Update on the Regional Assessment of Gas Potential in the Devonian Marcellus and Ordovician Utica Shales in New York

Reservoir Characterization Group at the New York State Museum

NYSERDA

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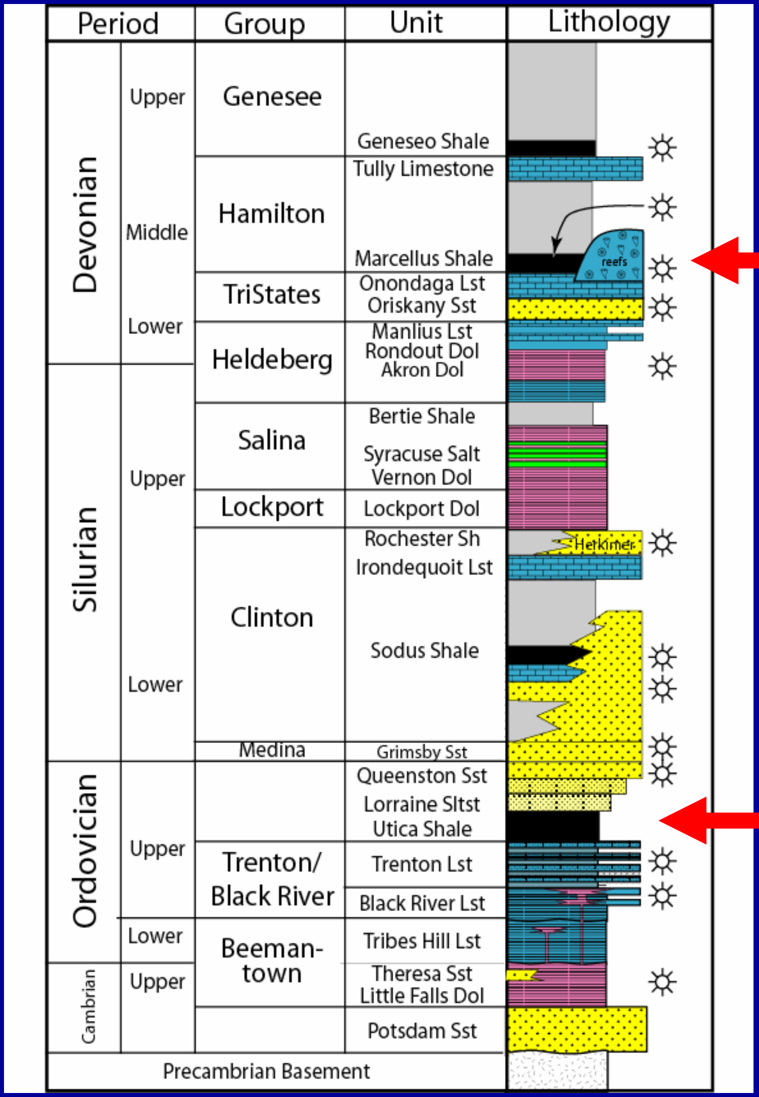
Assessing unconventional shale gas plays in New York

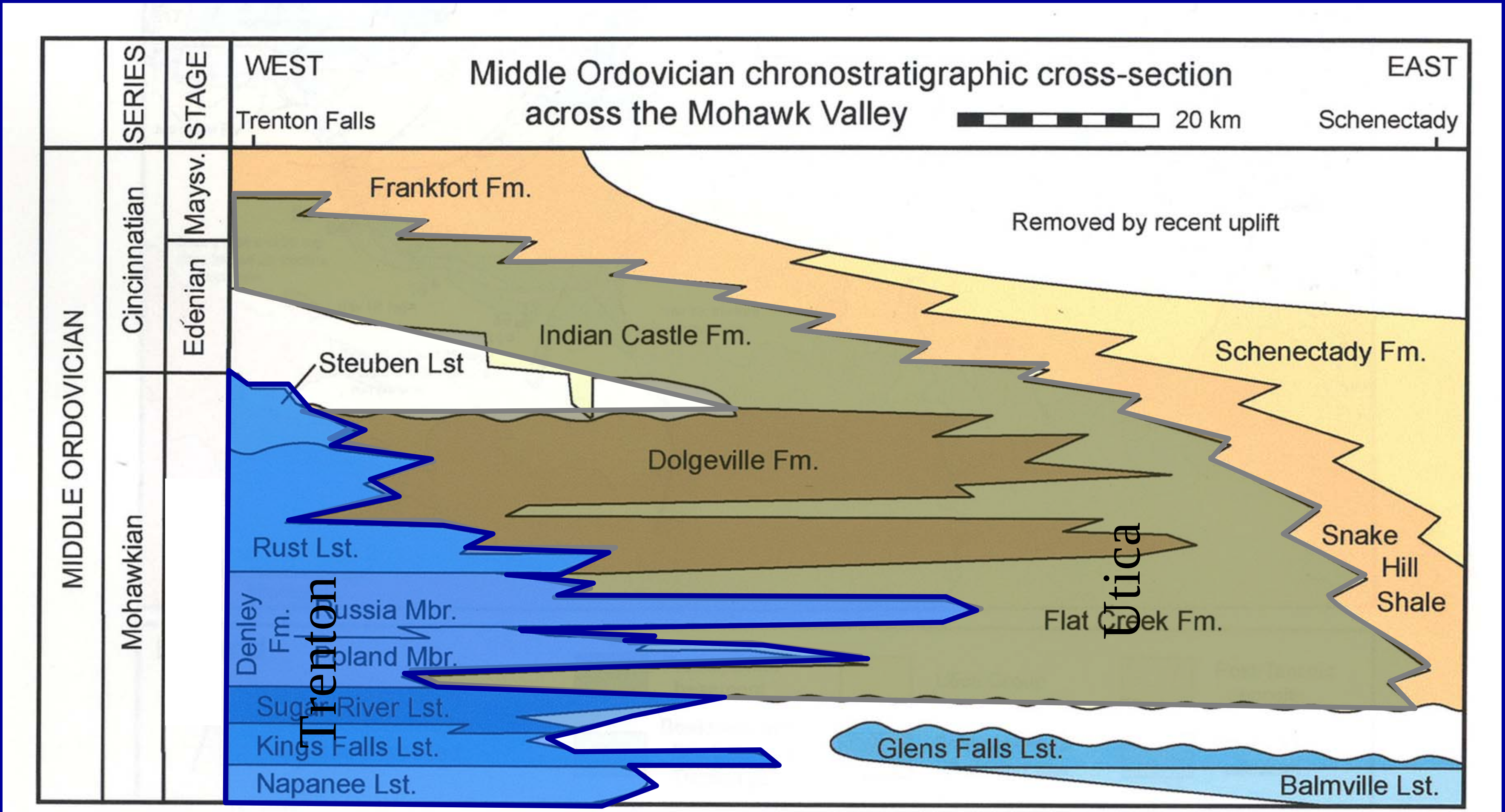
- Identify high gas potential fairways using same geochemical methods applied to the Barnett and other successful shale gas plays
- These include TOC, vitrinite reflectance, hydrogen index and transformation ratios
- Create new structure and isopach maps of shale formations and potential gas producing intervals

Two Similar Black Shales: Devonian Marcellus and Ordovician Utica



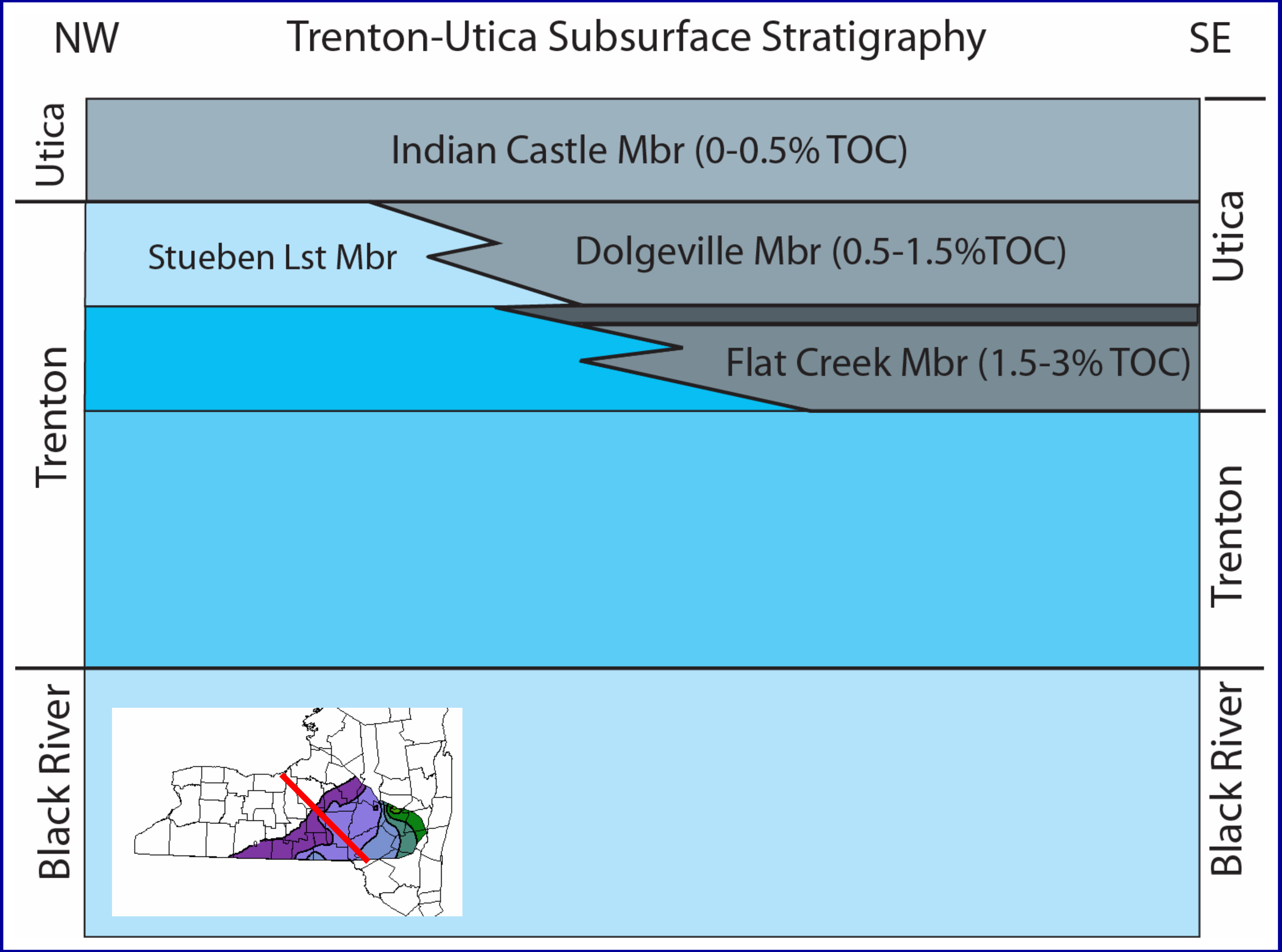
- Deposition of both shales followed lithospheric downwarping associated with tectonic loading
- Both shales terminated by shallow shelf carbonates
- Both shales thicken to the east

The Ordovician Utica Shale

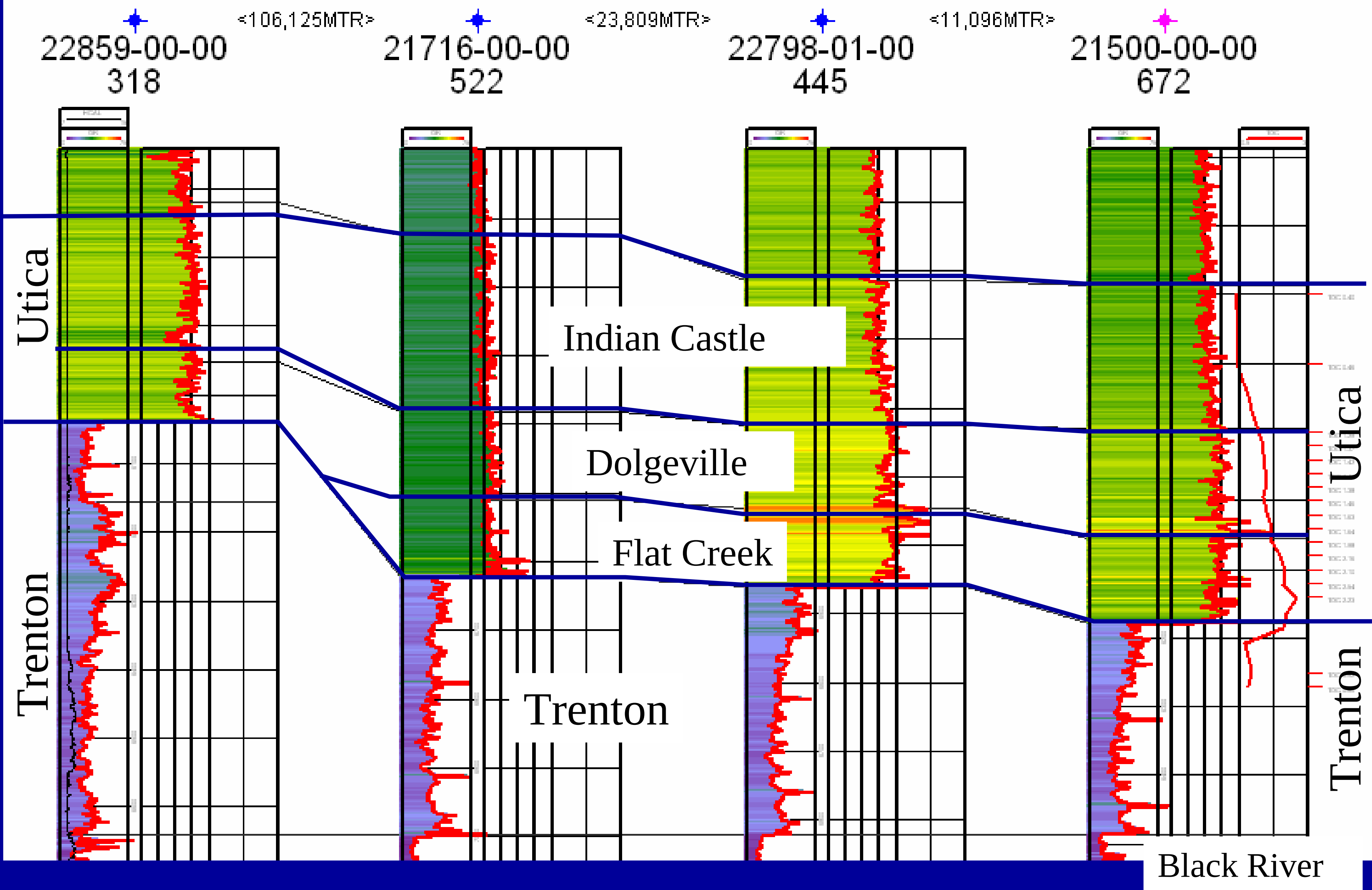


(Goldman, et al 1994)

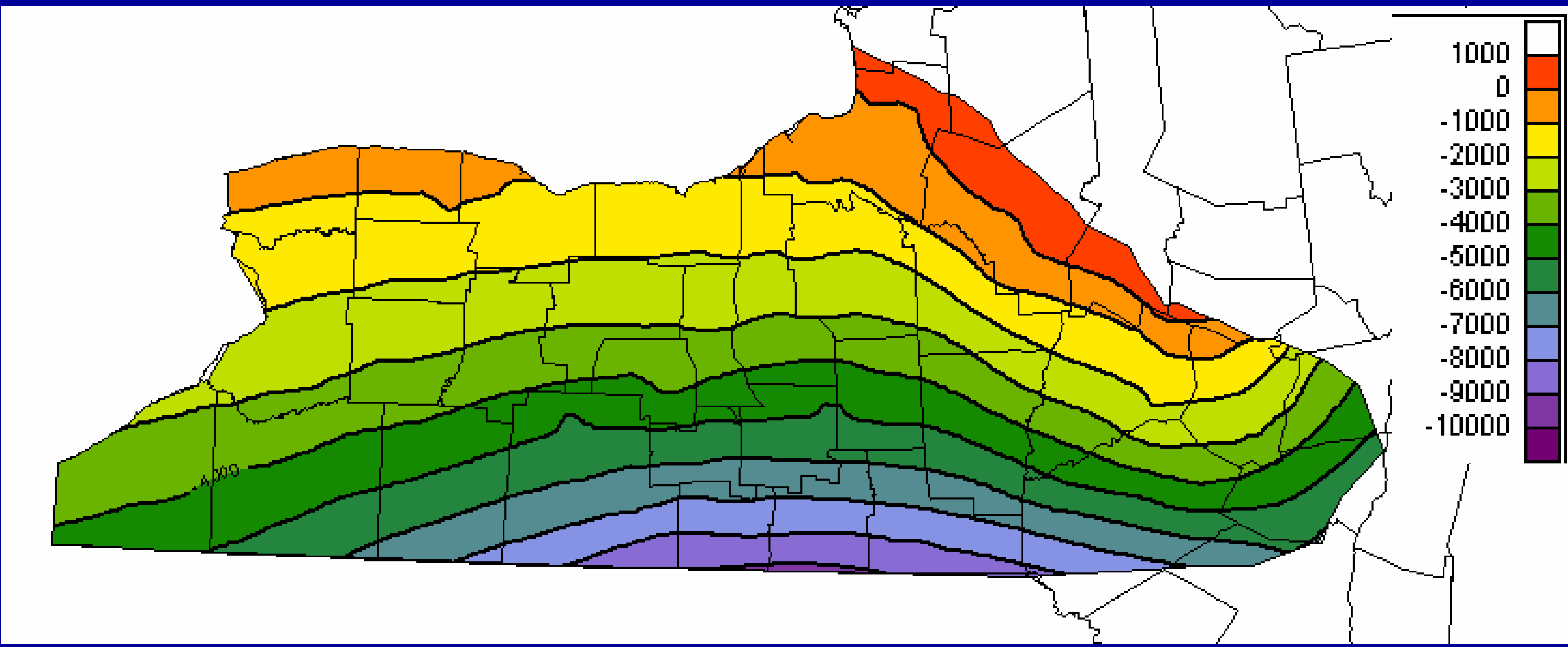
Trenton Limestone in blue colors is time-equivalent to Utica Shale in brown colors: Primarily interested in Flat Creek and to a lesser extent the Dolgeville Member


NW
Trenton-Utica Subsurface Stratigraphy
SE
Utica
Trenton
Black River
Indian Castle Mbr (0-0.5% TOC)
Stueben Lst Mbr
Dolgeville Mbr (0.5-1.5%TOC)
Flat Creek Mbr (1.5-3% TOC)
Utica
Trenton
Black River

Utica East-West Cross Section

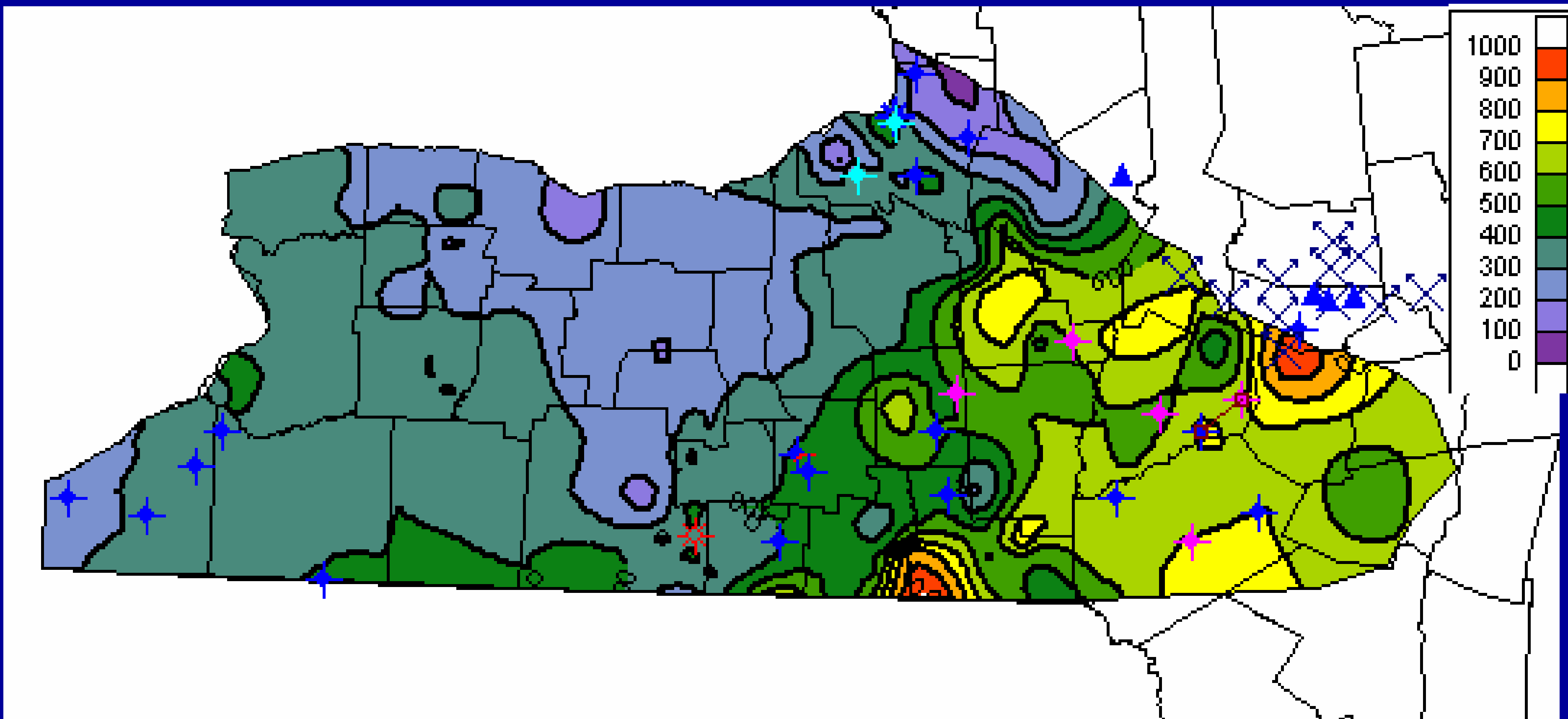


Utica Structure Contour Map



Utica gets deeper to the south

Utica Isopach Map



Utica formation thickens to the east

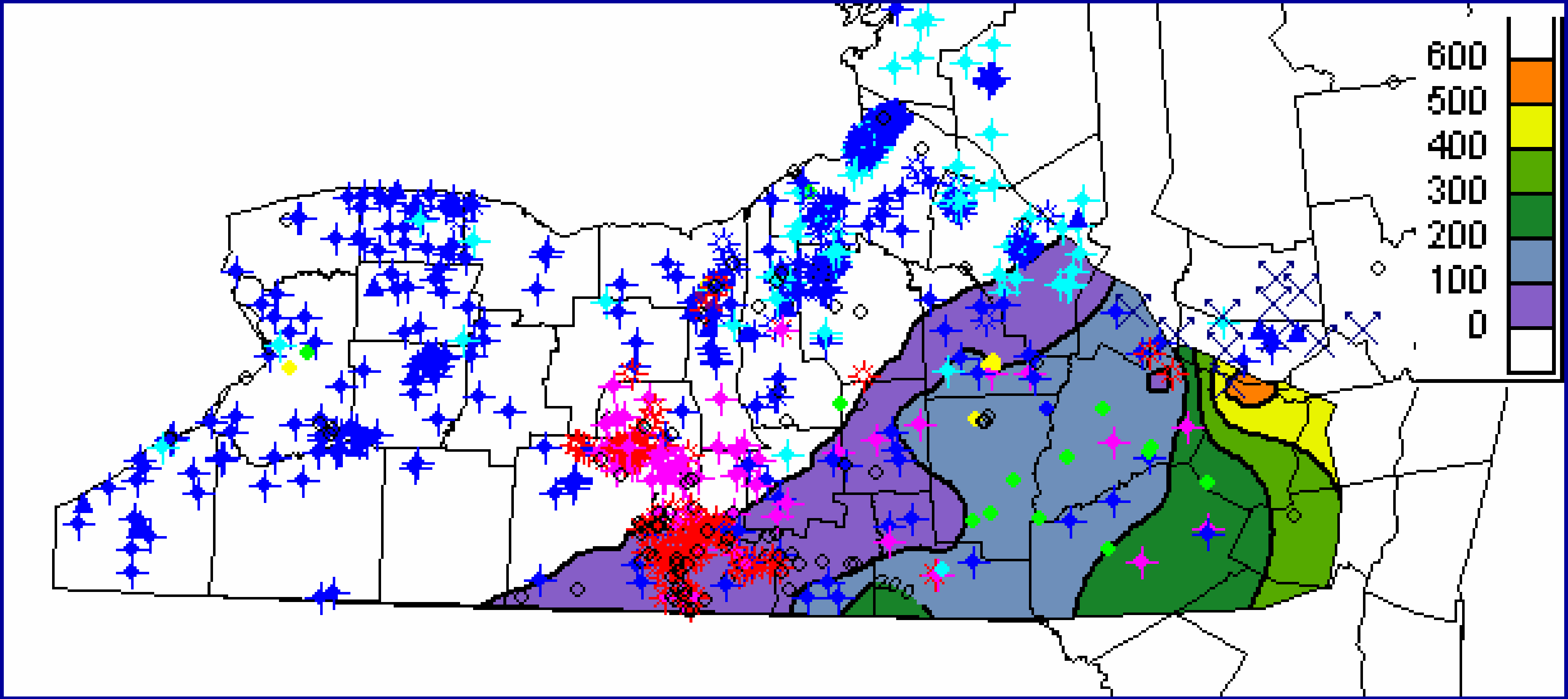
Utica Flat Creek Member

- Lowermost member of the Utica Formation
- K-bentonites and graptolites used to match key successions(Goldman, et al., 1994)
- Dark gray to black, variably calcareous shale with minor thin beds of argillaceous micrite and biomicrite (Lehmann, et al. 1995)
- Bounded by Dolgeville member on top

Utica - Flat Creek Member

Vertical calcite filled veins cutting Flat Creek Member in Chuctanunda Creek, Florida, NY

Utica Flat Creek Isopach Map



Utica Flat Creek member thickens to the southeast –
In the end, this is likely to be the Utica Fairway map

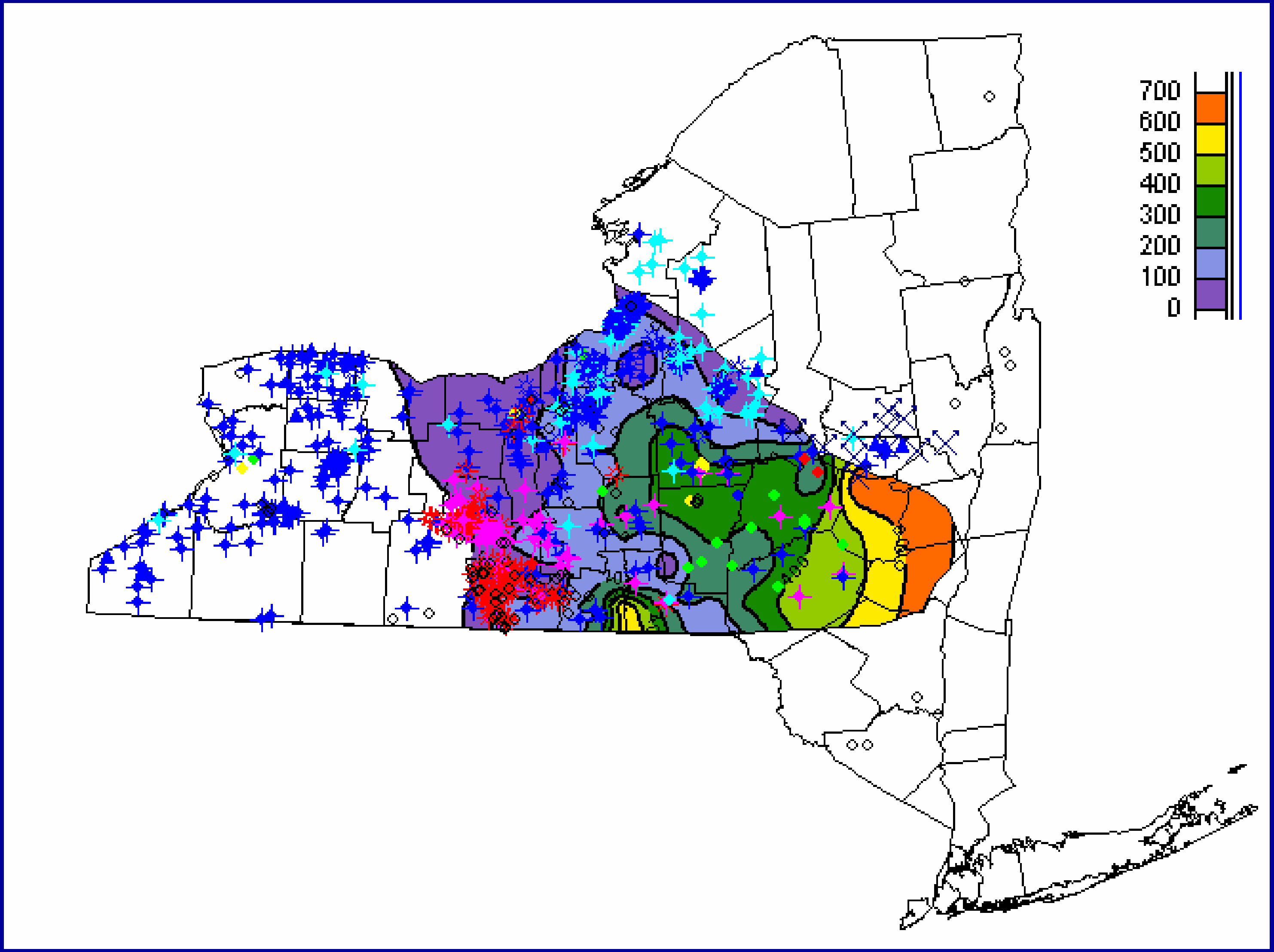
Utica - Dolgeville Member

- Interpreted as a slope facies peripheral to the Trenton platform
- Tabular ribbon limestones and dark gray to black shale beds
- Several geochemically correlated K -bentonites
- Bounded on top by Thruway unconformity
- Slump folds occur immediately below the unconformity
- Folds are dominantly asymmetrical with a westward vergence

Utica – Dolgeville Member

Asymmetrical slump fold in Dolgeville

Utica Dolgeville Isopach Map



Dolgeville thickens to southeast

Utica - Indian Castle Member

- Uppermost member of the Utica Formation blankets all of western NY
- Thin layers of fossil debris, phosphatic debris and quartz
- Condensed beds
- K-bentonites used to match key successions
- Sharp contact with underlying Steuben limestone, more subtle contact where it overlies Dolgeville
- Divided into the lower and upper sections

(Baird and Brett, 2002)

Utica - Lower Indian Castle Member

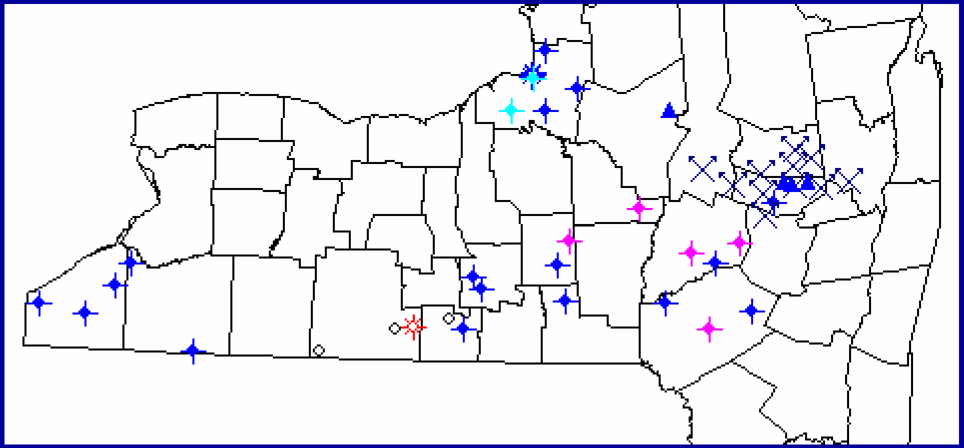
Characteristically hard, blocky shale with interbedded, tabular, impure limestone

Utica Upper Indian Castle

Monotonous fissile, black shale and silty black shale

Geochemical Study

- Using geochemistry in an attempt to define a general fairways for exploration in Utica and Marcellus
- Using the same Rock-Eval approach Jarvie et al used for the Barnett Shale



Used cuttings from 31 wells, and samples from 12 cores, 5 outcrops

Gas Production from Shales

- Gas production from tight shales requires maturation and cracking of oil that has been generated from live organic matter - need to have at least 2 percent TOC to begin with
- With increasing maturation carbon and hydrogen are lost from shale due to hydrocarbon generation
- Increasing thermal maturity therefore leads to decrease in TOC and hydrogen values
- Want shales with decent original TOC, with evidence that significant amounts of gas has formed from that TOC during thermal maturation

Geochemical Measurements

- TOC = Total organic carbon (%)
- Live carbon including S_1 (oil and gas present in shale) and S_2 (remaining kerogen)
- Tmax = The temperature at peak evolution of S_2 hydrocarbons from Rock Eval
- R_o% = Vitrinite Reflectance (calculated from Tmax)
- HI= Hydrogen Index (S_2 x100)/ TOC
- TR= Transformation or conversion ratio calculated from hydrogen index (HI)

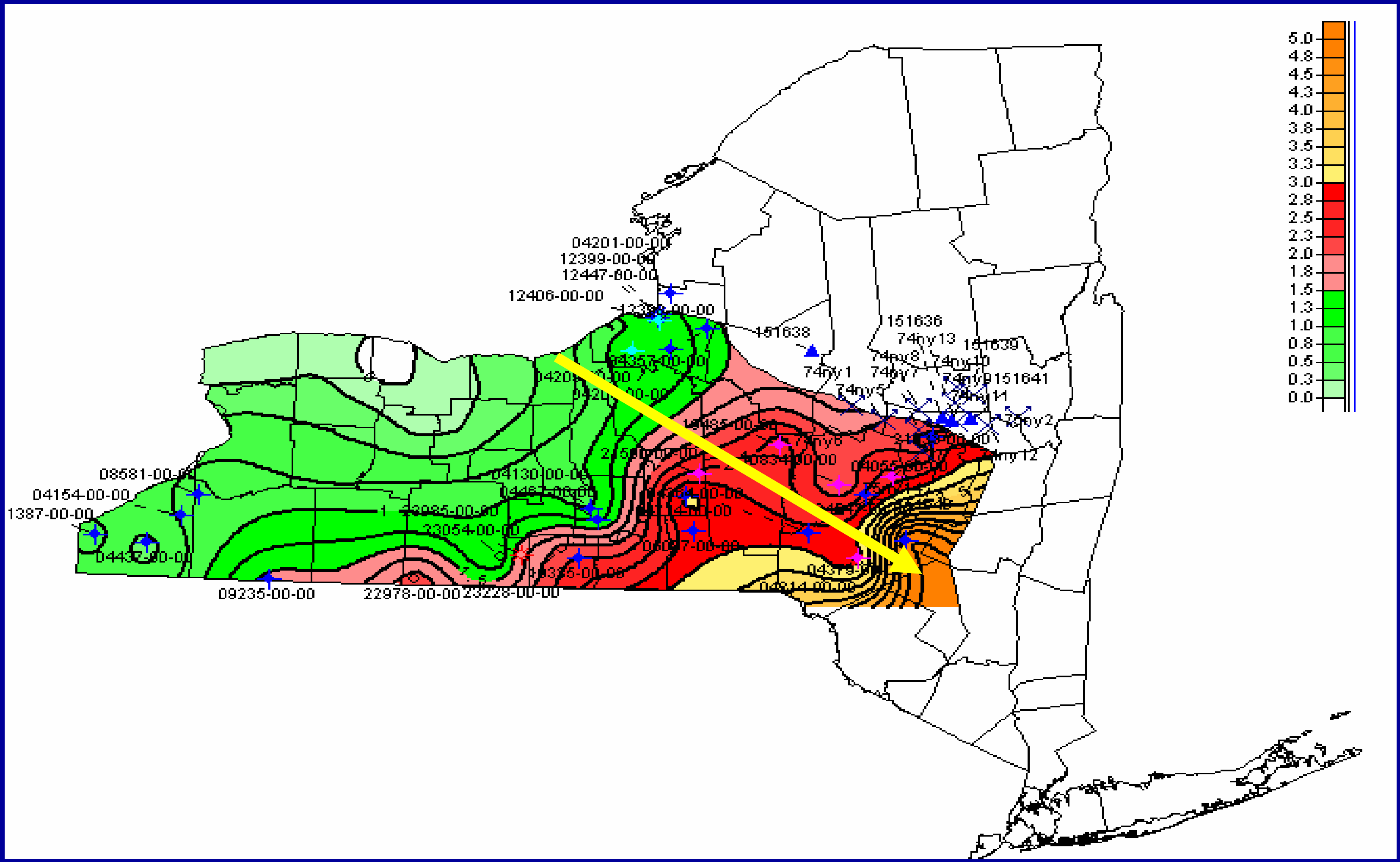
Geochemical TOC Data

- Indian Castle < .5%
- Dolgeville .5 - 1.5%
- Flat Creek 1.5 - 3%

In Jarvie, et al., 2005 study TOC from cuttings were 2.36 times lower than samples from core; therefore this same dilution effect would be seen on other geochemical parameters

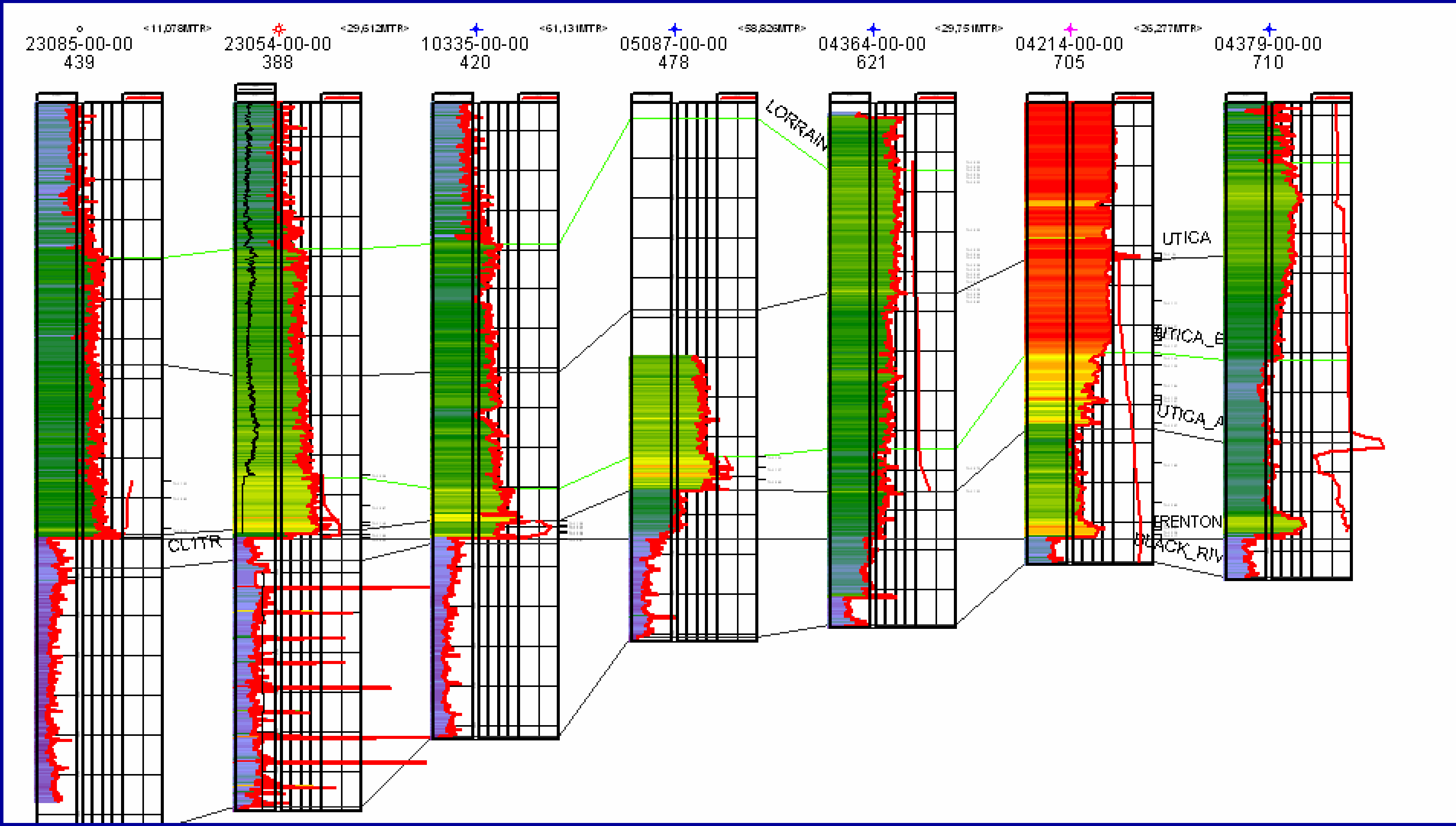
Productive shales are generally >2% TOC

Utica TOC Map



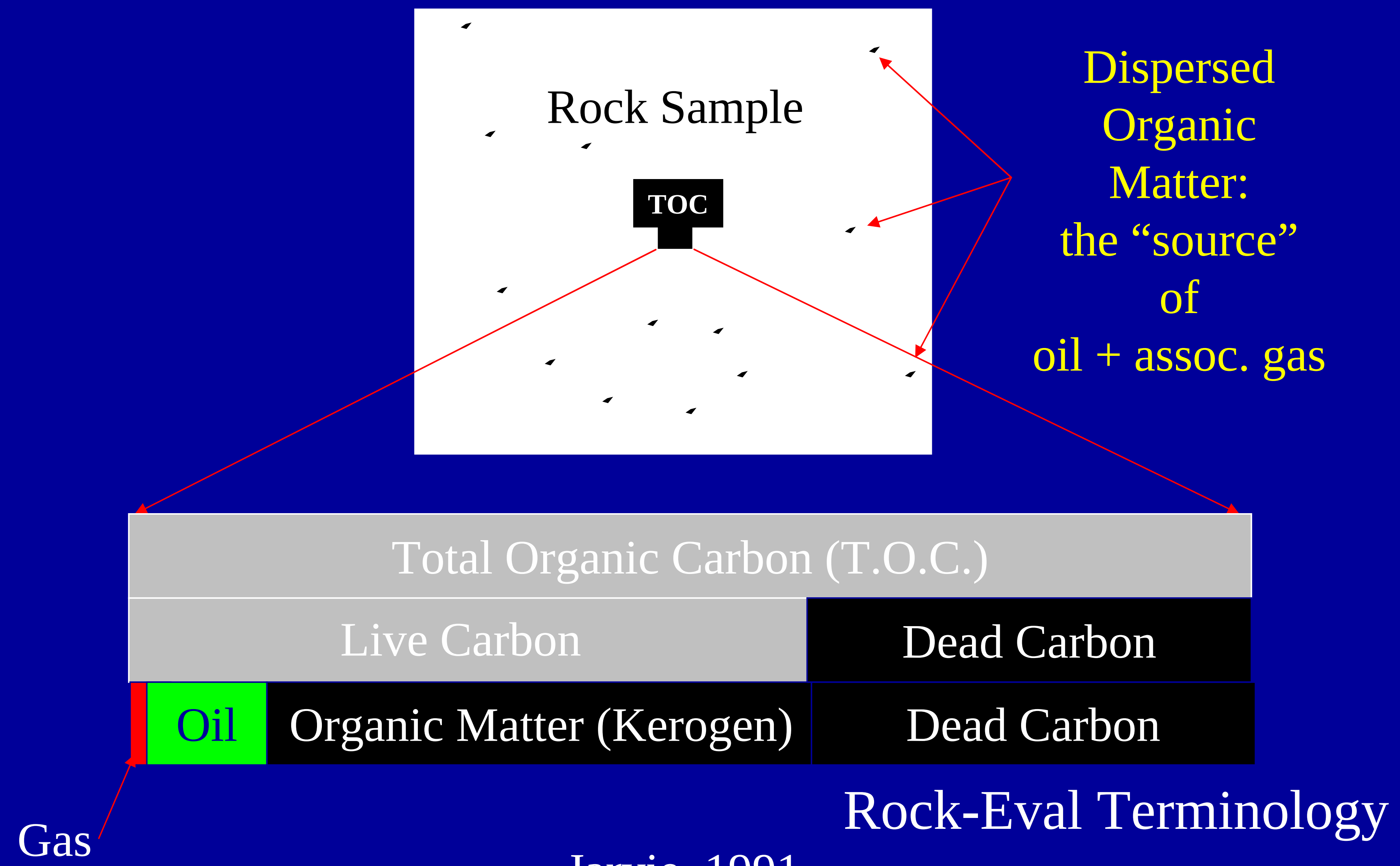
TOC increases to the SE as Utica (Flat Creek and Dolgeville members) also thickens in that direction

TOC Utica Cross Section



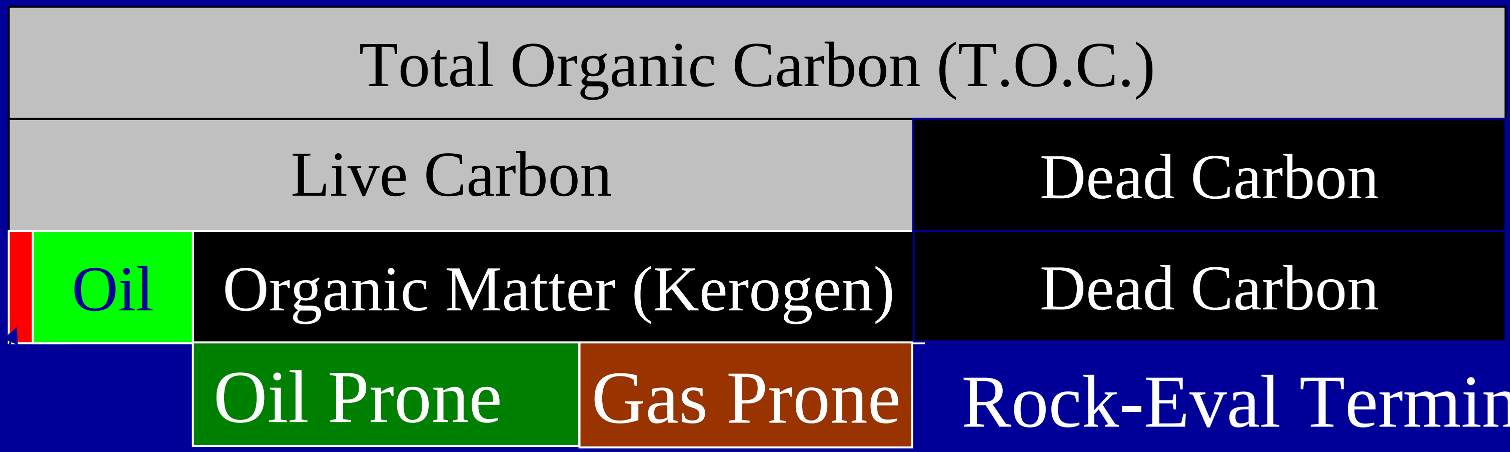
TOC increases in Dolgeville and increases more in the Flat Creek member

TOC



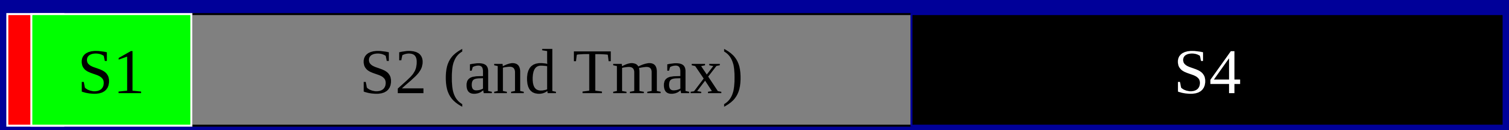
Jarvie, 1991

Distribution of Organic Matter in Rock Sample (low maturity)



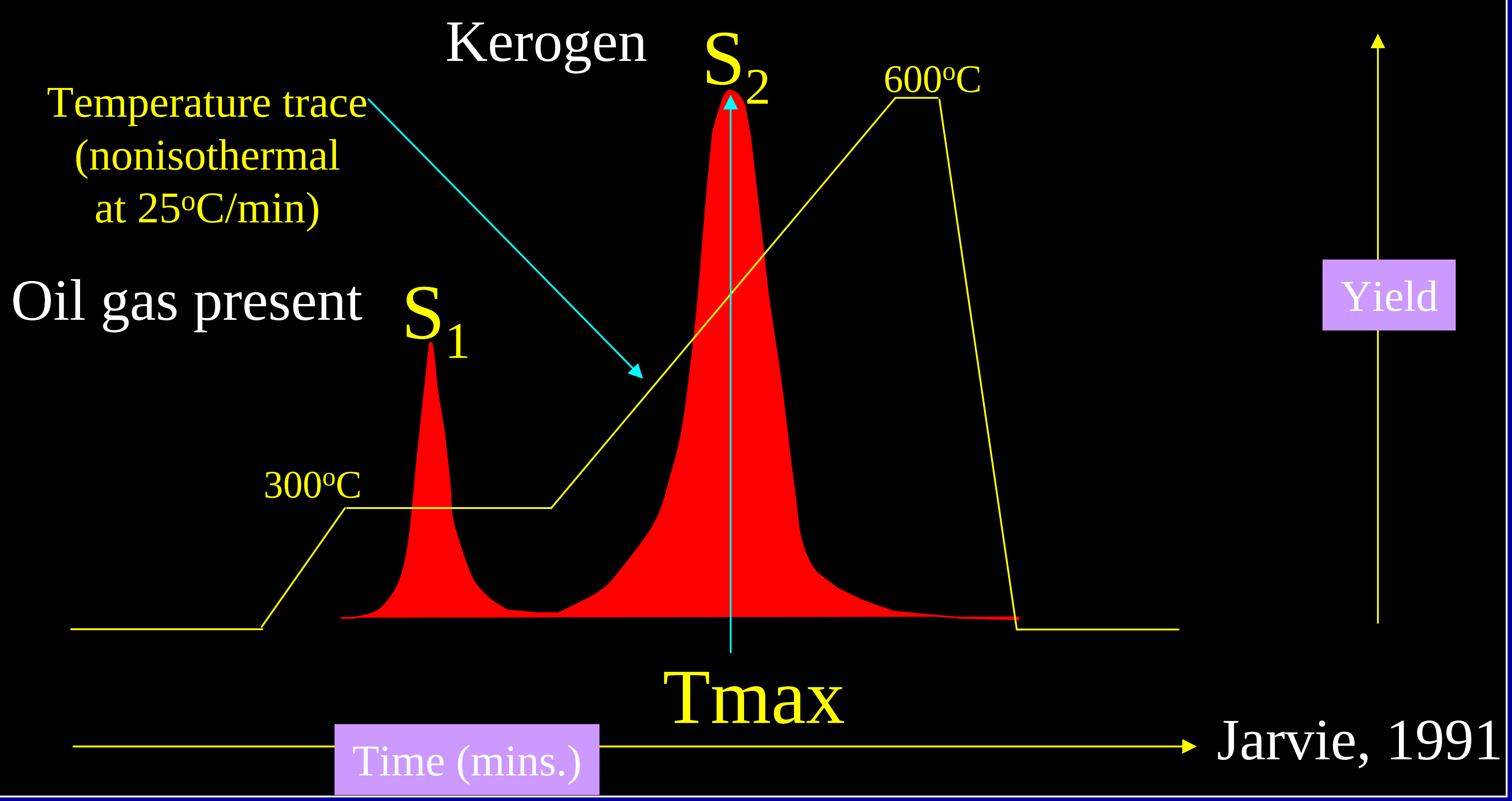
Rock-Eval Terminology

Rock-Eval analysis - terminology



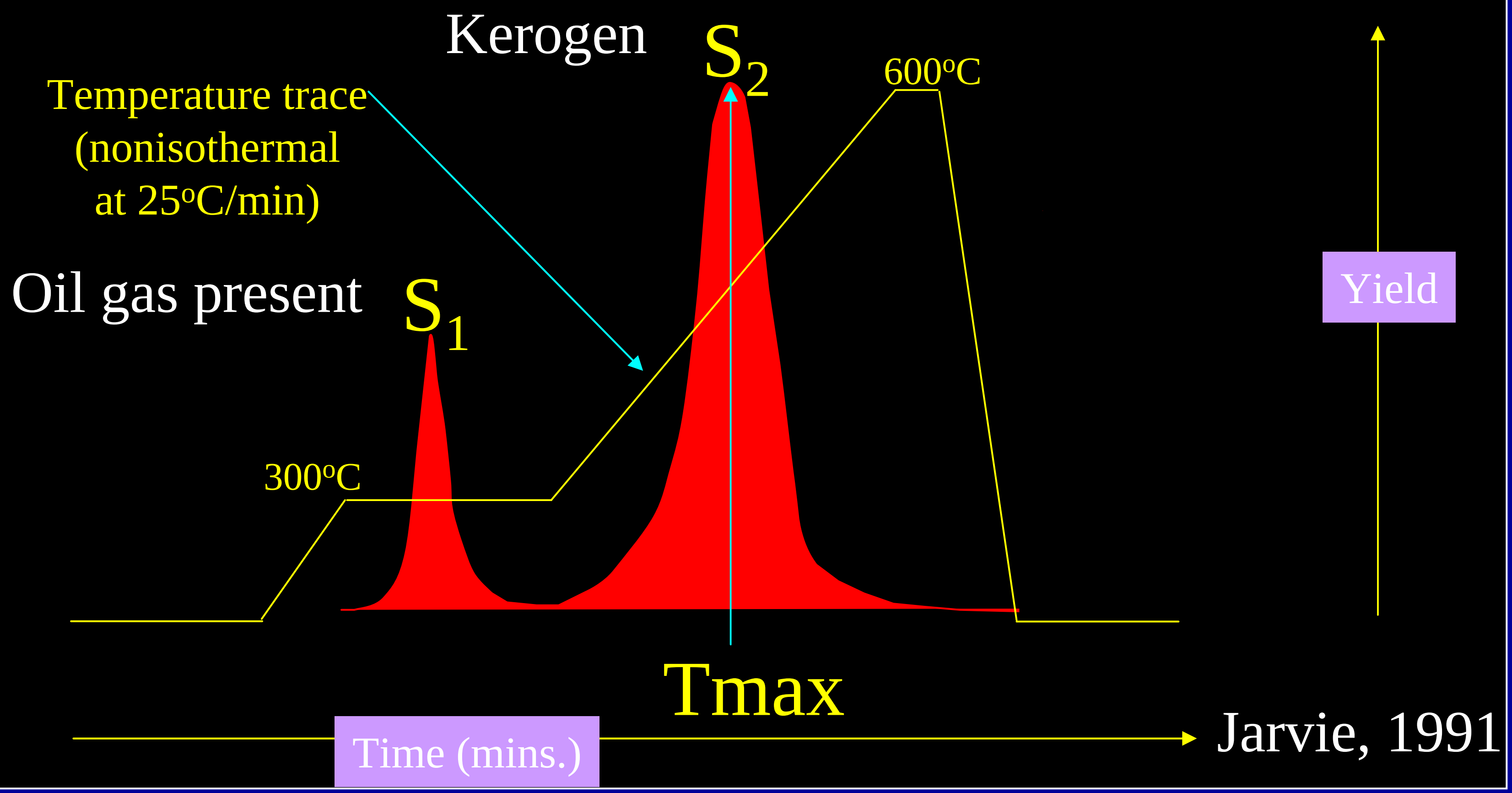
If S_1 and S_2 are very low, this means that almost all remaining carbon is dead carbon – the rock cannot and will not generate any more hydrocarbons

Rock-Eval or SR Analyzer “Pyrogram”



- S_1 = Free volatile hydrocarbons thermally flushed from a rock sample at 300°C
- S_2 =products that crack during standard Rock-Eval pyrolysis temperatures 300°C-600°C

Rock-Eval or SR Analyzer "Pyrogram"

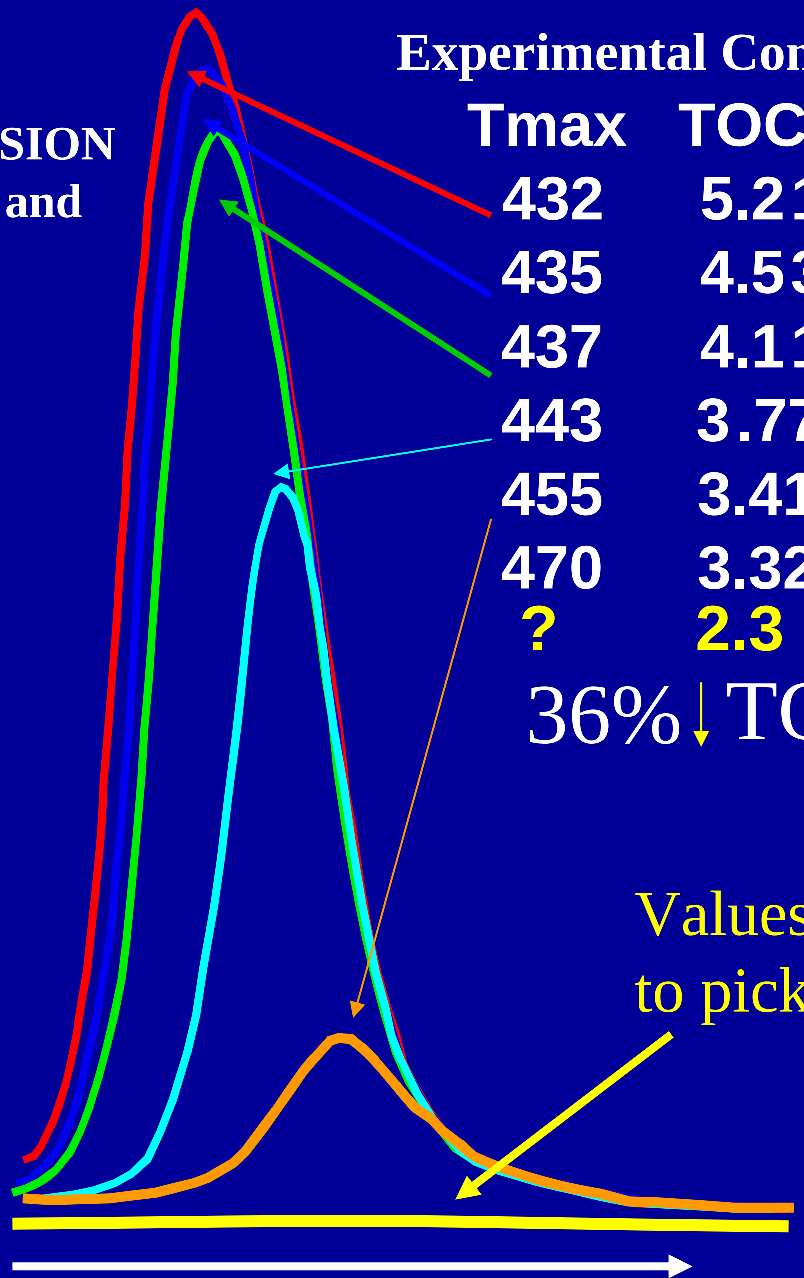


In order to get a reliable Tmax, it is necessary that $S_2>S_1$ and the value of $S_2>0.2$ - If $S_1>S_2$ or S_2 has very low values (<0.2) that means that there is very little remaining live carbon (kerogen or oil and gas)

Experimental Conversion of Barnett Shale

CONVERSION TO OIL and GAS

Remaining potential decreases



Tmax	TOC	S2	HI
432	5.21	19.80	380
435	4.53	13.45	297
437	4.11	10.27	250
443	3.77	5.88	156
455	3.41	1.81	53
470	3.32	1.36	41
?	2.3	<0.2	<10 ← Utica

36%↓TOC

89%↓ HI

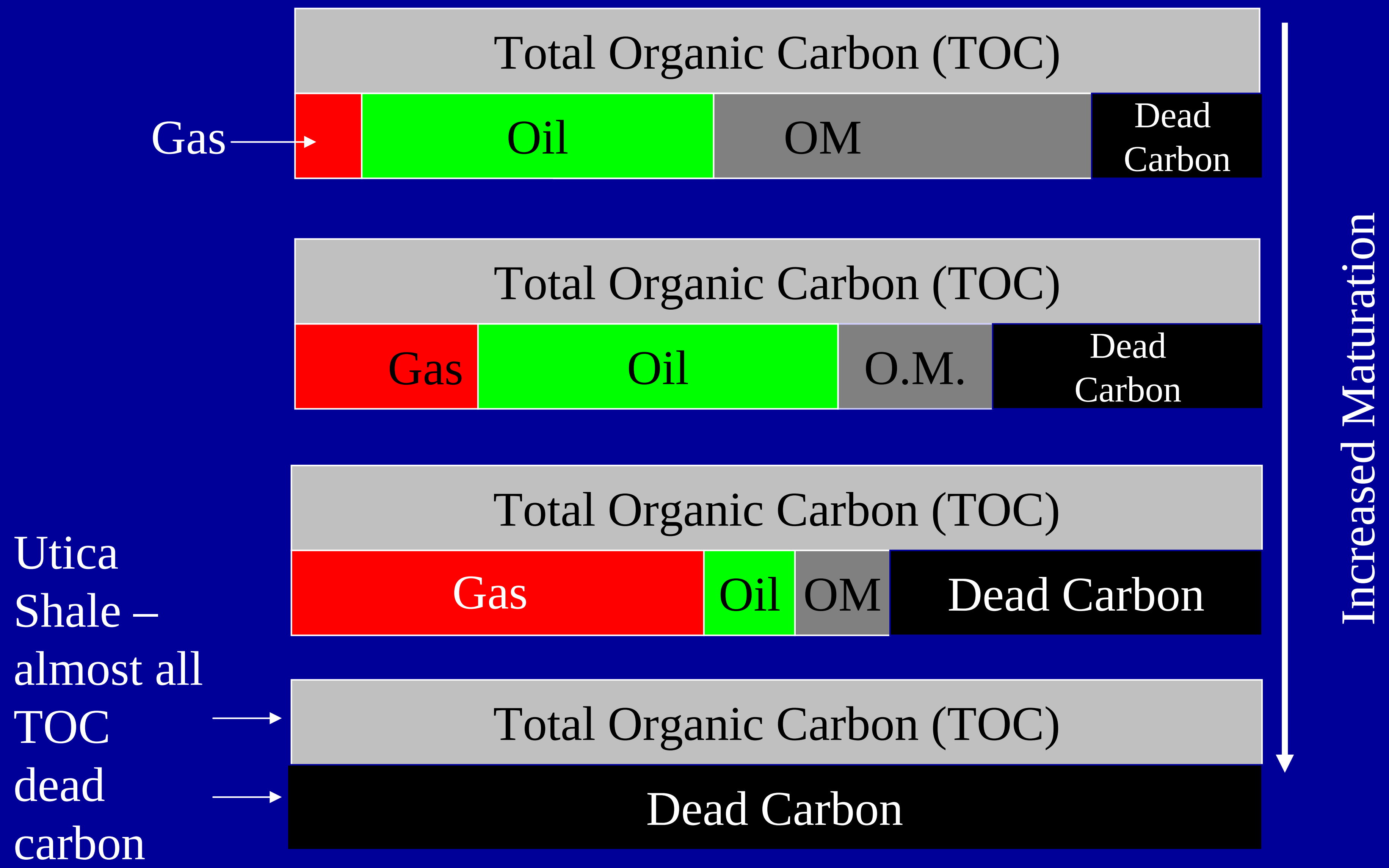
Values so low it is hard to pick Tmax

Utica →

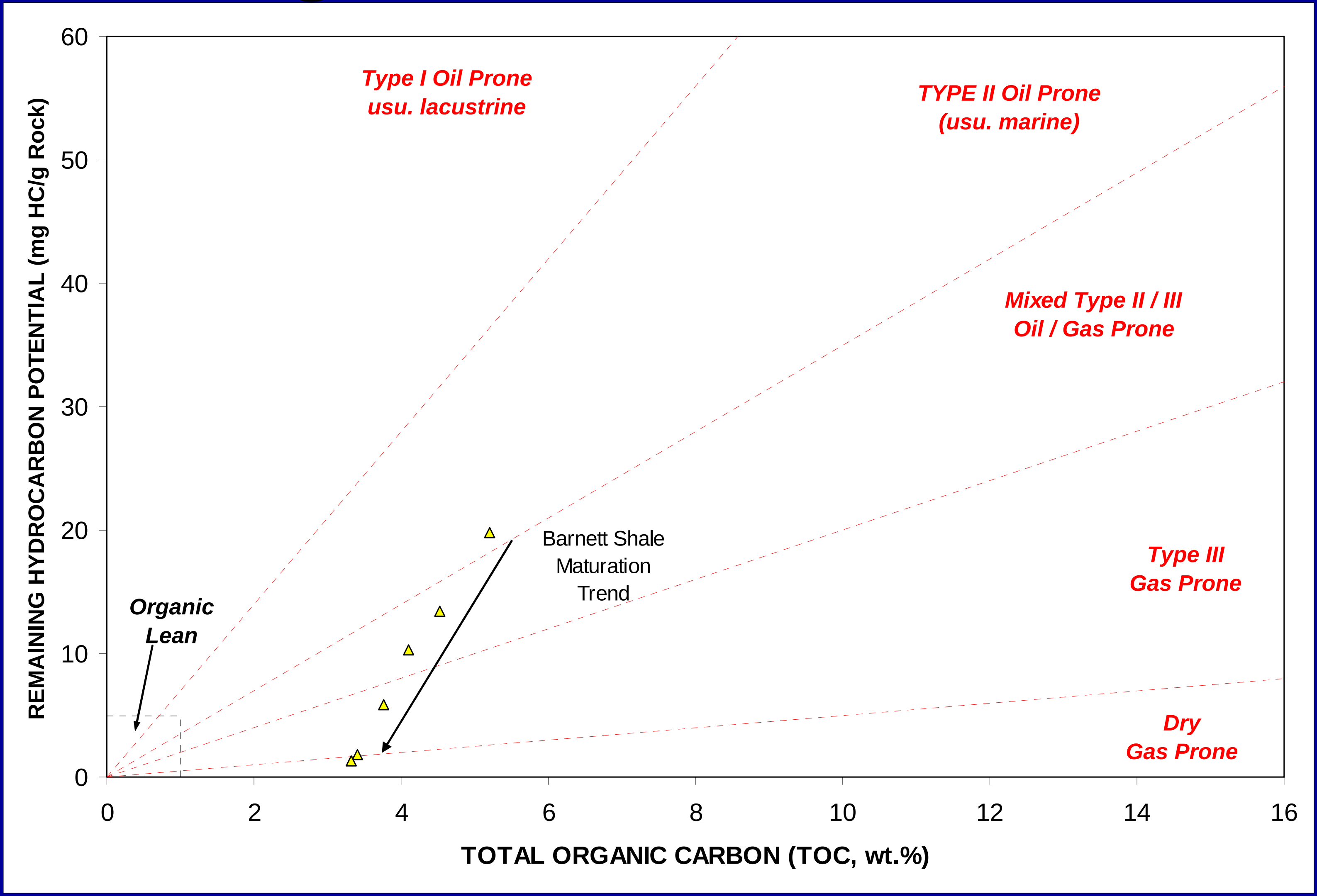
Tmax increases

INCREASING THERMAL MATURITY

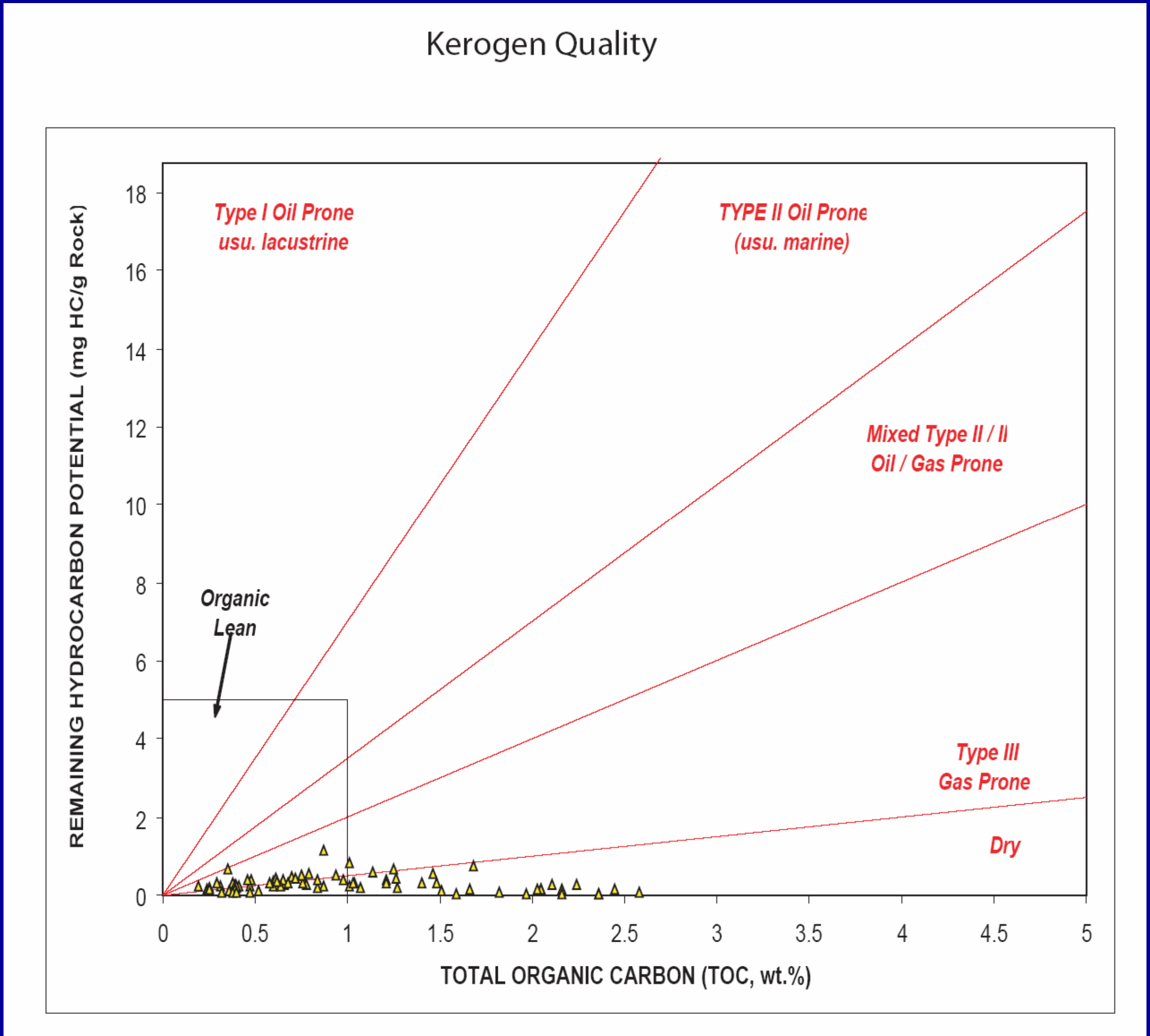
Maturation of Organic Matter – modified from Jarvie



Barnett Shale has samples with range of maturation values



Utica Samples



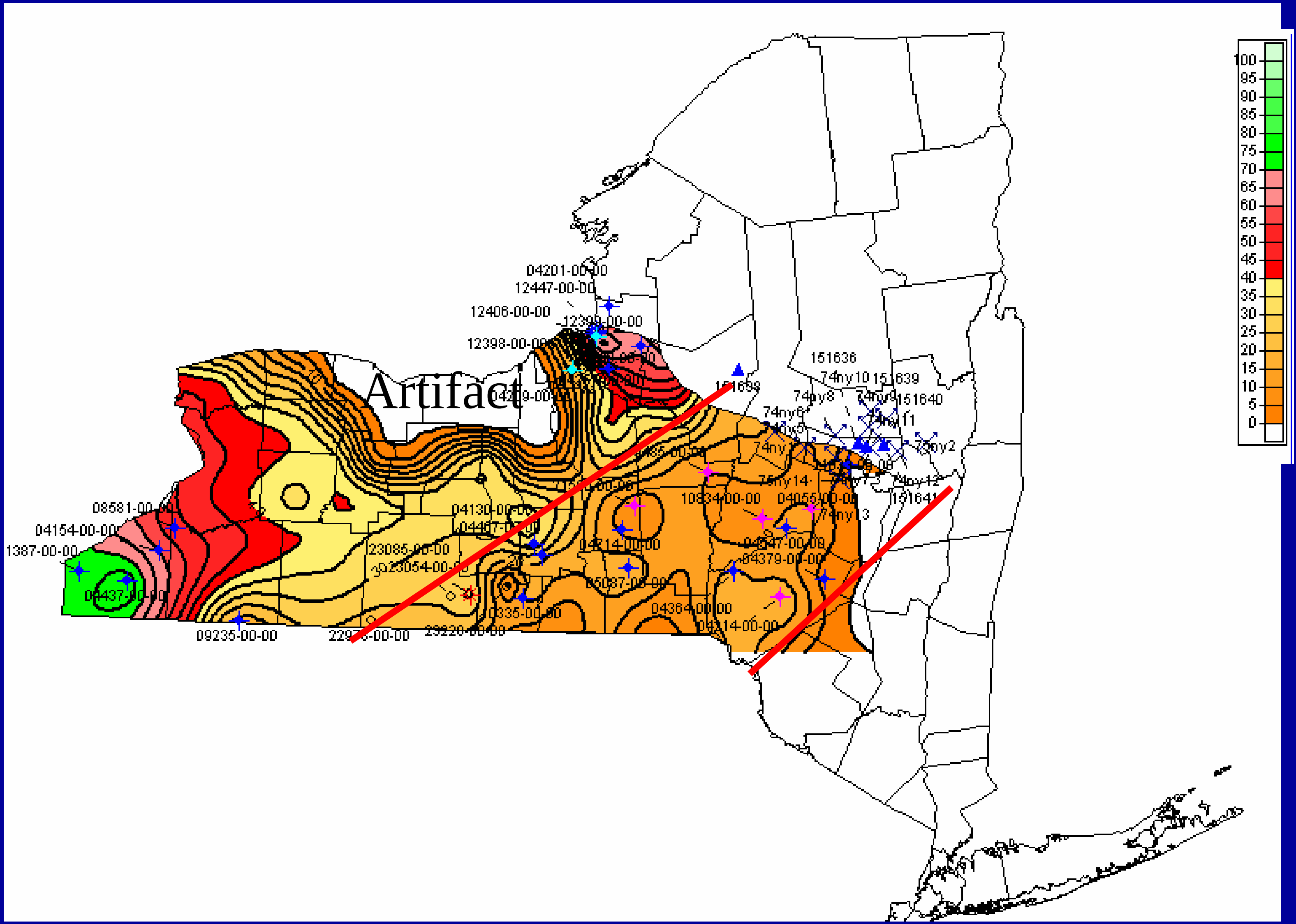
Utica T_{max} and Vitrinite Reflectance (R_o)

- Tmax is the temperature where S_2 peaks
- Because >95% of the S_2 values in the Utica are too low and/or <S_1, the T_{max} values are unreliable in the Utica Shale
- T_{max} can be used in some cases to obtain a calculated value for vitirinite reflectance (R_o) by the formula R_o=0.0180*Tmax-7.16
- Because T_{max} is unreliable in the Utica, it is not possible to calculate reliable values for R_o

Hydrogen Index

- Hydrogen Index (HI) is a calculation to determine the amount of hydrogen remaining in the shale
- $HI = (S_2*100)/TOC$
- HI decreases as thermal maturity increases because S_2 goes down
- Again, S_2 is uniformly very, very low in Utica so the HI values largely driven by TOC –
- Lower values are generally thought to be better in Utica as they represent higher original TOC

Utica Flat Creek HI Map

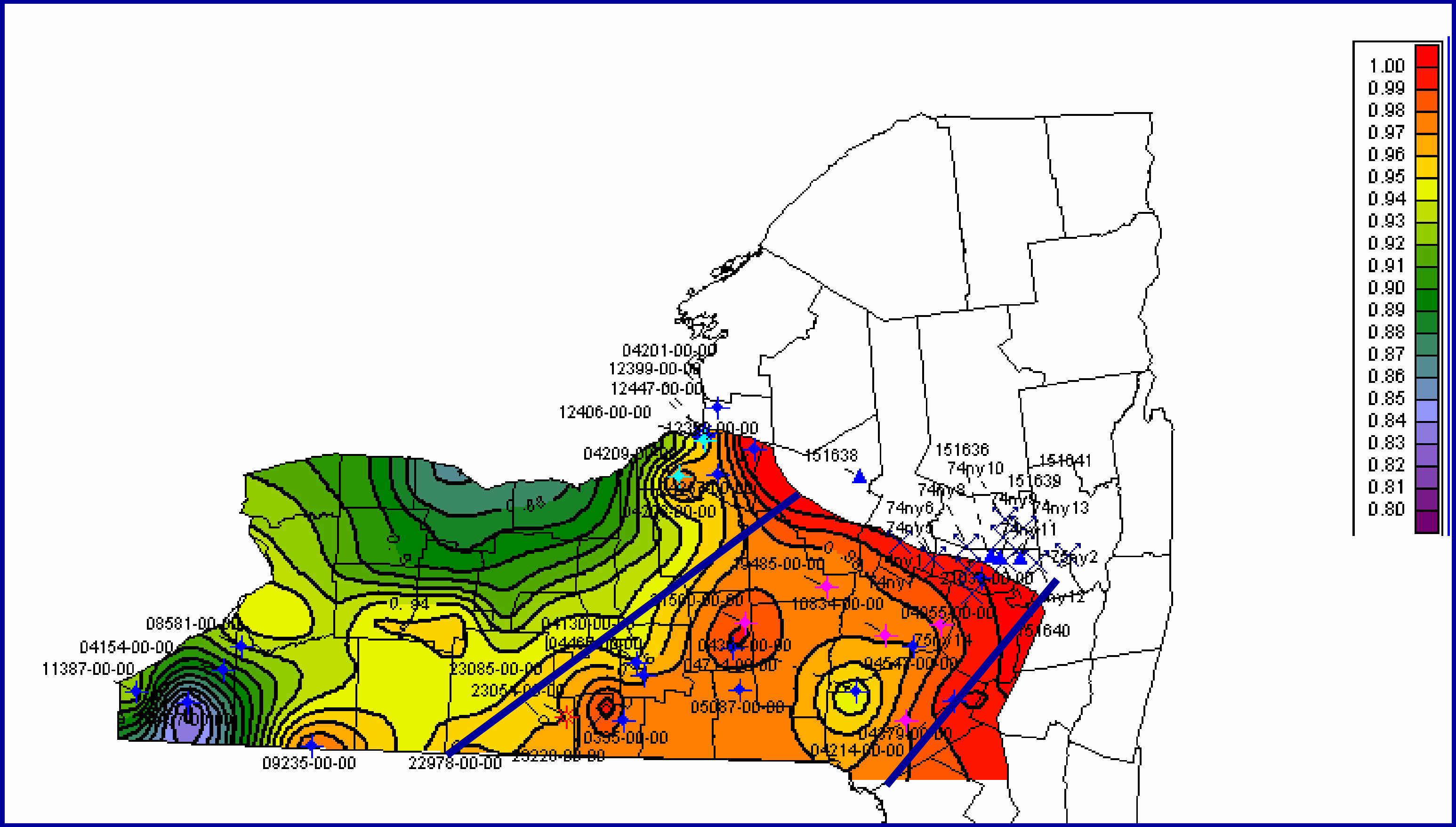


Lowest values occur where TOC was highest in Flat Creek and Dolgeville

Transformation Ratio

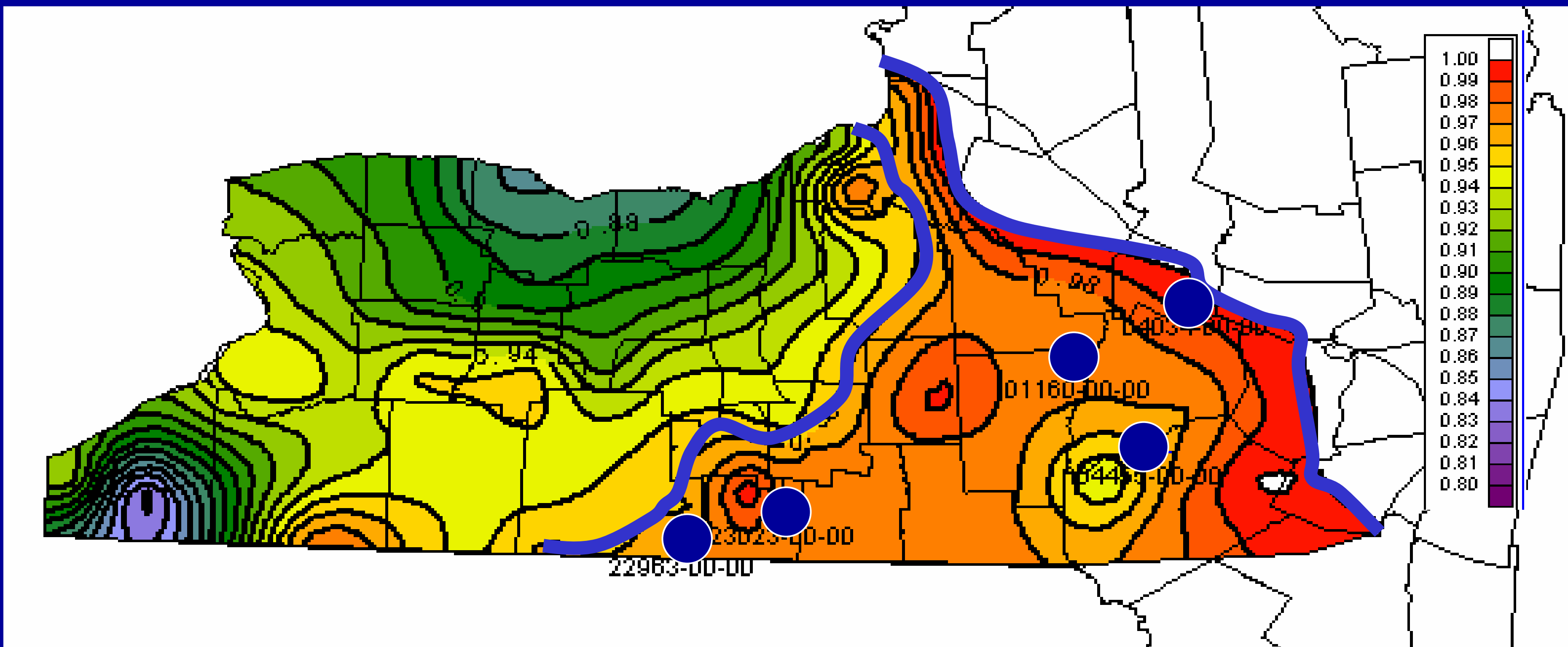
- Evaluates the conversion directly by measuring changes in the kerogen (organic matter) yields
- In order to calculate this ratio, you need the present day Hydrogen index (HI_{pd}) and original Hydrogen index (HI_o) (see Jarvie, et al., 2007 for formula)
- Areas with highest potential for production have values approaching 1, lower values = lower potential

Utica Flat Creek Transformation Ratio Map



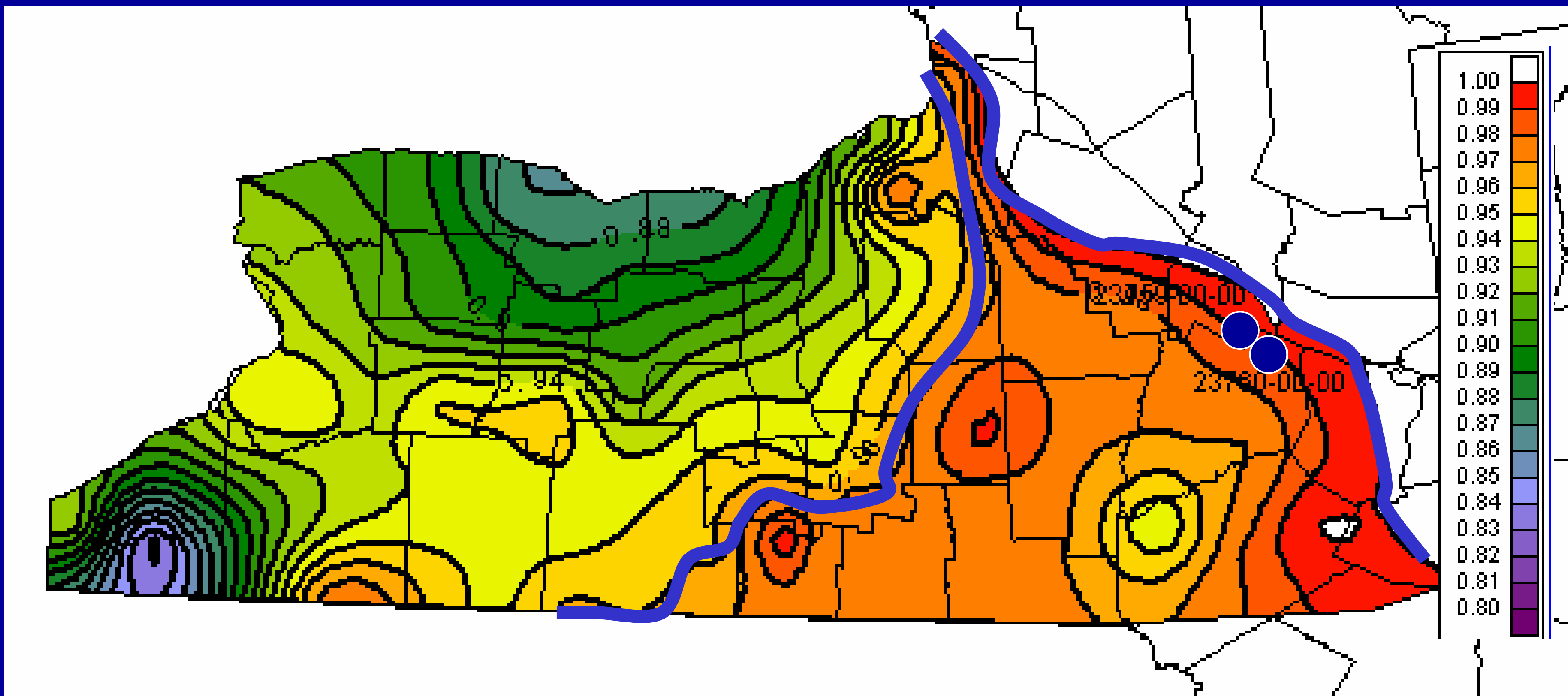
Best TR values occur where the Flat Creek and Dolgeville occur – all of these values driven by higher TOC in those members

Wells with good Utica shows and TR Map



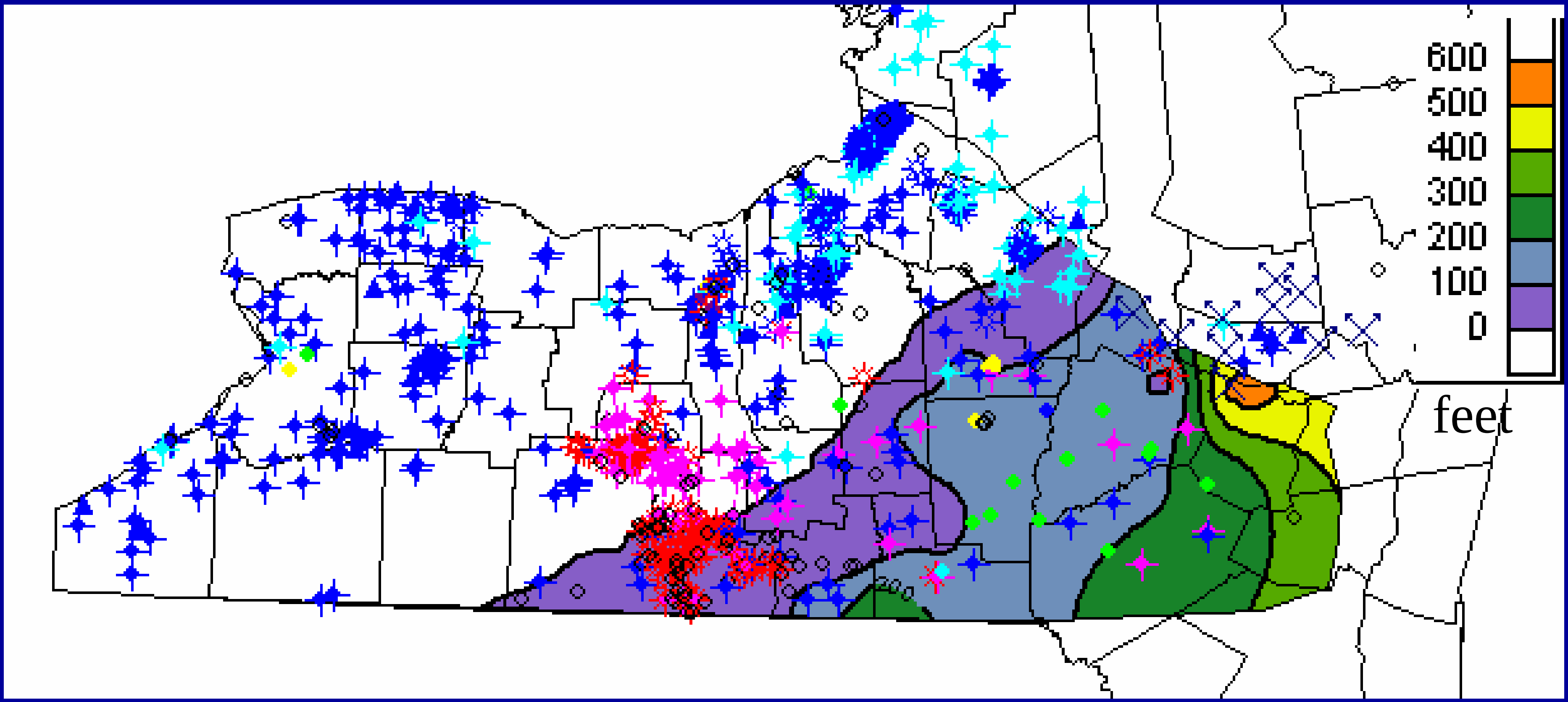
Inside the blue lines as defined by the transformation ratio might be a productive fairway for Utica Flat Creek prospects

New Utica wells and TR map



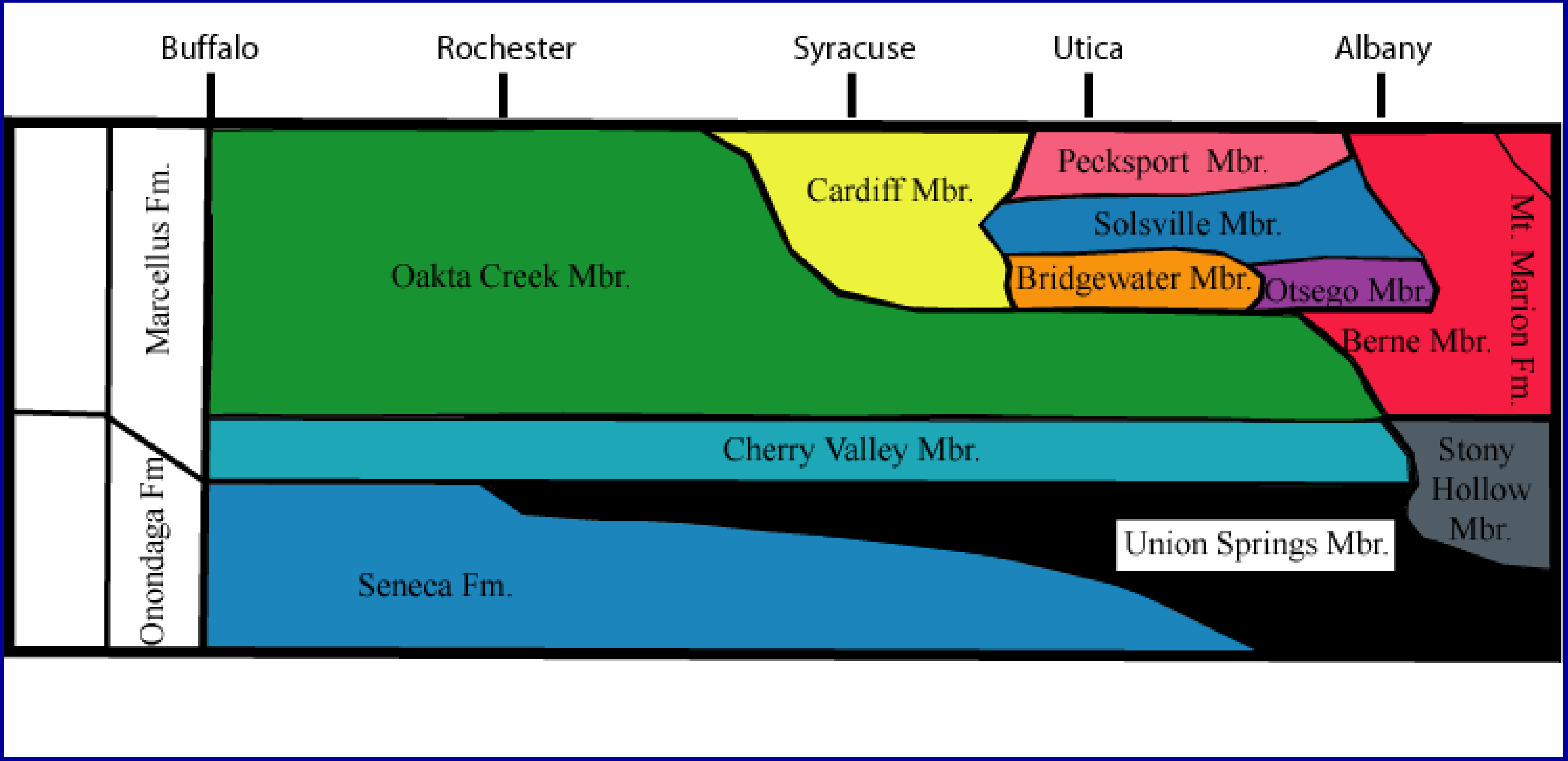
Inside the blue lines as defined by the transformation ratio are the newly drilled wells – awaiting results

Utica Flat Creek Isopach Map



The Utica Fairway is probably best defined by the Flat Creek Mbr isopach map – All of the Utica is supermature; the Flat Creek had the highest original TOC which drives HI and TR maps

The Devonian Marcellus Shale



Primarily interested in Union Springs and Lowermost Oakta Creek Members

Marcellus Union Springs

- Organic rich thinly bedded blackish grey to black shale with thin silt bands
- The member is between the Cherry Valley and Onondaga Limestone
- Characterized as pyritiferous; farther east the Union Springs becomes the Bakoven member that becomes darker, less organic and has few limestone members
- Lenses in and out in localities in far Western New York

Marcellus Union Springs

Union Springs with vertical calcite filled fractures in the Onesquethaw Creek, Albany County, NY

Marcellus Cherry Valley

- Consists of skeletal limestones and shaly intervals
- Westward thinning of the Marcellus Formation in western and central New York leads to the condensation and union of the Cherry Valley limestones with limestones in the upper part of the Union Springs

Marcellus Cherry Valley

Cherry Valley dark shaly interval and limestone near Cherry Valley, NY

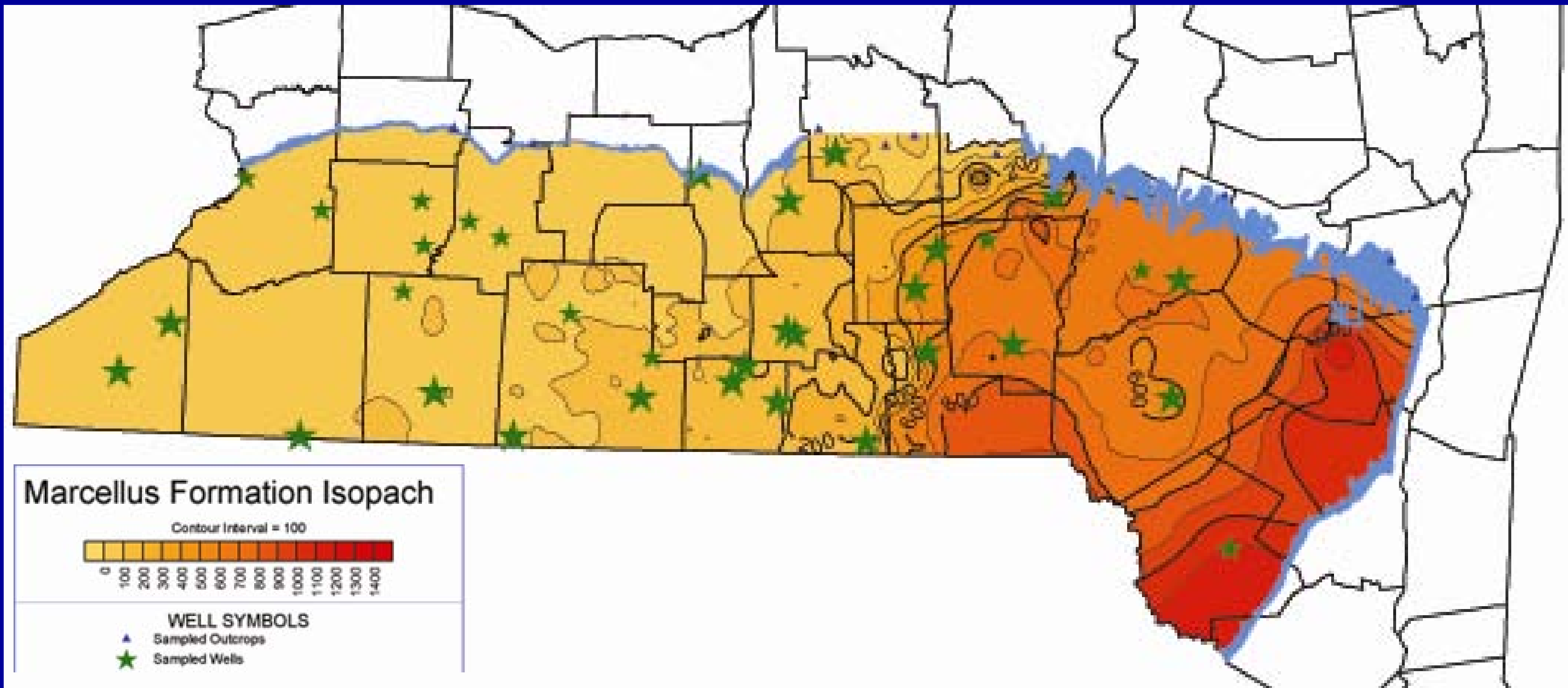
Marcellus Oatka Creek

- Upper member of the Marcellus Formation in Western and central New York
- Becomes Cardiff and Chittenango members in Central and Eastern New York
- Is confined in Western New York by Stafford and Onondaga limestones
- Farther east it is between the Stafford and Cherry Valley limestones where it is present
- Dark grey to black organic rich shale

Marcellus Oatka Creek

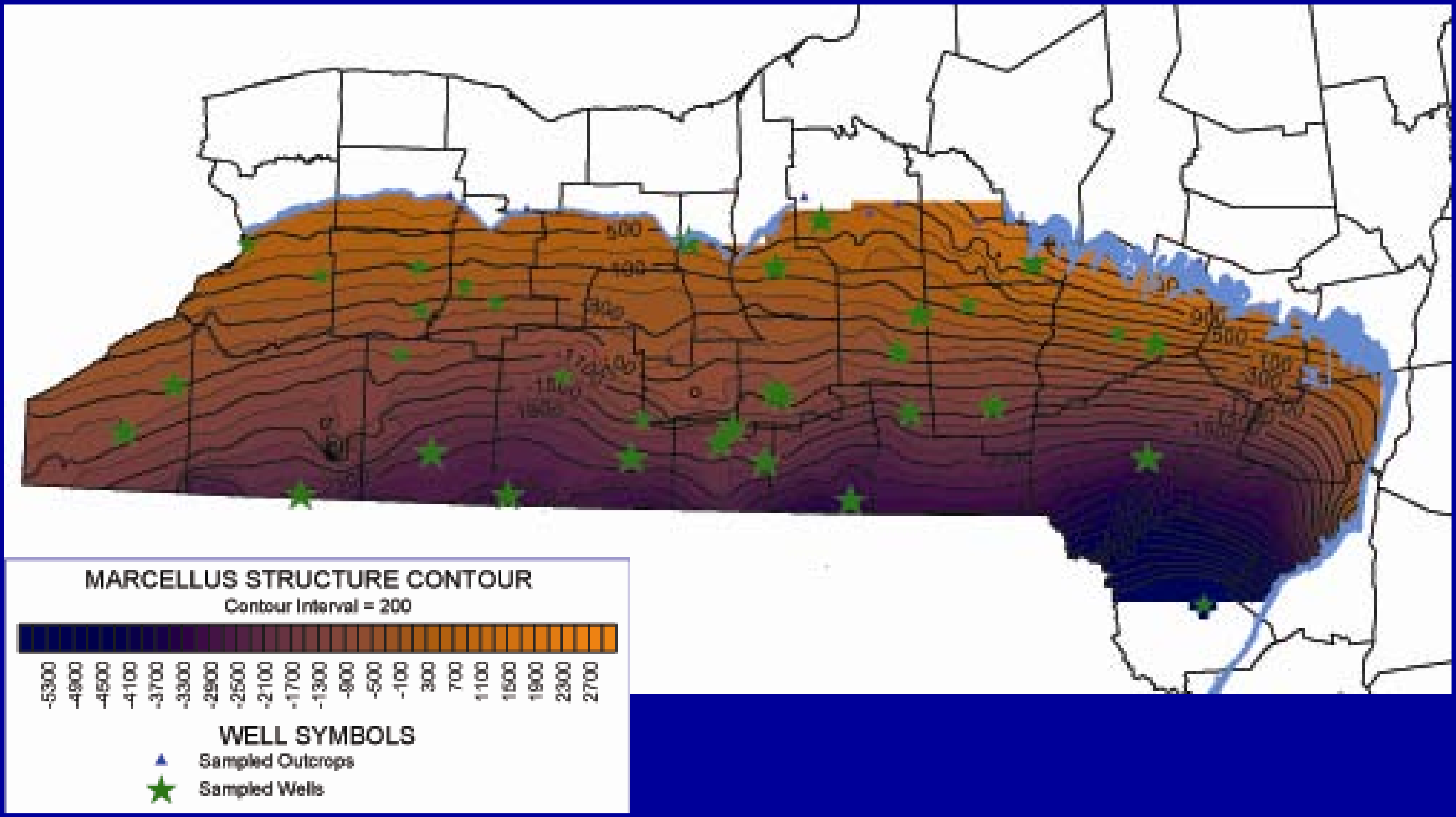
Oatka Creek shale in Oatka Creek, LeRoy, NY

Marcellus Isopach



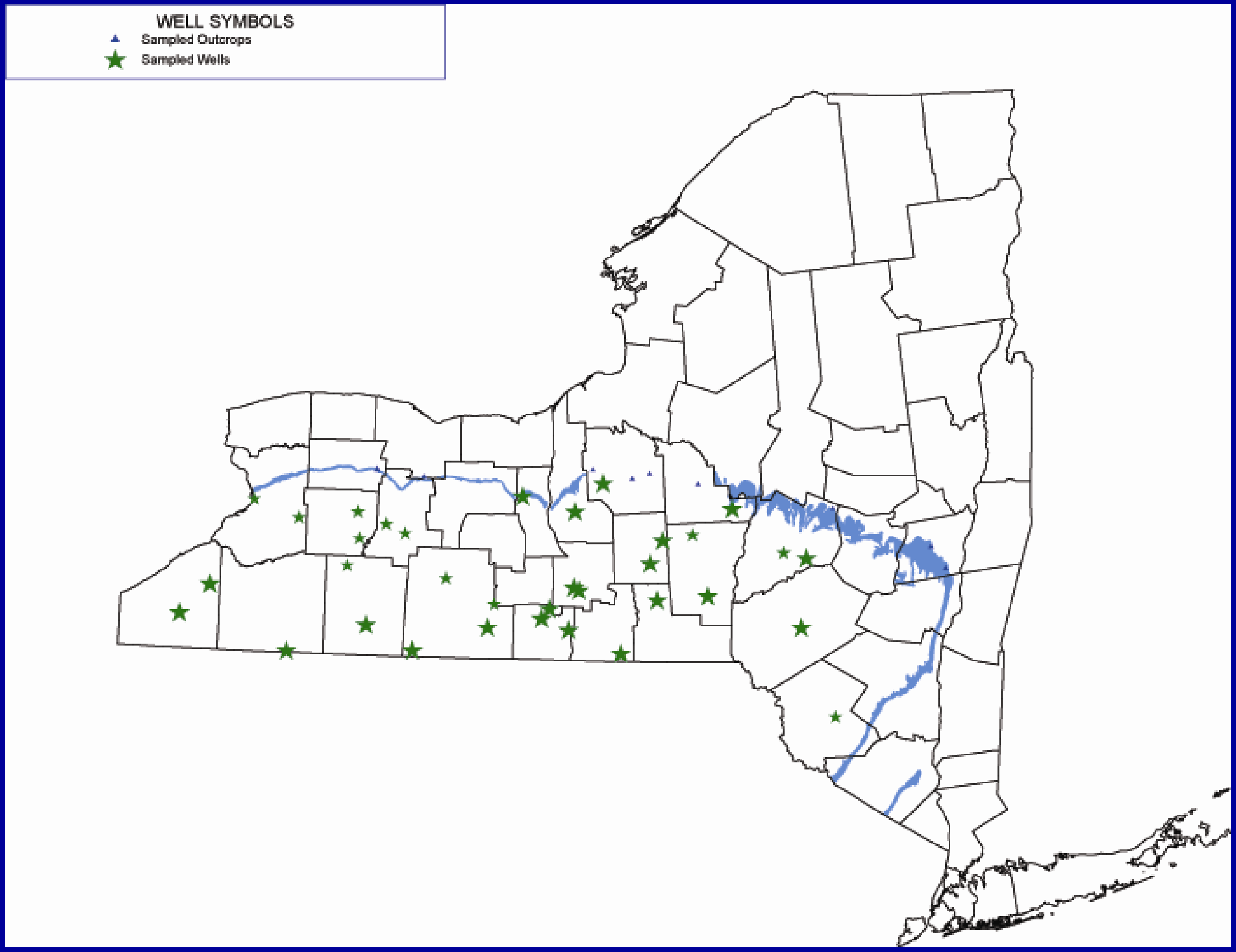
Marcellus thickens to the east

Marcellus Structure Contour Map



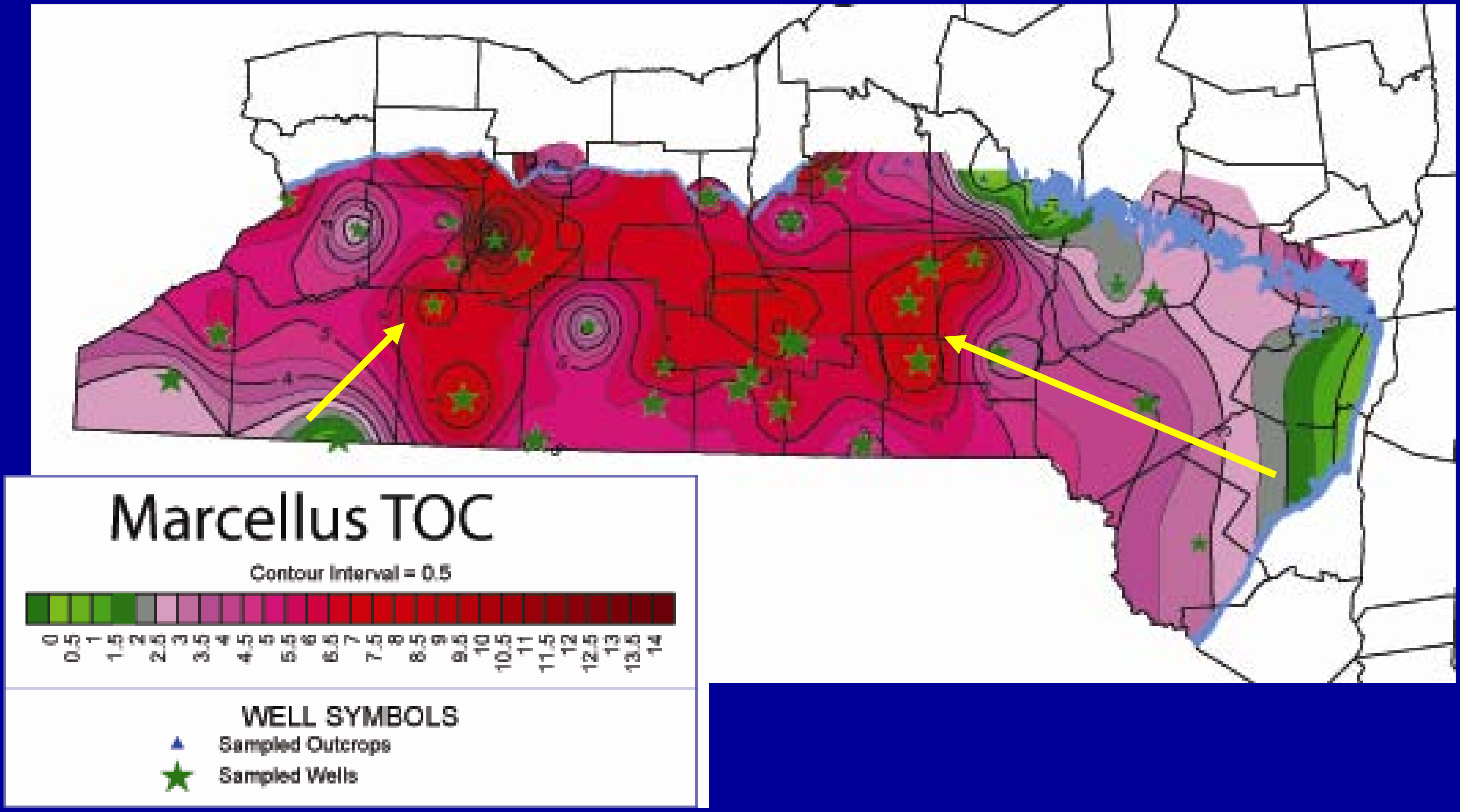
Marcellus has a general east-west strike is gently dipping south

Map of Marcellus Geochemical Locations



33 wells, 2 cores, 9 outcrops

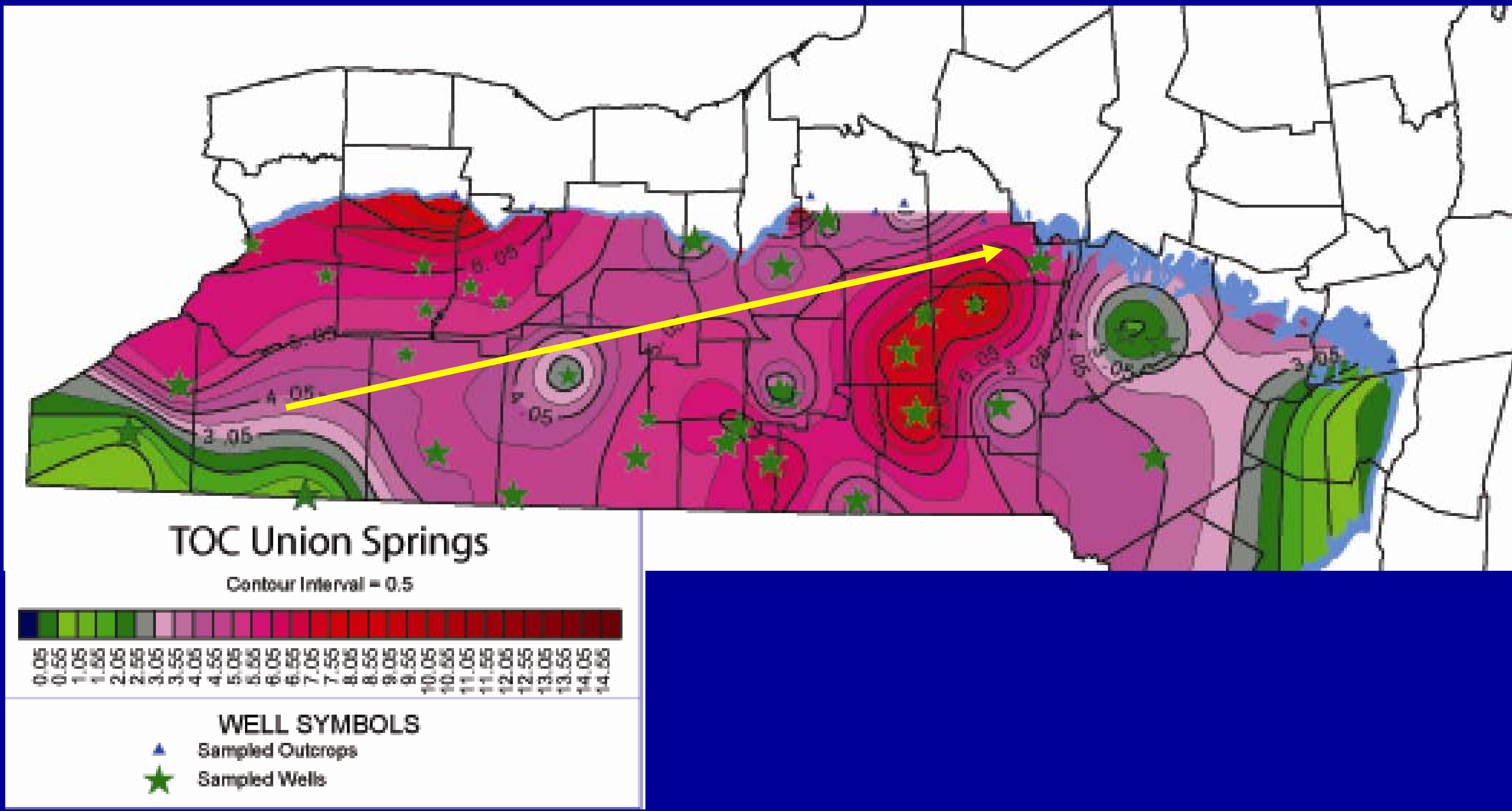
Marcellus TOC Map



TOC much higher in Marcellus than in Utica (up to 12%)

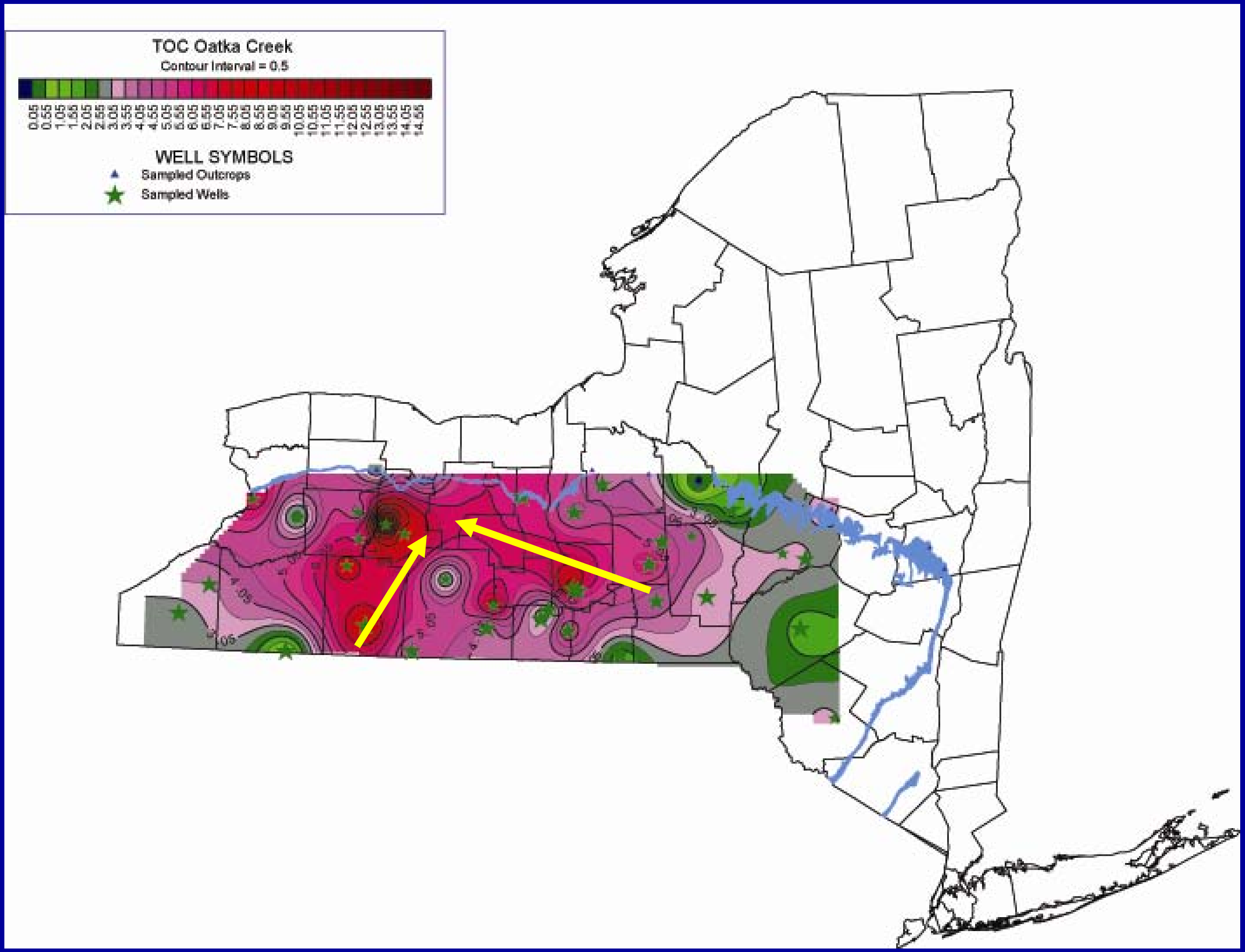
TOC values are highest in central part of state and decrease to east

Marcellus Union Springs TOC Map



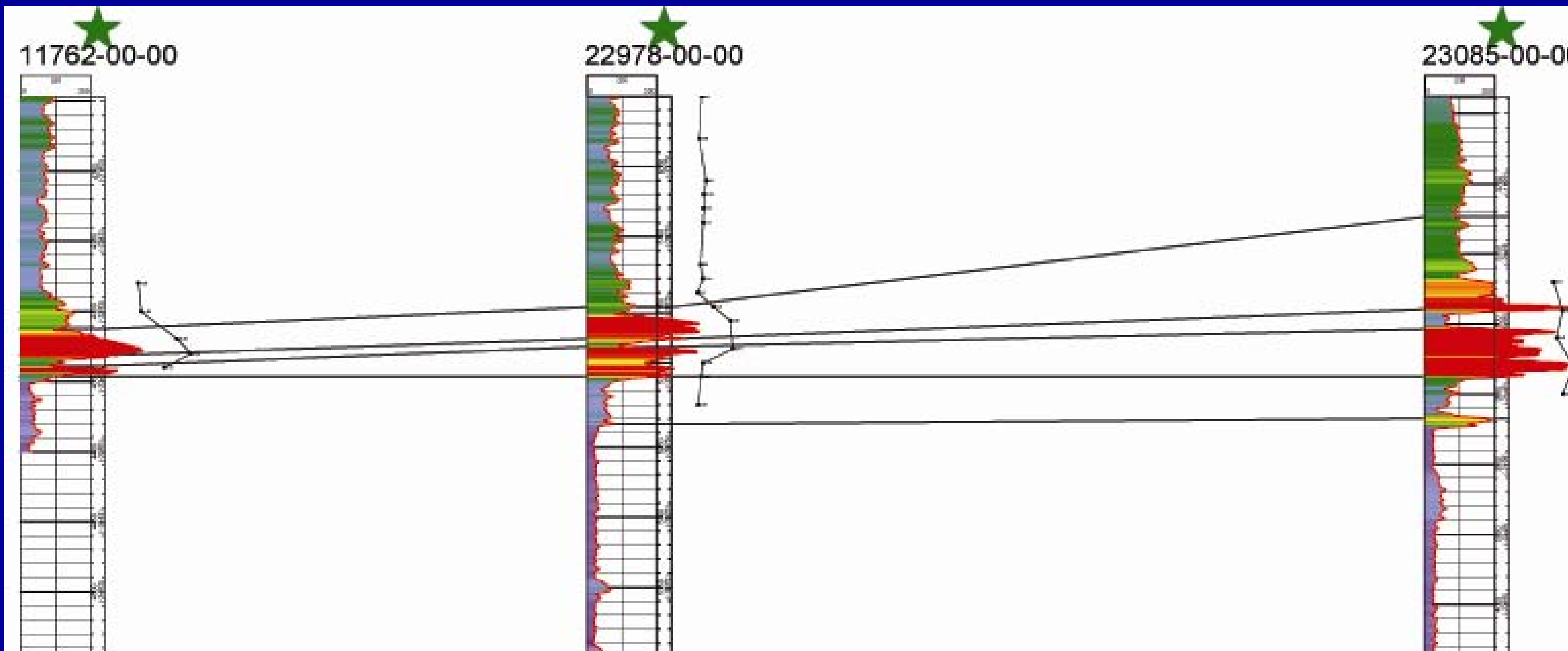
TOC in the Union Springs increases from the western part of NY to the central eastern side of NY

Marcellus Oatka Creek TOC Map



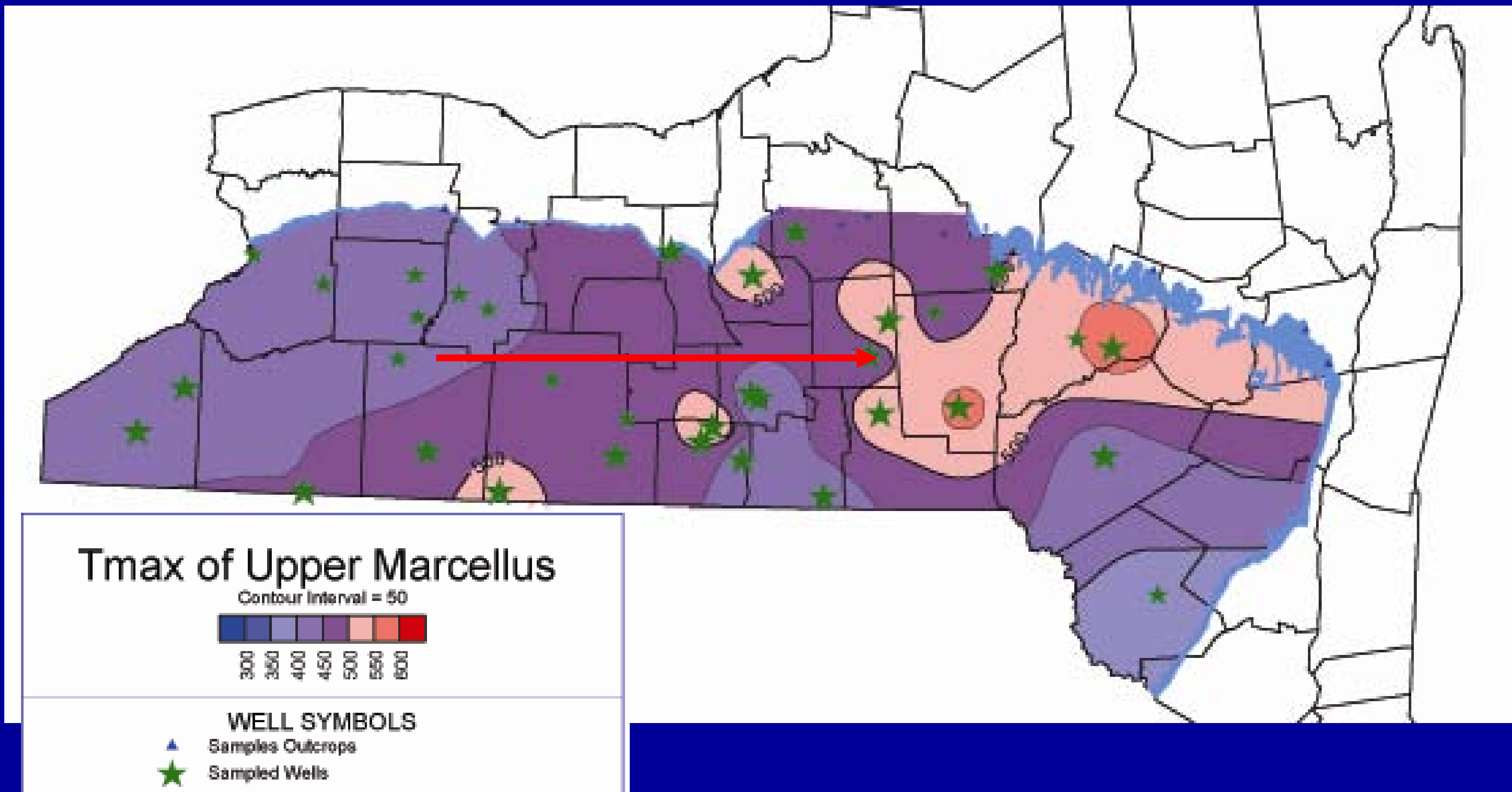
TOC increases in the Oatka Creek to the northeast and west-northwest

TOC Marcellus Cross Section



TOC increases in Oatka Creek and the Union Springs member

Tmax (deg C°) Marcellus



About half of the S_2 values in the Marcellus can be trusted for T_{max} values – using these, T_{max} increases to east as would be expected

Vitrinite Reflectance Calculation

- Vitrinite refelctance (R_o) is a measure of thermal maturity that can be done directly on plant matter
- R_o can be estimated from reliable T_{max} data using the following calculation
- R_o (%)=(0.0180*Tmax)-7.16
- The T_{max} data in the Marcellus is much better than the Utica – about half the points have useable S_2 values

Vitrinite Reflectance (Ro%)

Well Cuttings

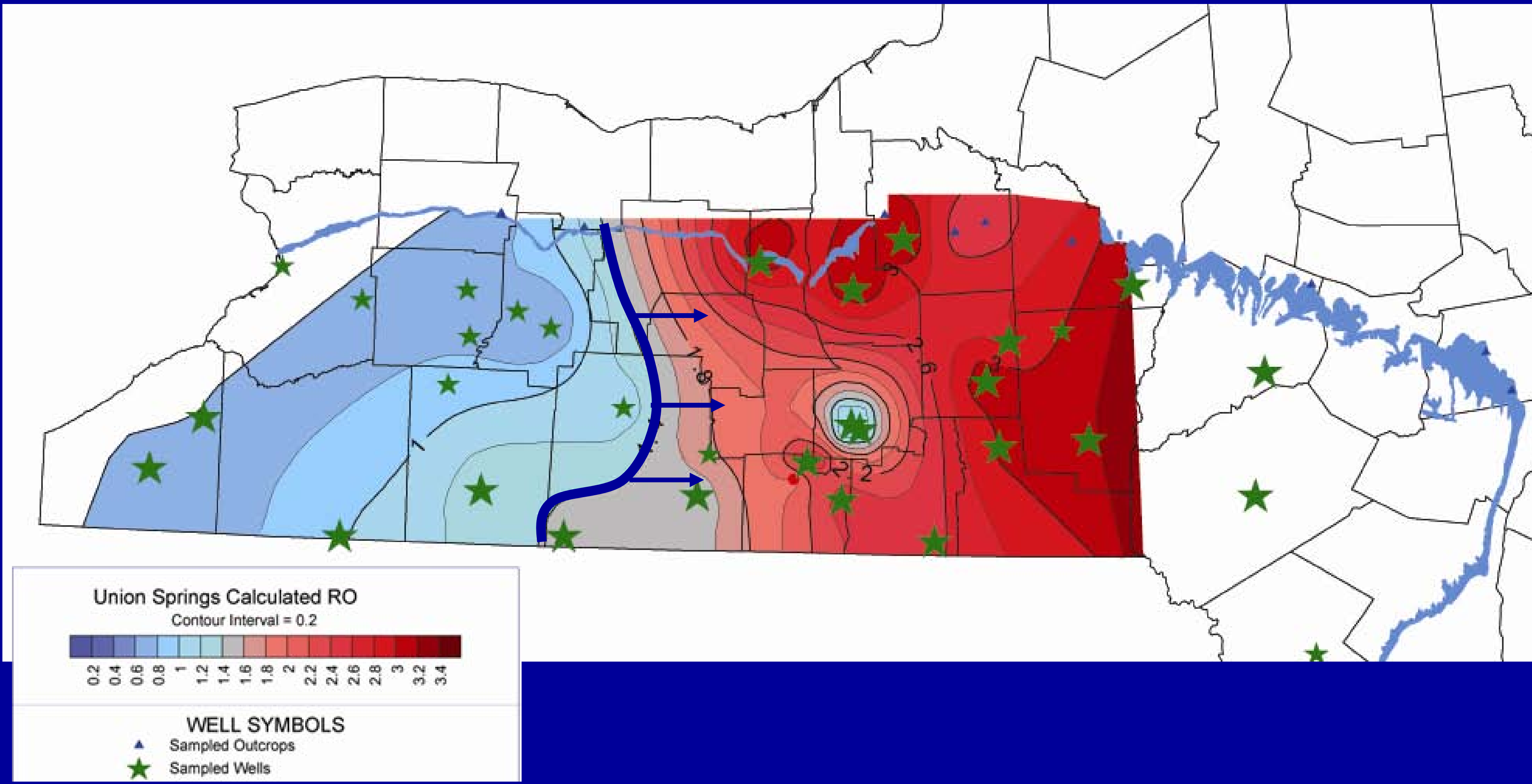
- Low maturity source rocks 0.0 – 0.55%
- Oil window 0.55% -1.0%
- Condensate - wet gas window 1.0 %- 1.40%
- Dry gas window > 1.40%

Core

- Low maturity source rocks 0.0 - 0.55%
- Oil window 0.55%- 1.15%
- Condensate – wet gas window 1.15% -1.40%
- Dry gas window > 1.40 %

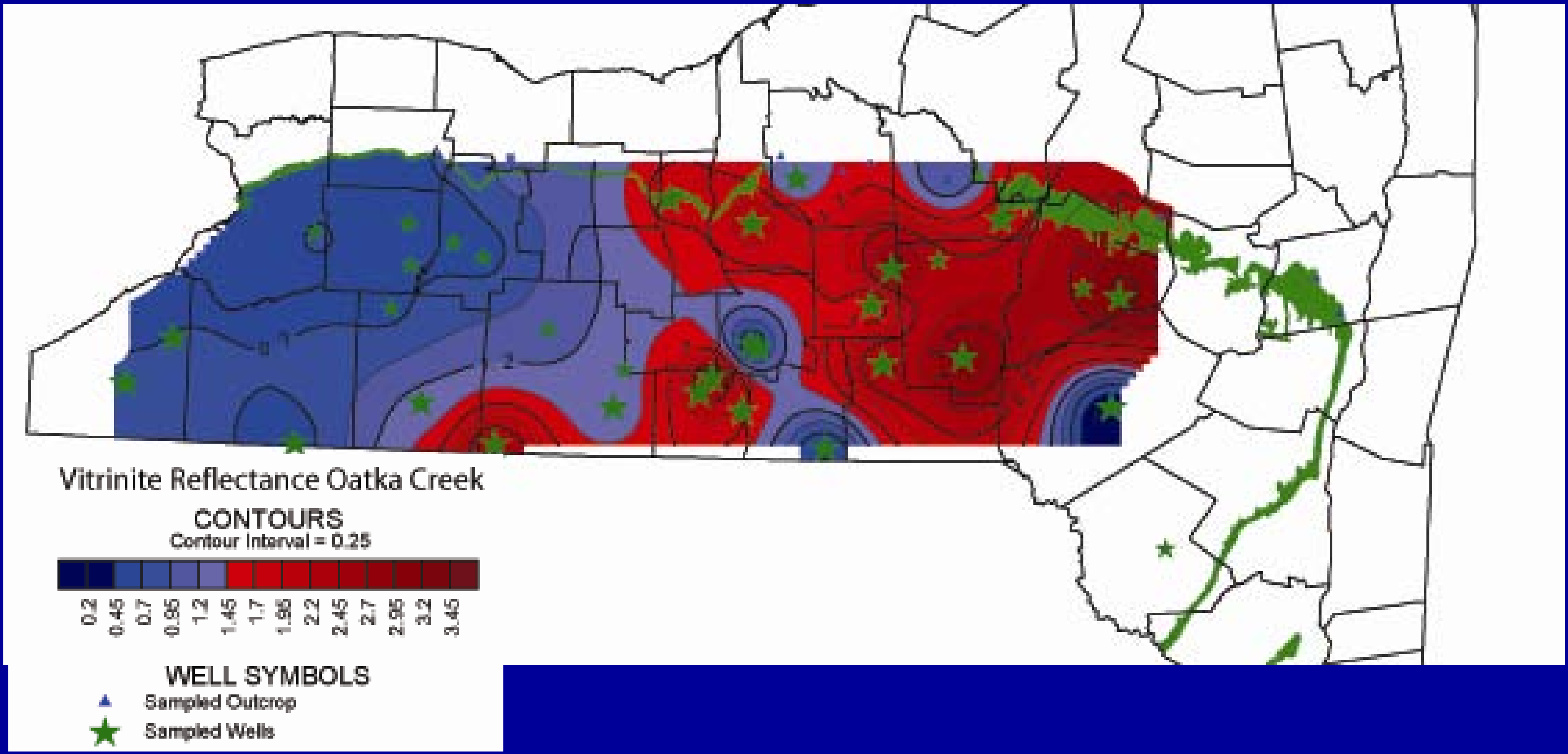
based on Jarvie, et al, 2005

Marcellus (Union Springs) Ro%



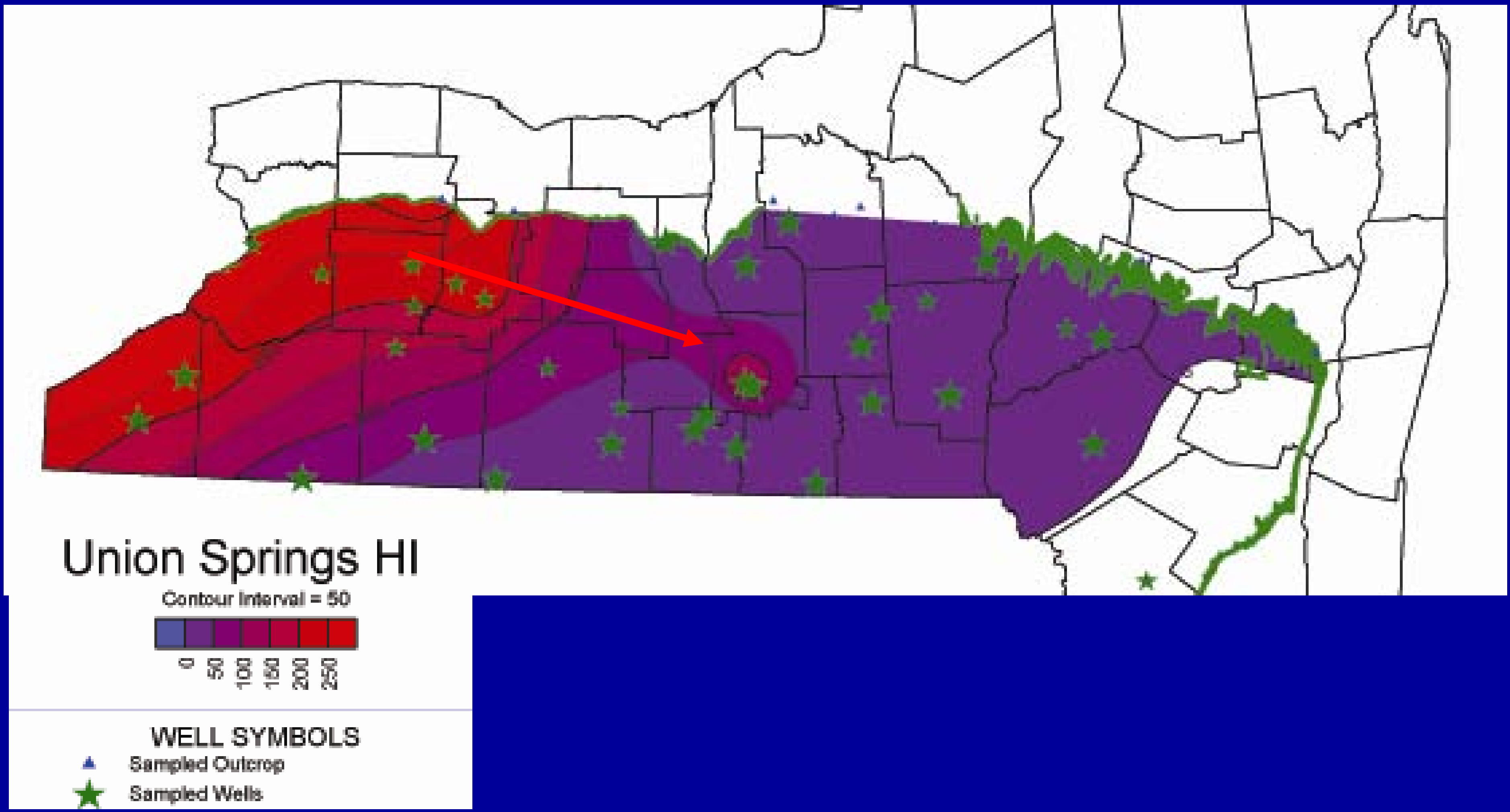
Optimum Ro% for Marcellus Union Springs is in the central and eastern New York

Marcellus (Oatka Creek) Ro%



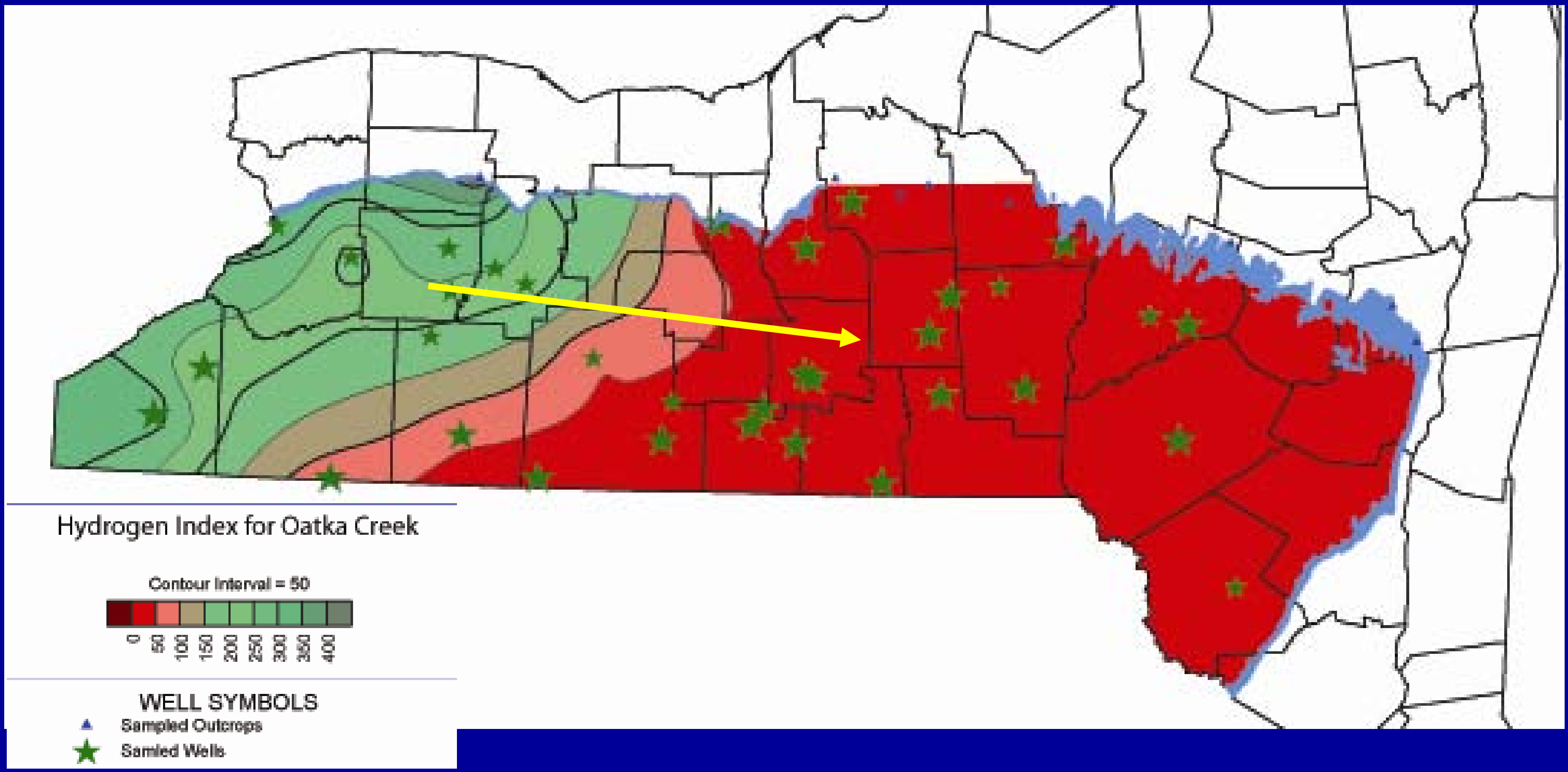
Optimum Ro% for Oatka Creek is in eastern side of basin – based on this it is best to avoid western half of state

Marcellus Union Springs HI Map



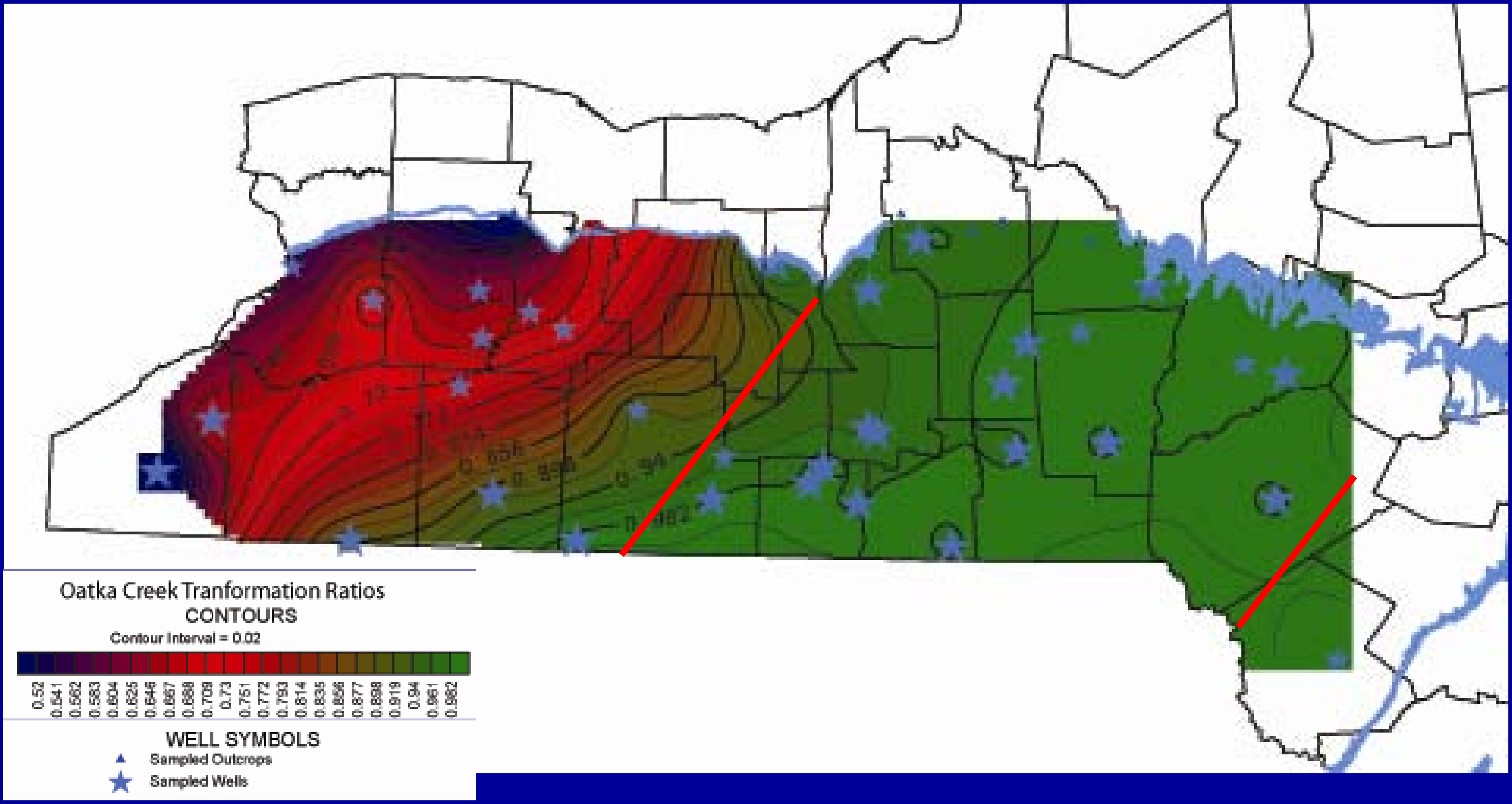
Union Springs HI decreases to the east

Marcellus Oatka Creek HI Map

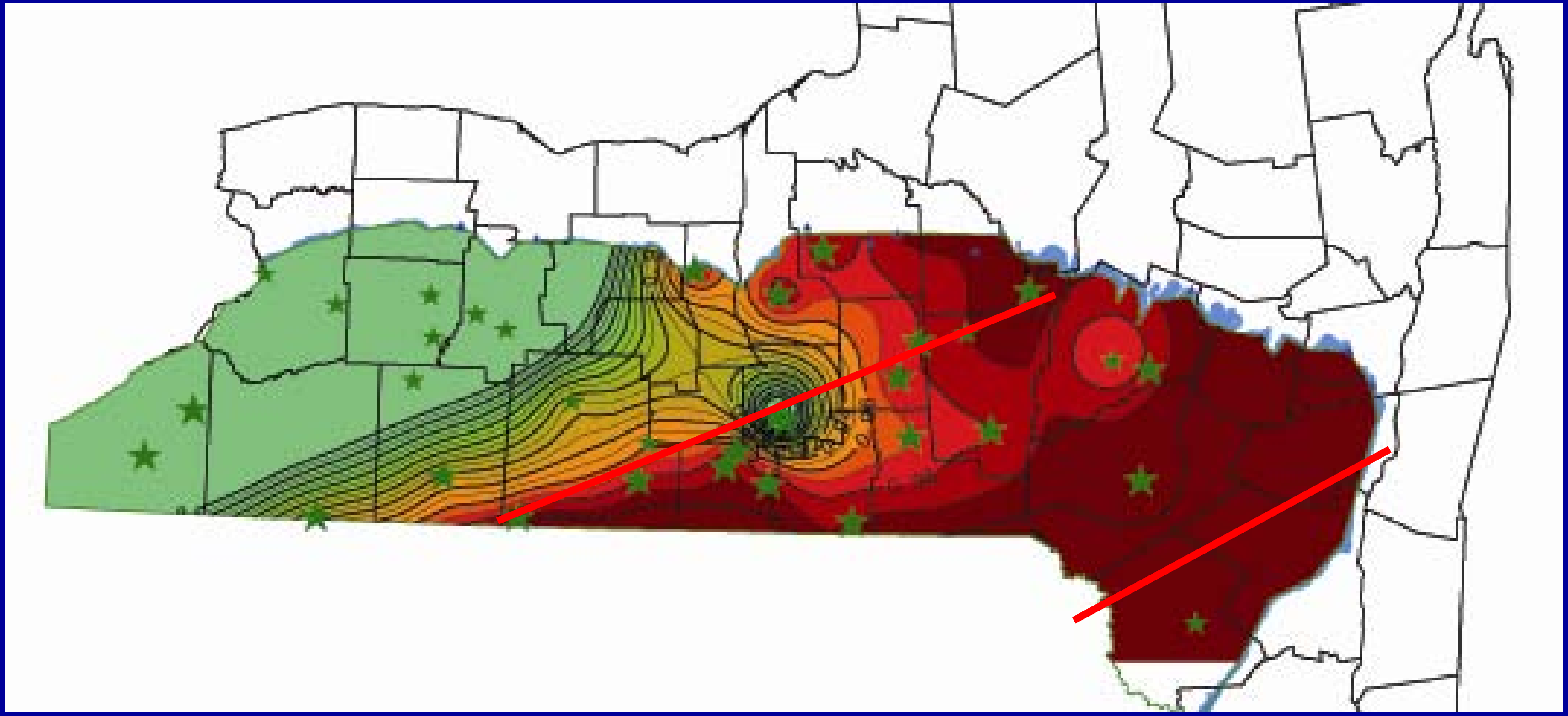


Oatka Creek HI decreases from west to east

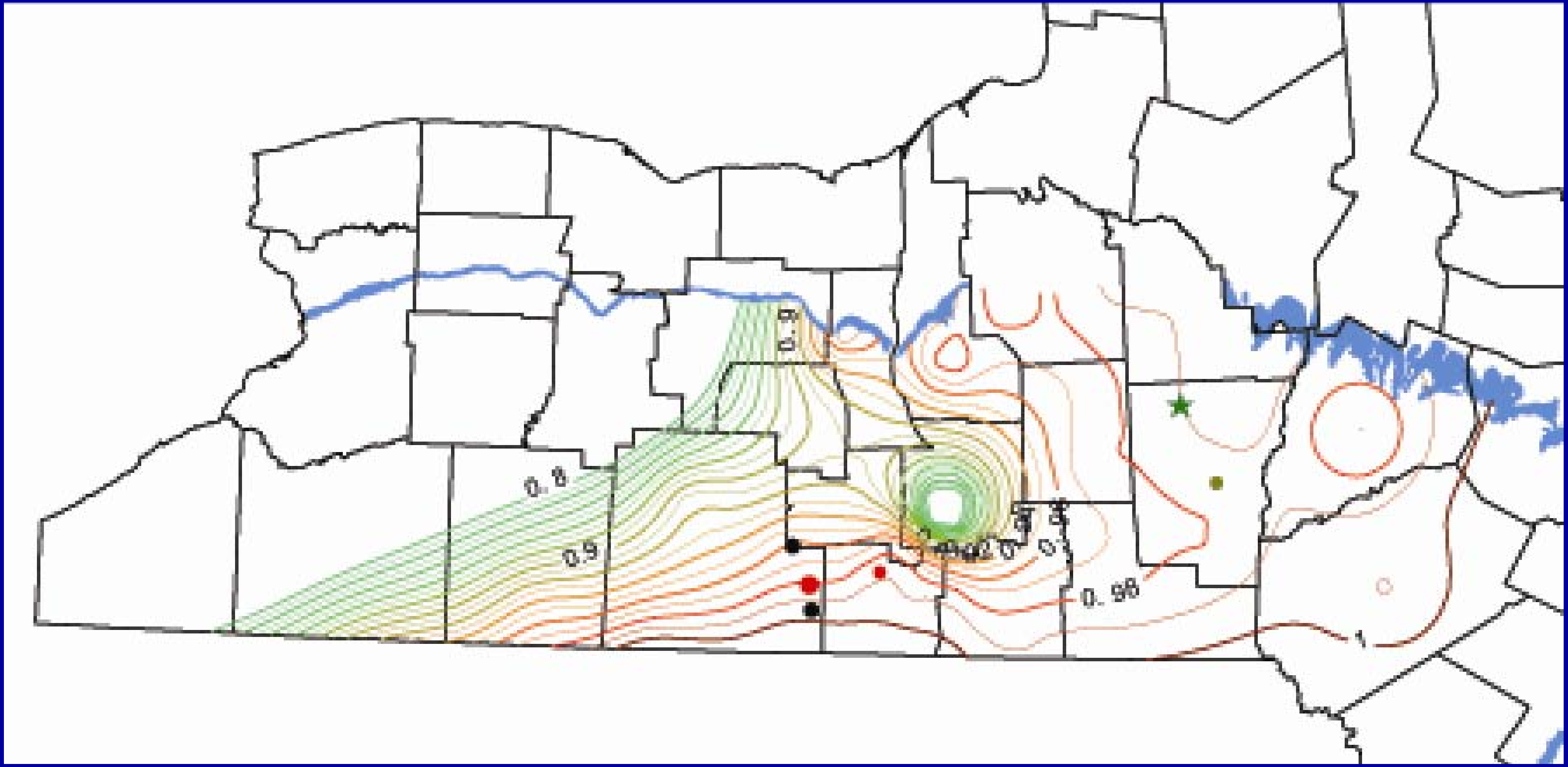
Marcellus Oatka Creek Transformation Ratio Map



Marcellus Union Springs Transformation Ratio Map



New Marcellus wells and the TR Map

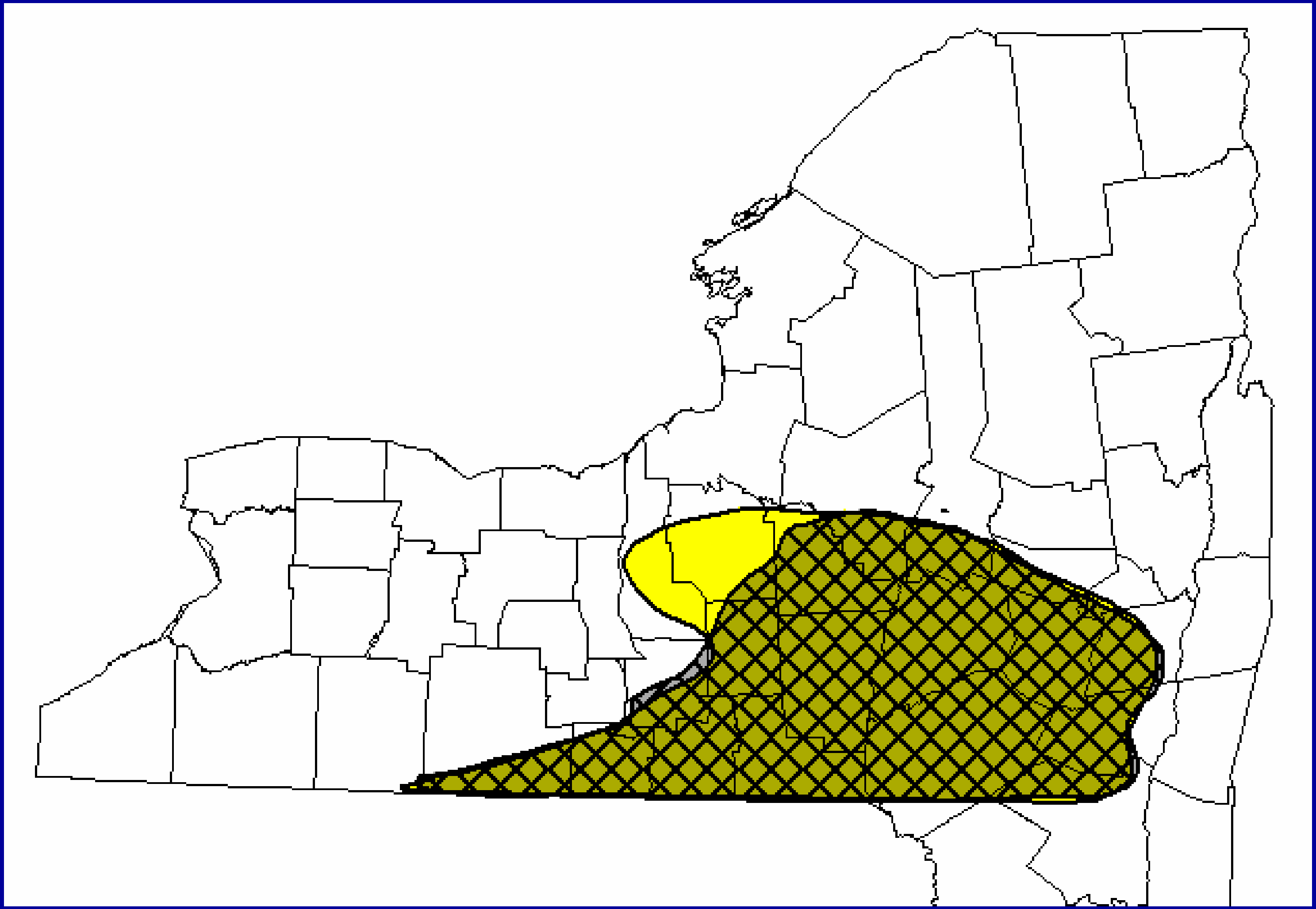


The geochemistry work that we have done suggest that the shales in this area are favorable - some wells drilled here have not produced

Marcellus

- Some wells, such as the Beaver Meadows well, were drilled in what is the geochemical fairway for Marcellus but were not completed and are assumed to be dry holes. Why?
- Other aspects may be equally important
  - completion/frac practices need to be refined
  - may need certain silica content
  - too much TOC?
  - Overcooked?
- More work is needed

Utica and Marcellus fairways



They overlap in eastern side of basin

Future Work

- Calculate and make maps of original TOC, S2 and HI
- Get analysis of gas samples from newer wells whenever possible
- Get mineralogy data for shales
- Resample areas where data is questionable or missing and test conclusions with new samples in fairways
- See what happens with newer wells in fairways that have new drilling/completion/frac concepts

Conclusions

- The Marcellus and Utica Shales both contain fairways that are favorable to gas exploration based on geochemical data
- Both fairways occur in overlapping areas in the eastern Southern Tier of the State where there are not many wells drilled to date
- Wells with good shows occur in predicted fairways
- Within the Utica Shale, the Flat Creek and to a lesser extent the Dolgeville Members, which both thicken to the east and pinch out to the west have the best potential
- In the Marcellus Shale, the Oatka Creek and Union Springs Members have the best potential
- The Marcellus is organically richer than the Utica

Acknowledgements

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- Fortuna Energy
- EOG Resources
- Jay Leonard of Platte River Associates for geochemical data on eastern most Utica well cuttings