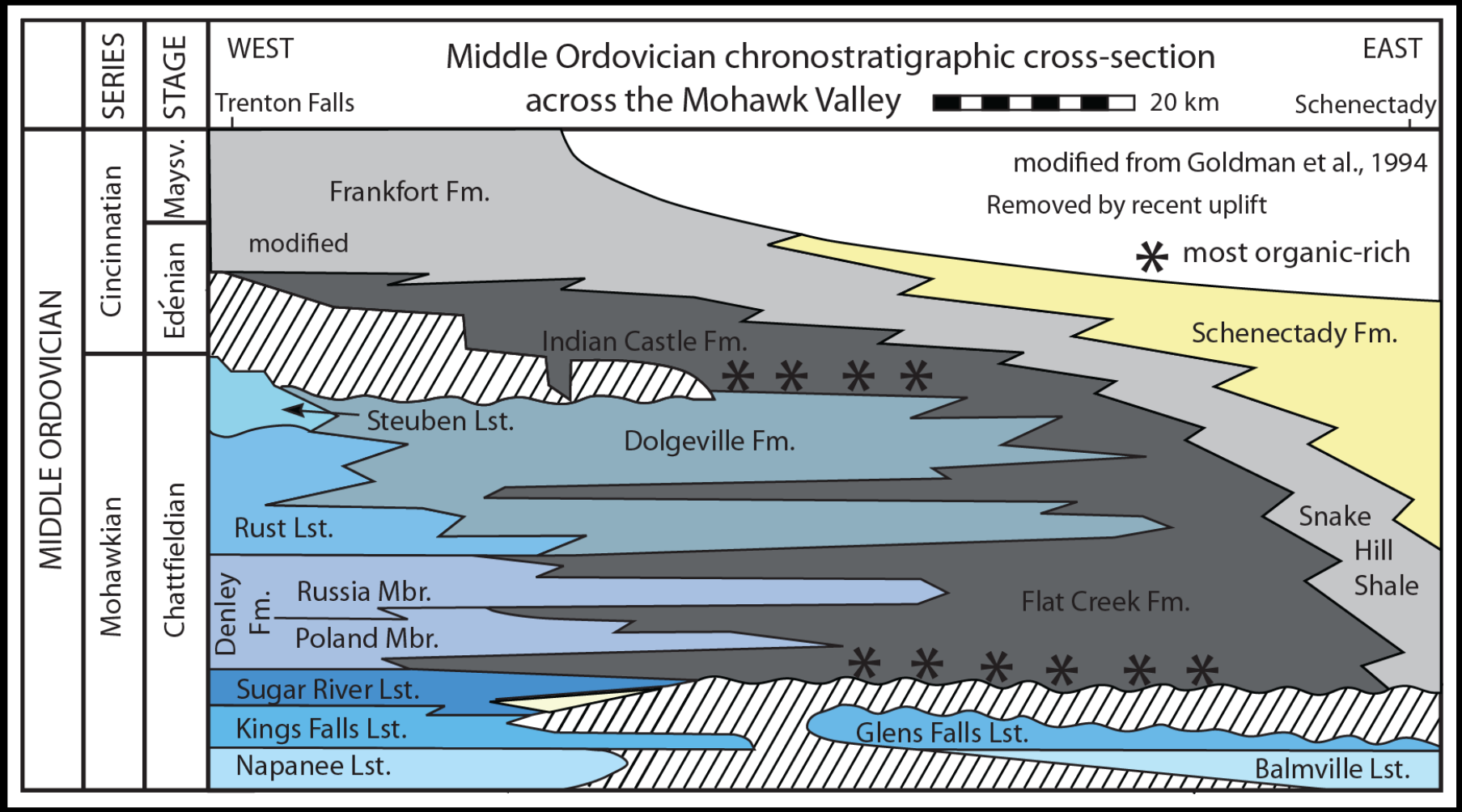
Best areas probably where thickest and deepest – A key question is how deep the shale needs to be to produce economically – some shales are only economic at >4000 feet, others appear to be profitable at shallower depths

Ordovician Utica Shale

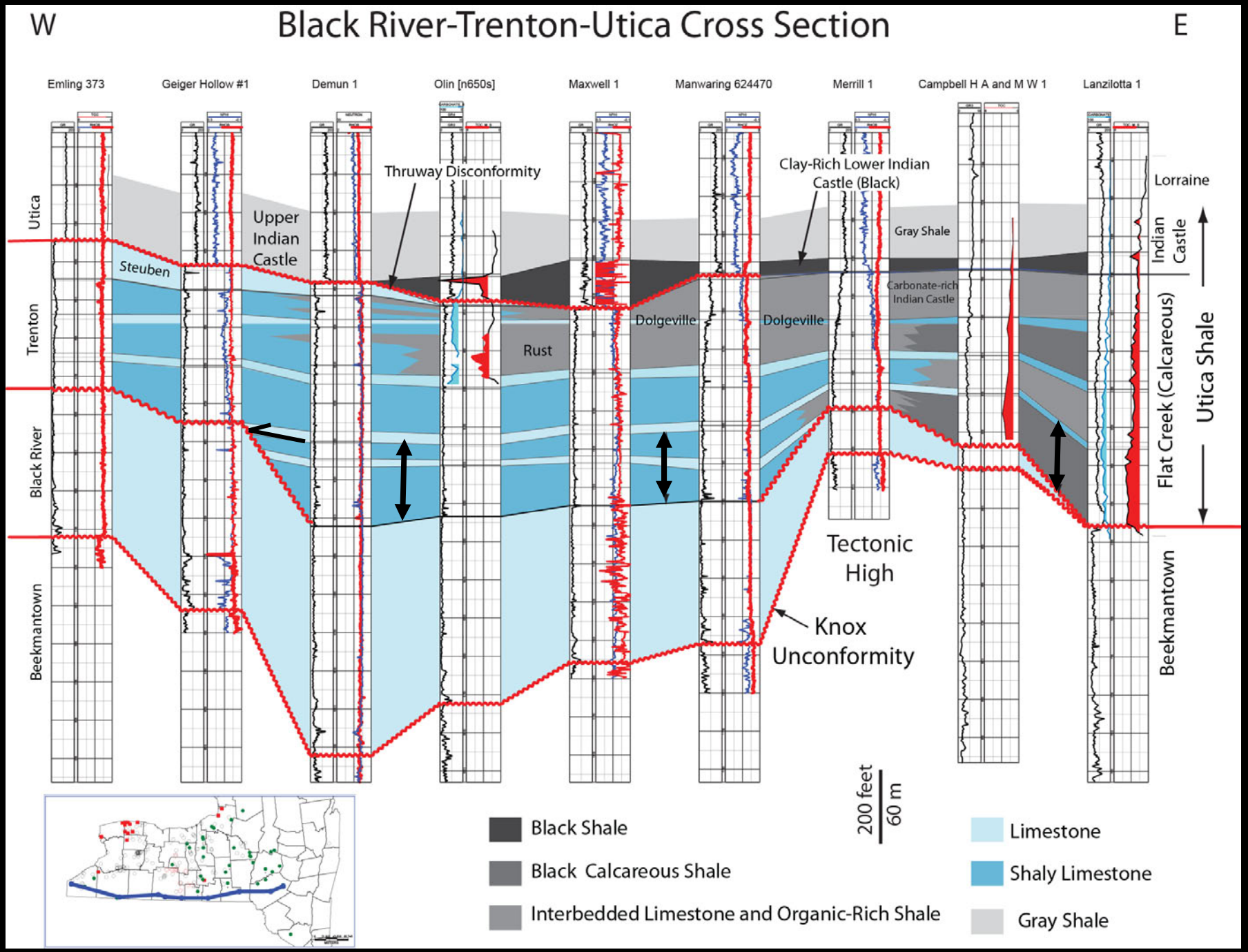


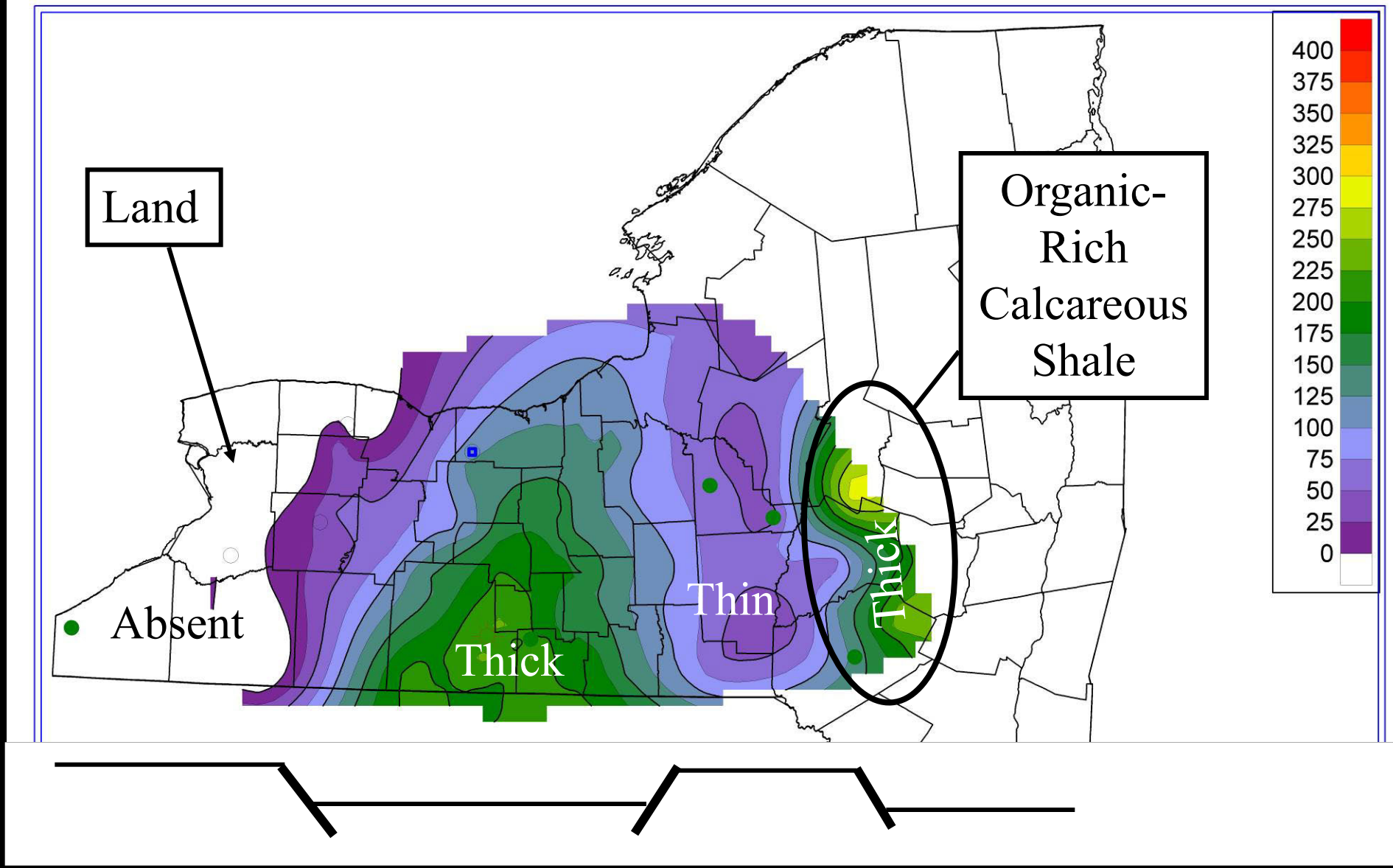


Utica Shale deposited during Ordovician Taconic Orogeny

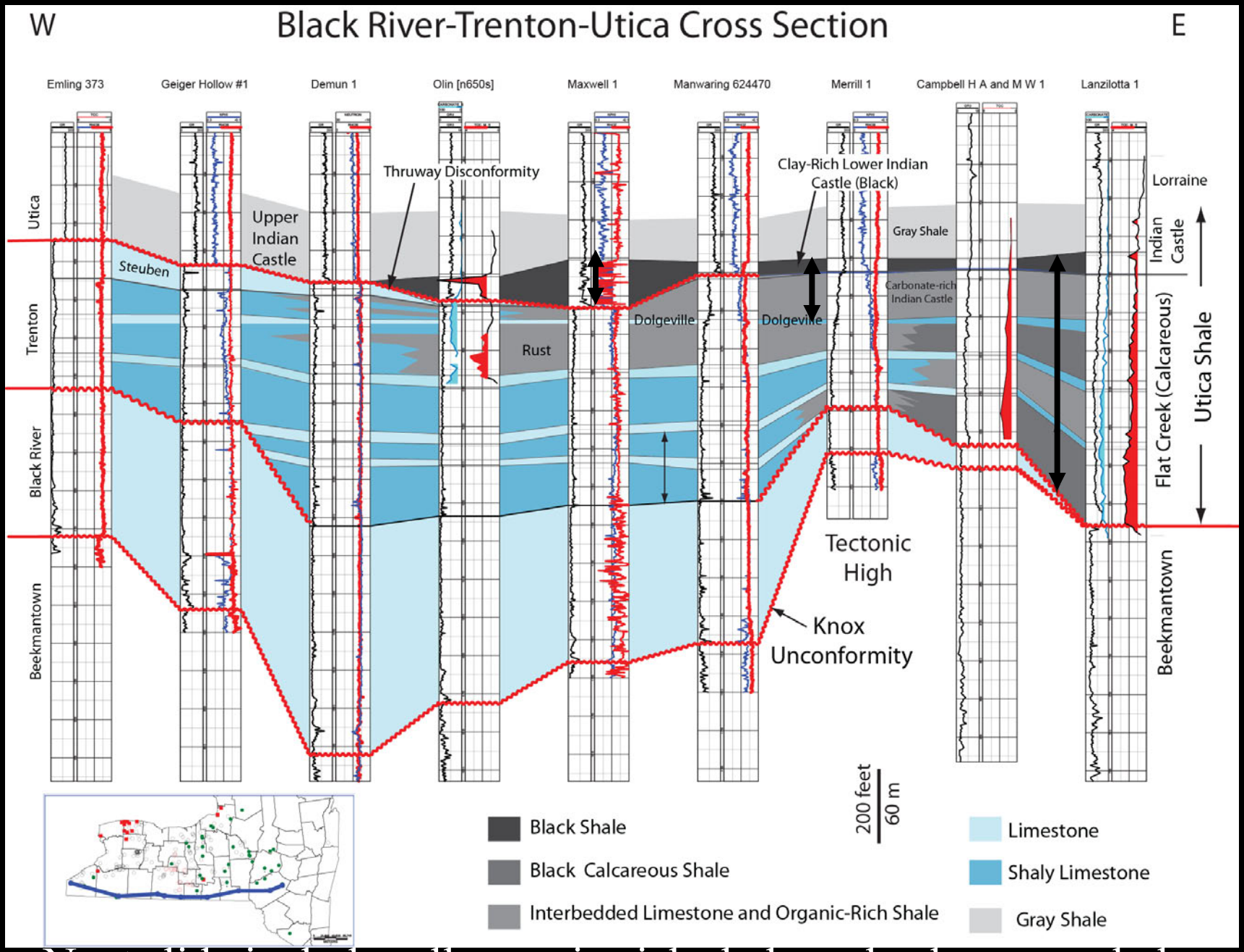


Outcrop Stratigraphy from Mohawk Valley – Utica consists of Flat Creek (which is time-equivalent to Trenton Limestone) and Indian Castle Shales (which postdates Trenton) – the beds with the highest TOC immediately overlie or are laterally-equivalent to unconformities

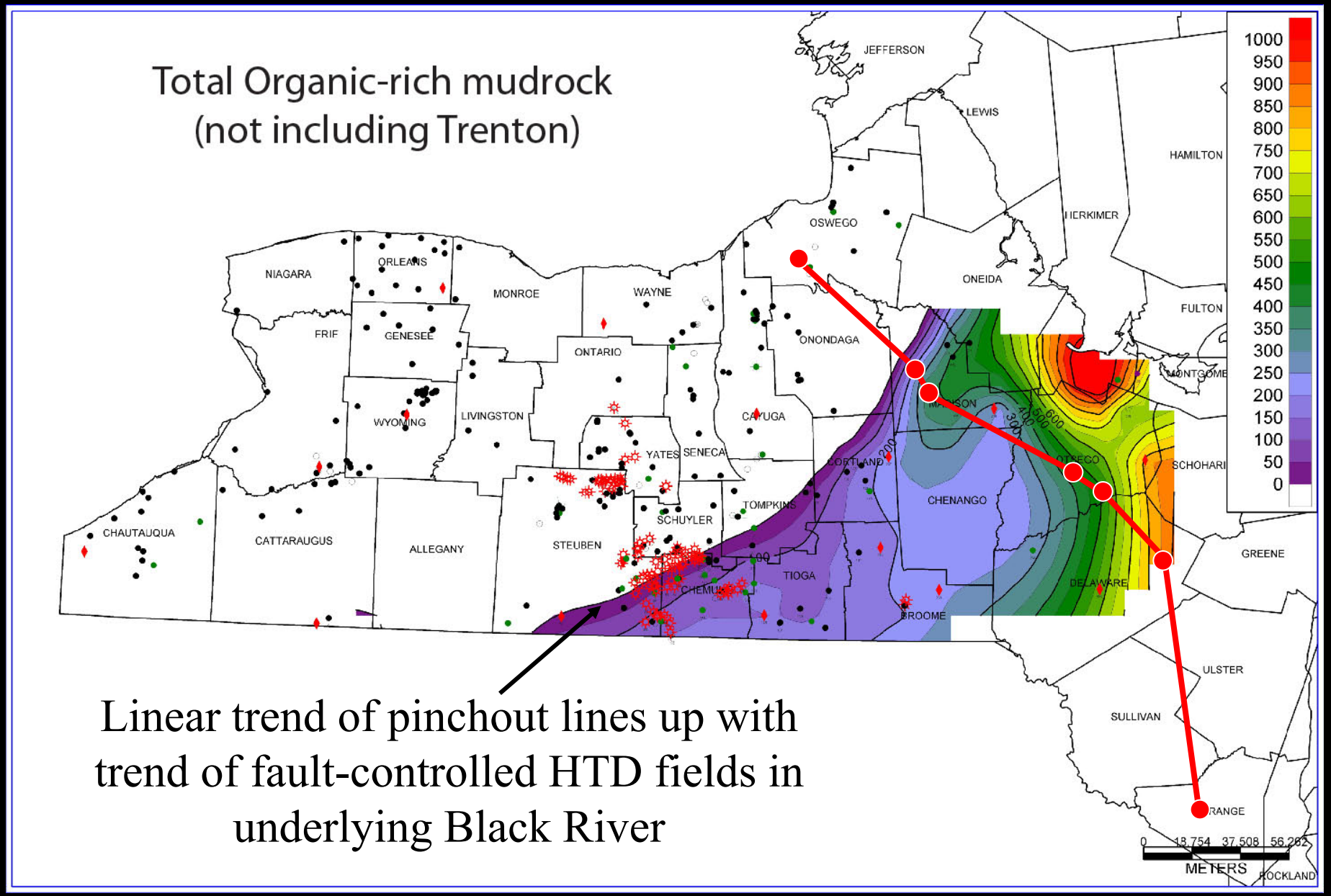

W
Black River-Trenton-Utica Cross Section
E
Emling 373
Geiger Hollow #1
Demun 1
Olin [n650s]
Maxwell 1
Manwaring 624470
Merrill 1
Campbell H A and M W 1
Lanzilotta 1
Utica
Trenton
Black River
Beekmantown
Steuben
Upper Indian Castle
Thruway Disconformity
Clay-Rich Lower Indian Castle (Black)
Gray Shale
Carbonate-rich Indian Castle
Dolgeville
Dolgeville
Rust
Tectonic High
Knox Unconformity
Lorraine
Indian Castle
Flat Creek (Calcareous)
Utica Shale
Beekmantown
200 feet
60 m
Black Shale
Black Calcareous Shale
Interbedded Limestone and Organic-Rich Shale
Limestone
Shaly Limestone
Gray Shale



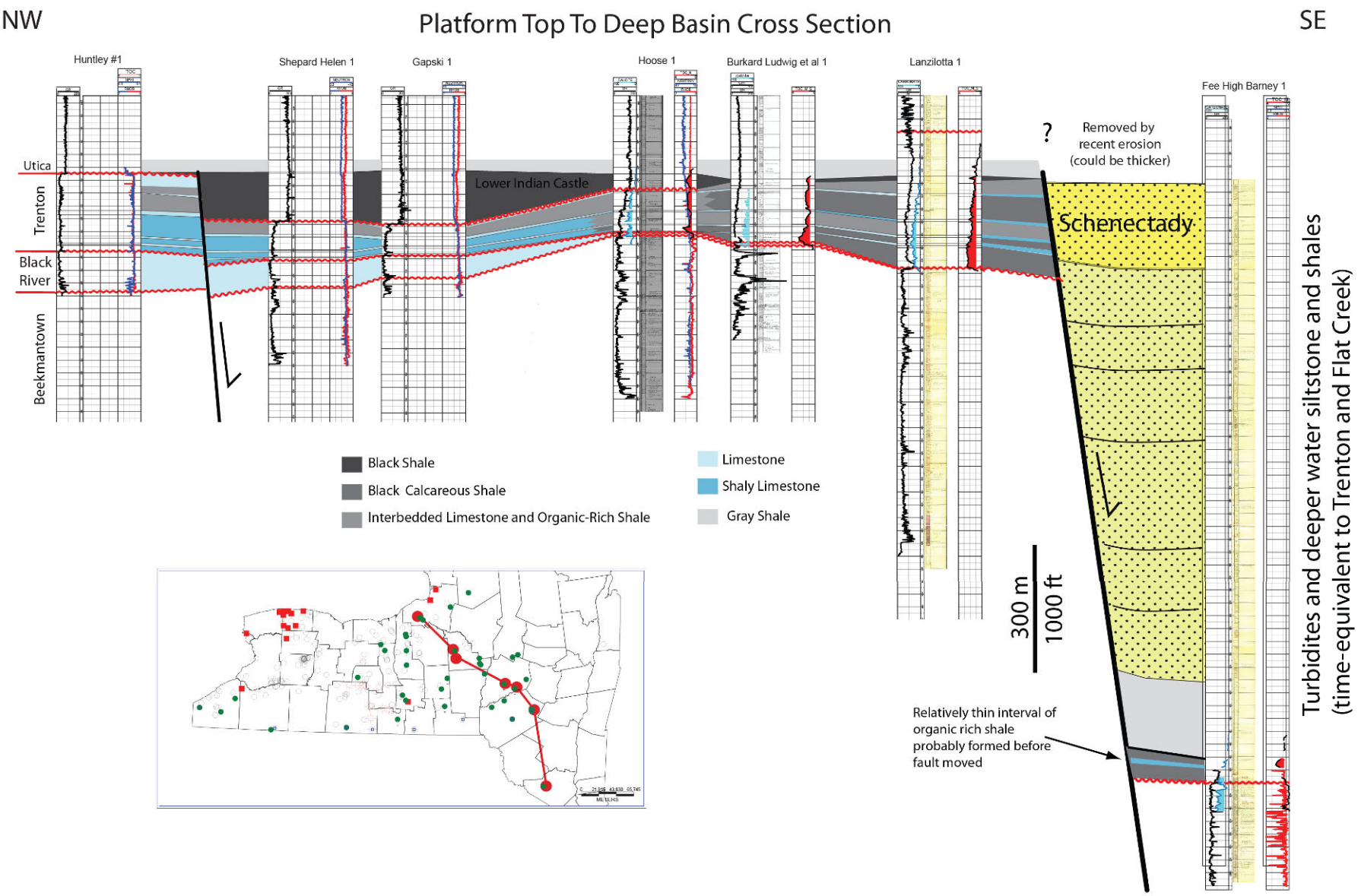
Map of lower Trenton and Flat Creek Thickness – likely to be structurally controlled – basal Trenton and Flat Creek only in lows



Next slide includes all organic-rich shale and calcareous shale

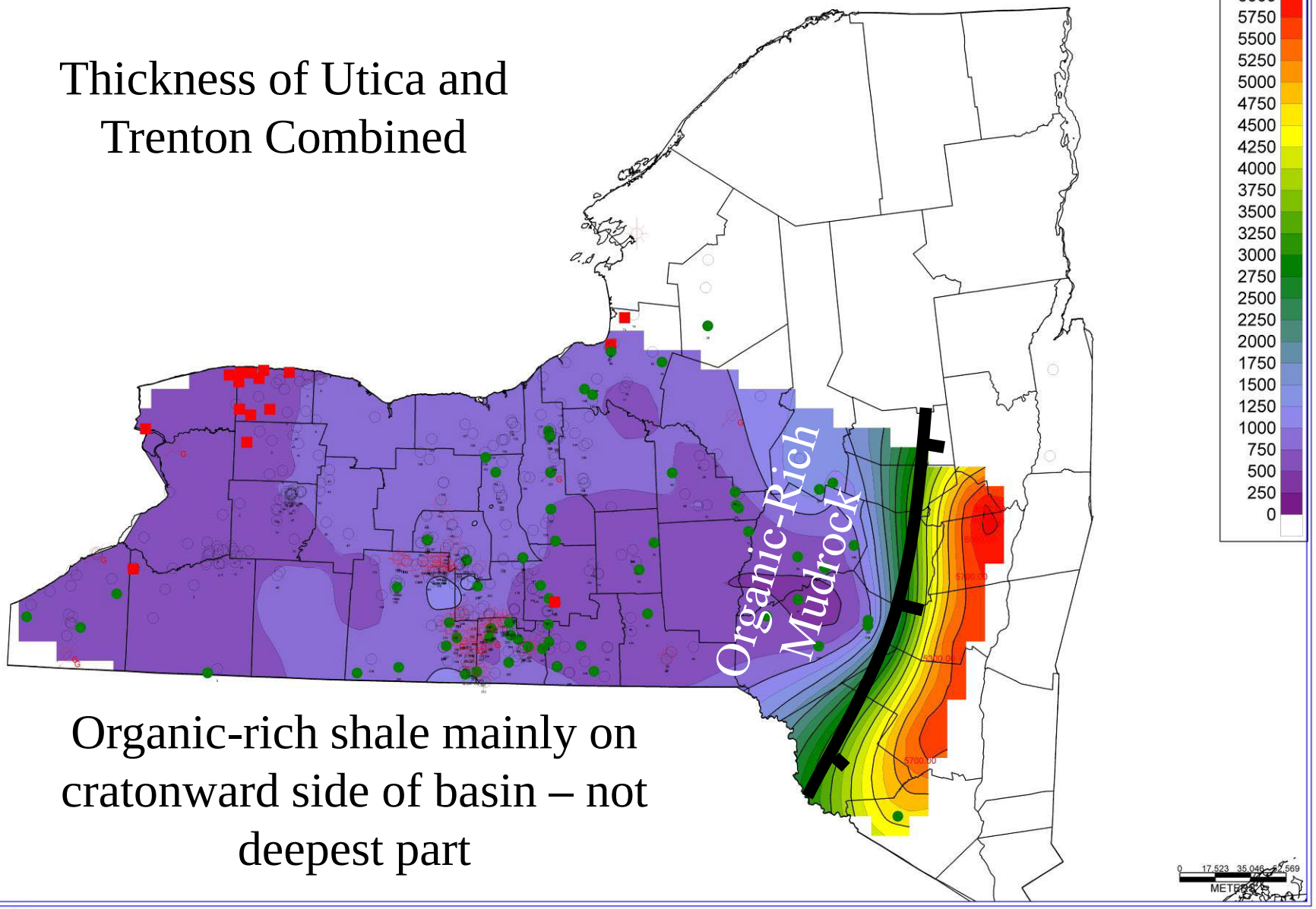


Linear trend of pinchout lines up with trend of fault-controlled HTD fields in underlying Black River



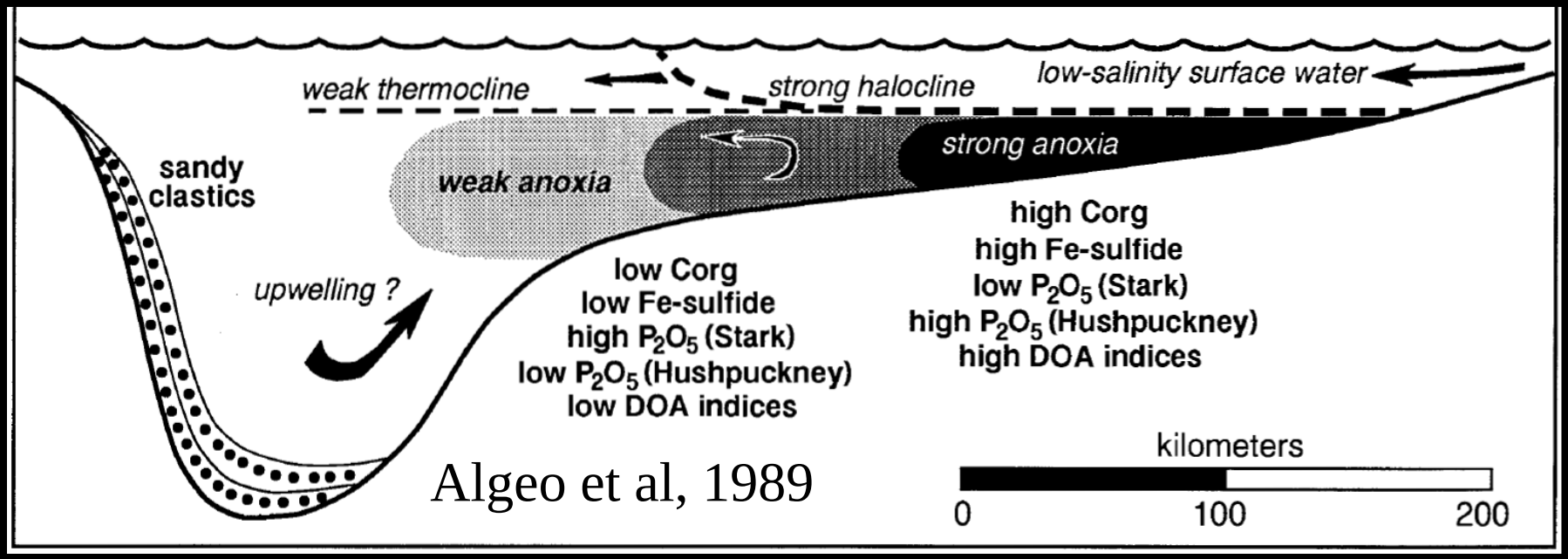
5500 feet of Utica equivalent clastics on downthrown side of fault with only minor organic-rich shale at base

Thickness of Utica and Trenton Combined

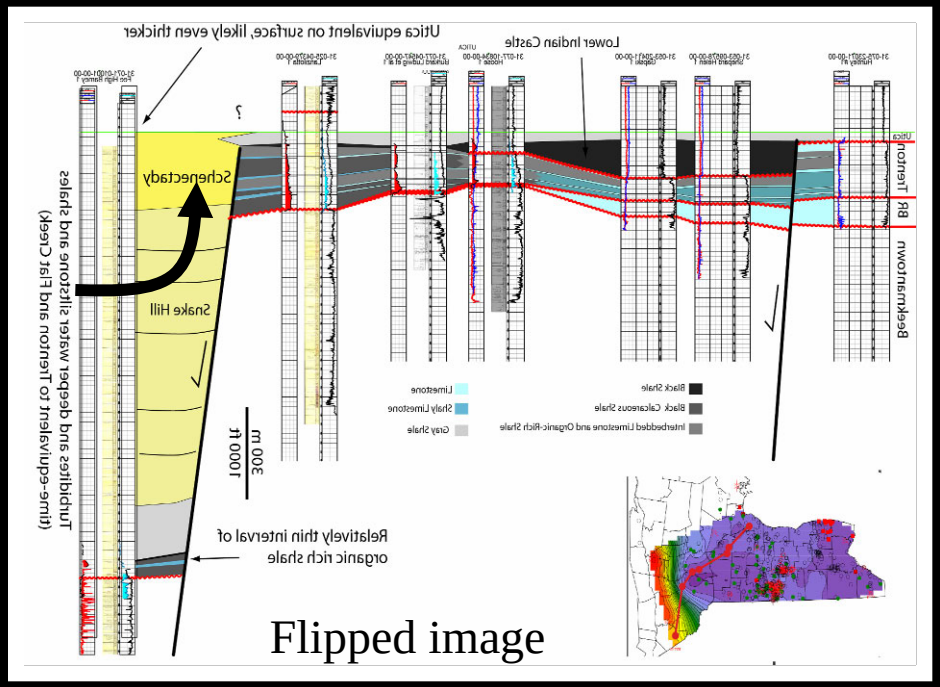


Organic-rich shale mainly on cratonward side of basin – not deepest part

Organic-rich shale mainly on upthrown shallow side of fault

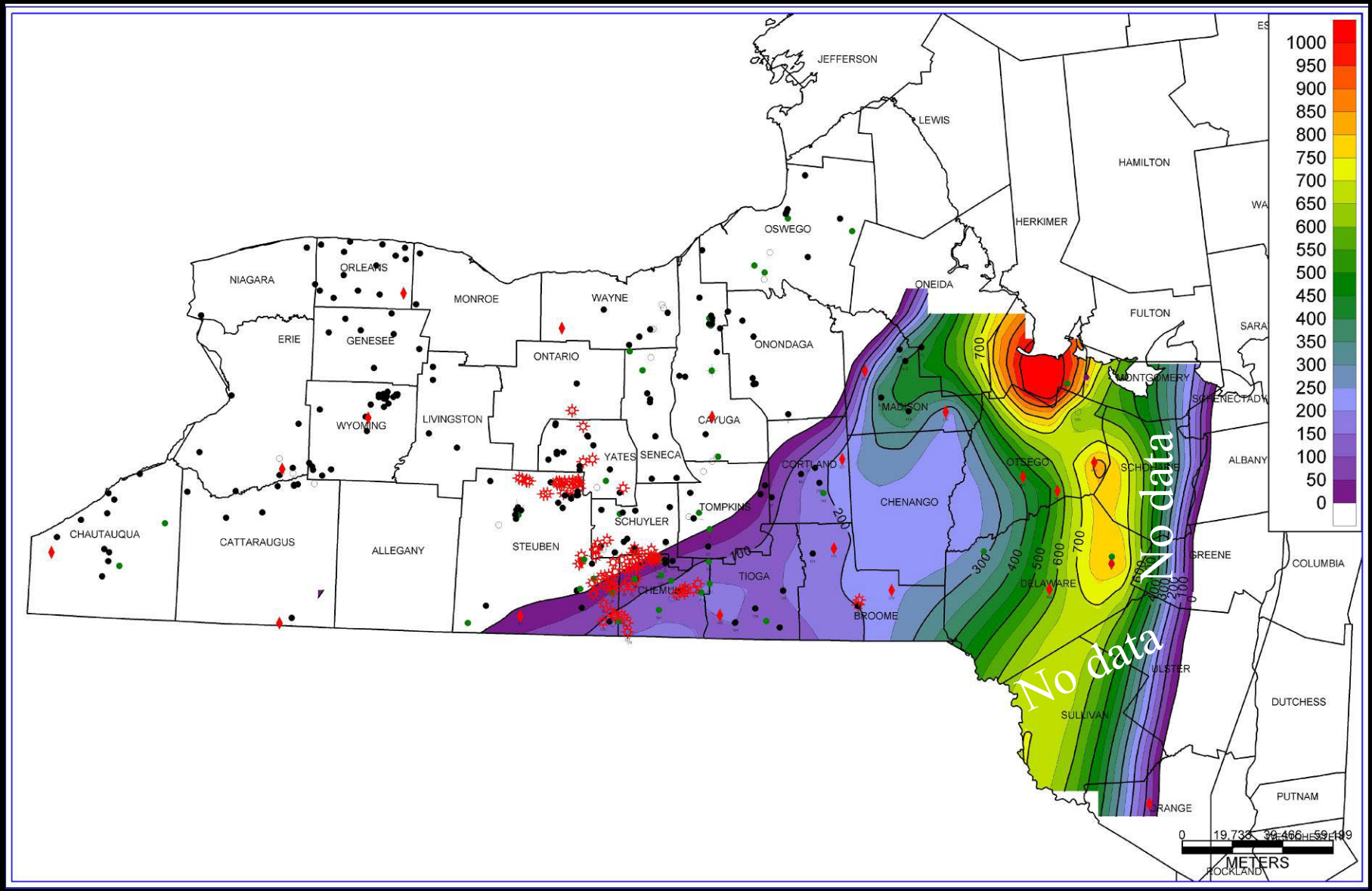


Algeo et al, 1989

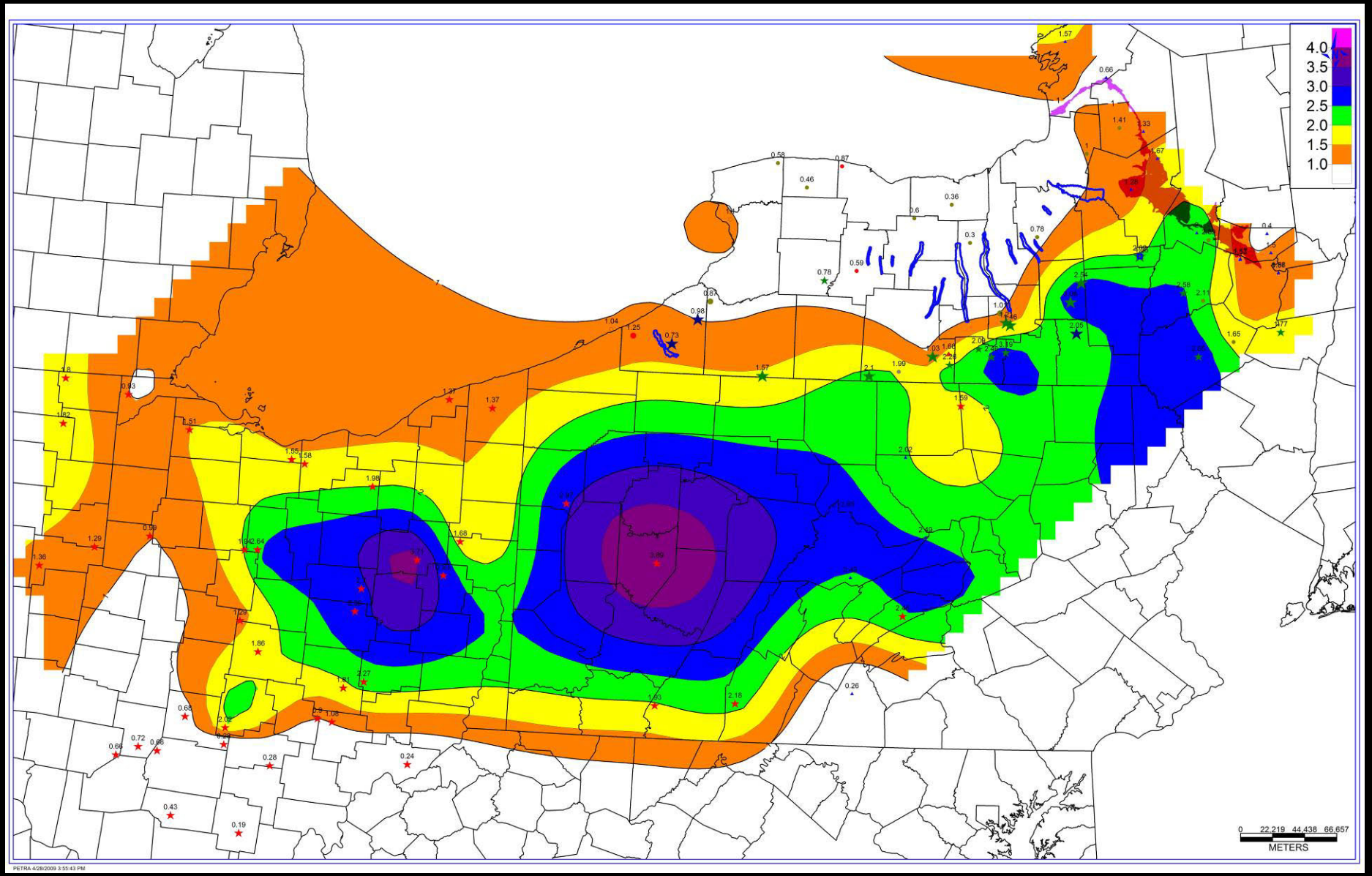


Flipped image

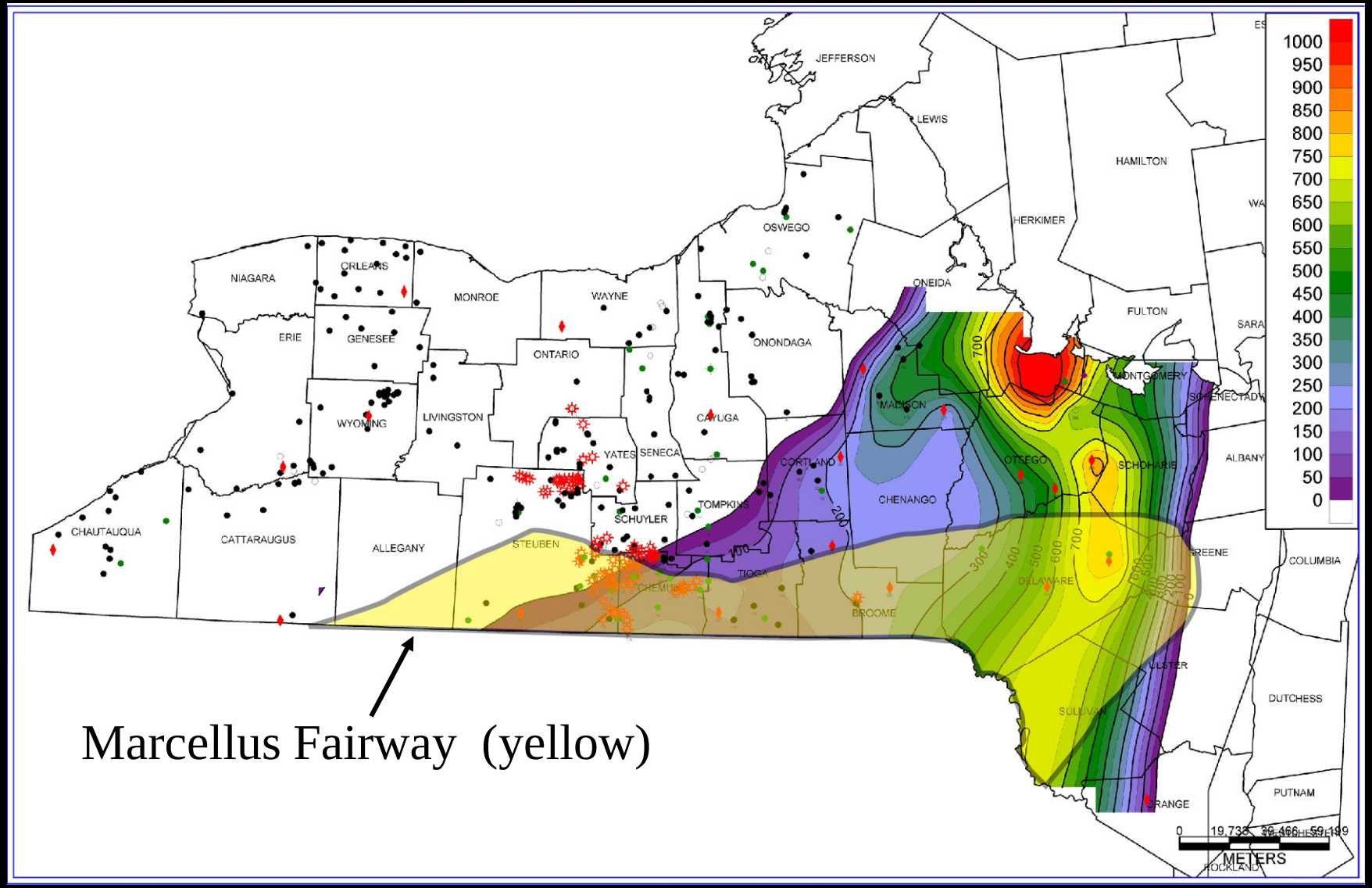
Many workers have started to question the deep basinal model for black shales and in fact many are now suggesting that these widespread shales form in 10-50 meters of water with the deeper water toward the mountain front fully oxygenated - this seems to be the case here



Estimated total thickness of organic-rich Utica (including Flat Creek, Indian Castle speculative in east where there is little data



TOC map for Ordovician Utica Shale plotting highest value for each well in northeastern US – IN NY highest TOC to southeast



Marcellus Fairway (yellow)

Special: 2 for 1- Utica and Marcellus fairways overlap in southern counties

Conclusions

- Great Potential for natural gas production in Marcellus and Utica Shales
- Both shales formed mainly on western cratonward side of foreland basin where they onlap unconformities in relatively shallow water of 10-50m, not in deepest part of basin

Thanks

- John Martin and NYSERDA as well as Range Resources, Talisman Energy, Chesapeake Energy, Southwest Energy, Anschutz Exploration, East Resources, Anadarko Petroleum for their financial support
- Reservoir Characterization Group