Paleotopographic and Depositional Environment Controls on "Sweet Spot" Locations in Unconventional Resource Shales: Woodford and Barnett Shale Examples: Part 2*

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Abstract

The Woodford Shale (Oklahoma, U.S.A.), like many prolific unconventional resource shales, sits atop a major unconformity on the surface of underlying carbonates and shales. There is variable topographic relief on this unconformity surface due to incised valley and/or karst formation during lowstand periods of subaerial exposure. This variable topography may result in a variety of depositional environments/subenvironments, including open marine, restricted marine, restricted-to-open marine, hypersaline lakes and swamps, and perhaps even perennial lakes. As a result, stratigraphy can vary locally as well as regionally within, and between basins and adjacent shelf areas. Anomalously thick intervals of the shale can form within these topographic depressions, giving rise to potential 'sweet spots' as drilling targets; they can be recognized on subsurface well logs by their anomalous thickness. Inversion of 3D seismic data to TOC distribution revealed TOC-enriched, compartmentalized intervals. Also, gamma ray logs often exhibit a high-API interval at or near the basal unconformity due to early marine transgression into topographic depressions, which hinders water circulation and gives rise to localized anoxic depositional environments conducive to preservation of organic matter. With continued rise in sea level, marine circulation might improve, giving rise to less preserved TOC, and lower gamma-ray log response.

Selected References

Althoff, C.D., 2012, Characterization of Depositional Megacycles in the Woodford Trough of Central Oklahoma: M.S. Thesis, University of Oklahoma, Norman, Oklahoma, 99 p.

Comer, J.B., 2008, Woodford Shale in Southern Midcontinent, USA-Transgressive System Tract Marine Source Rocks on an Arid Passive Continental Margin with Persistent Oceanic Upwelling: AAPG Annual Convention, San Antonio, TX, poster, 3 panels.

Dutton, T.C., 2013, Using Latest Production and Well Results to Identify Optimal Completion Methods for the Mississippi Lime and Woodford Shale Reservoirs in the Sooner Trend Portion of the Mississippi Lime Play: Emerging Shale Plays Conference, Houston, TX.

Hester, T.C., J.W. Schmoker, and H.L. Sahl, 1990, Log-derived Regional Source-rock Characteristics of the Woodford Shale, Anadarko Basin, Oklahoma: U.S. Geological Survey Bulletin 1866-D, 38 p.

Grotzinger, J., and T.H. Jordan, 2010, Understanding the Earth: W.H. Freeman, New York, 672 p.

Jarvie, D.M., 2012, Shale Resource Systems for Oil and Gas: Part 2 - Shale-oil Resource Systems, *in* J.A. Breyer, (ed.), Shale Reservoirs—Giant Resources for the 21st century: AAPG Memoir 97, p. 89–119.

Lambert, M.W., 1993, Internal Stratigraphy and Organic Facies of the Devonian-Mississippian Chattanooga (Woodford) Shale in Oklahoma and Kansas, *in* B.J. Katz and L.M. Pratt, (eds.), Source Rocks in a Sequence Stratigraphic Framework: AAPG Studies in Geology 37, p. 163-176.

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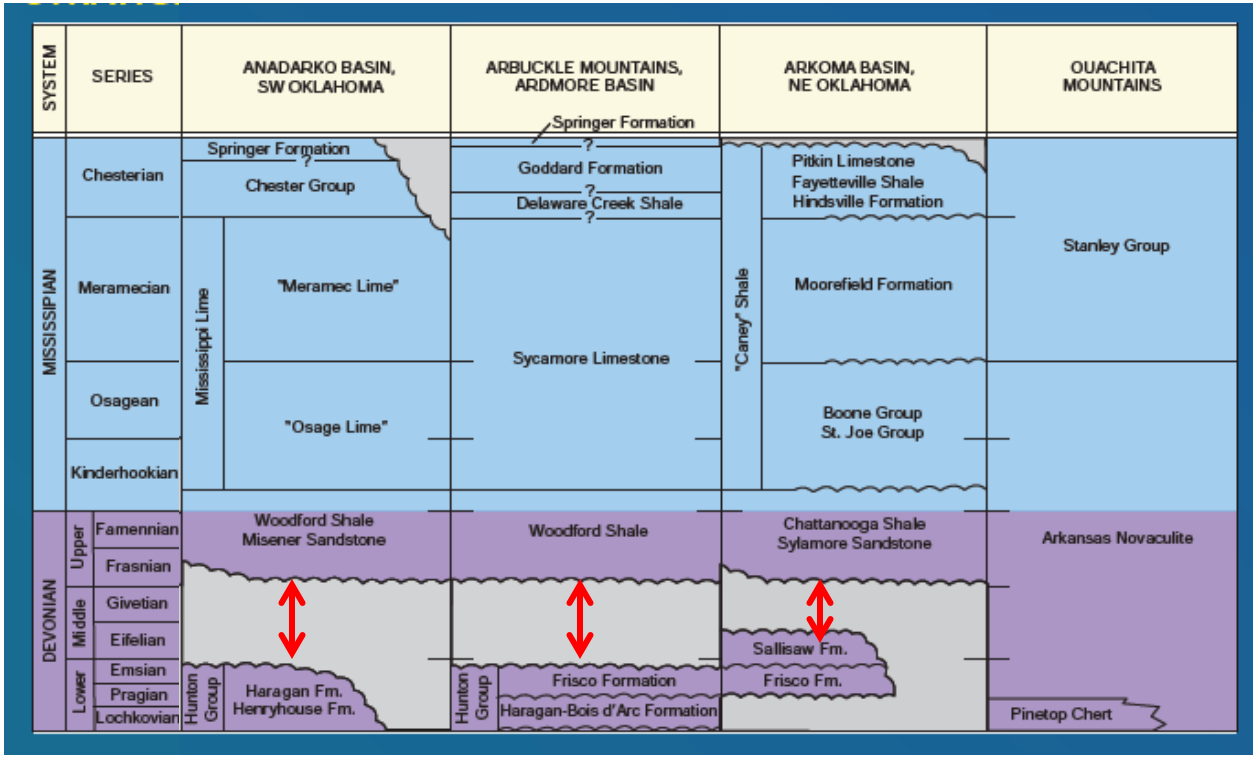


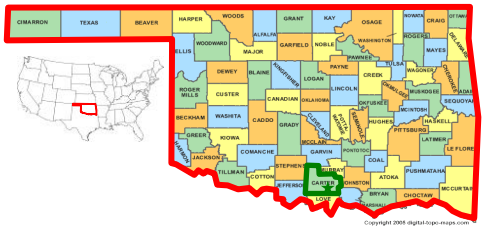
Major unconformity

DEVONIAN-MISS. STRATIGRAPHIC COLUMN, OKLAHOMA

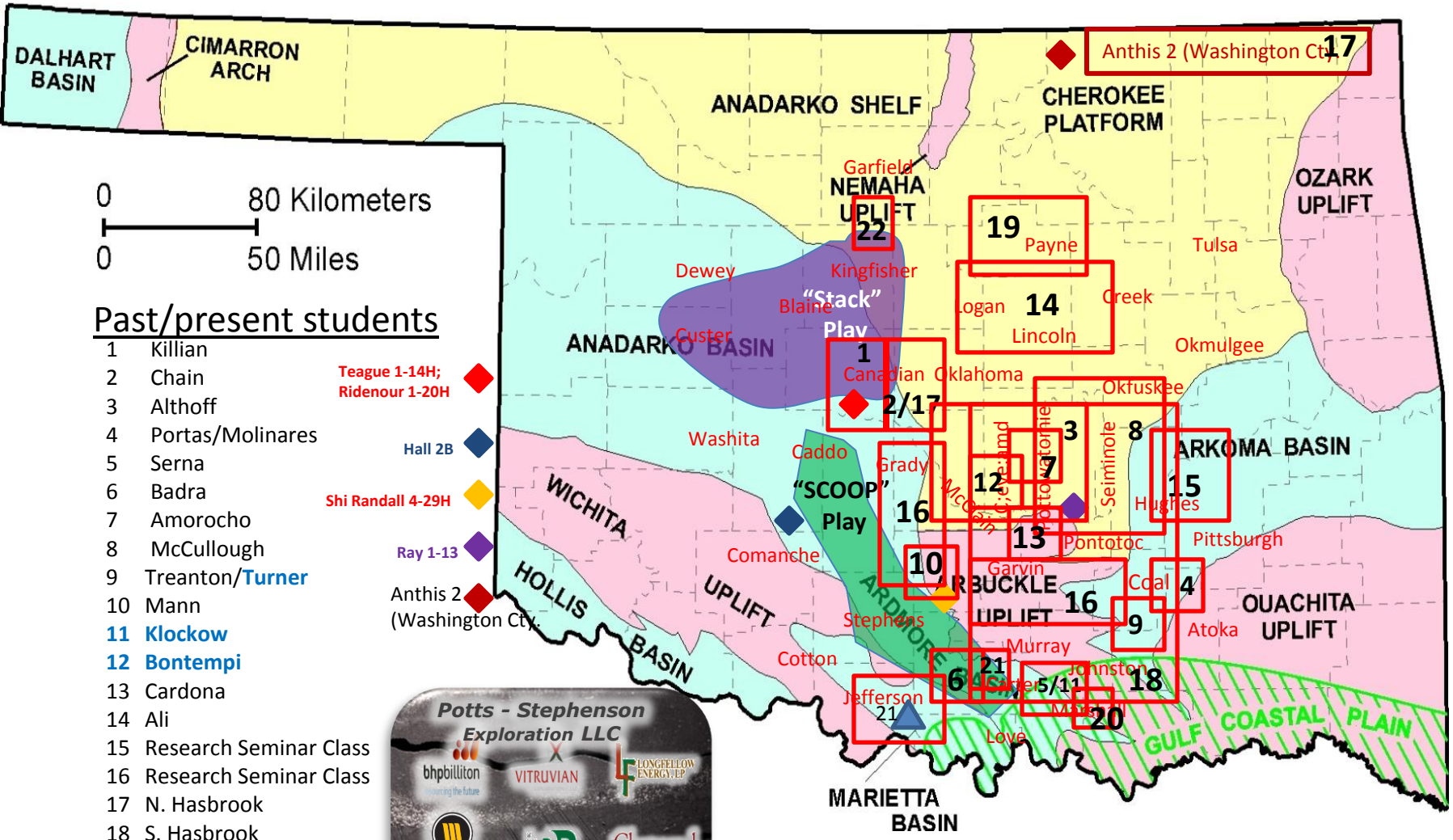
1Insitute of Reservoir Characterization, University of Oklahoma

2 Devon Energy

3 University of Adelaide



Woodford Studies in Oklahoma



Past/present students

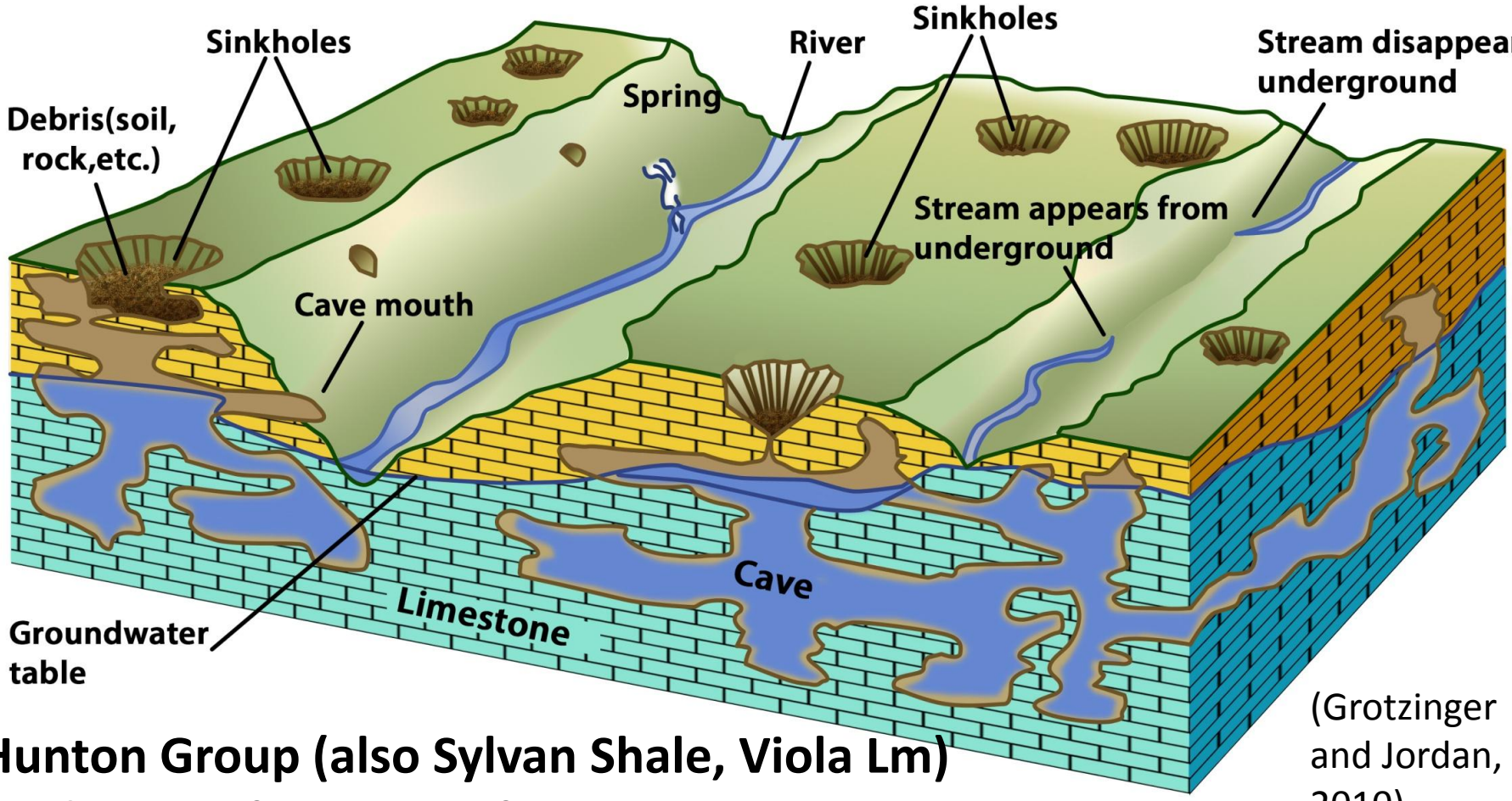
1 Killian
2 Chain
3 Althoff
4 Portas/Molinares
5 Serna
6 Badra
7 Amorocho
8 McCullough
9 Treanton/**Turner**
10 Mann
11 Klockow
12 Bontempi
13 Cardona
14 Ali
15 Research Seminar Class
16 Research Seminar Class
17 N. Hasbrook
18 S. Hasbrook
19 Infante
20 Rush
21 Brito
22 Zhang

Current sponsors

Paleotopography develops on unconformity surface:

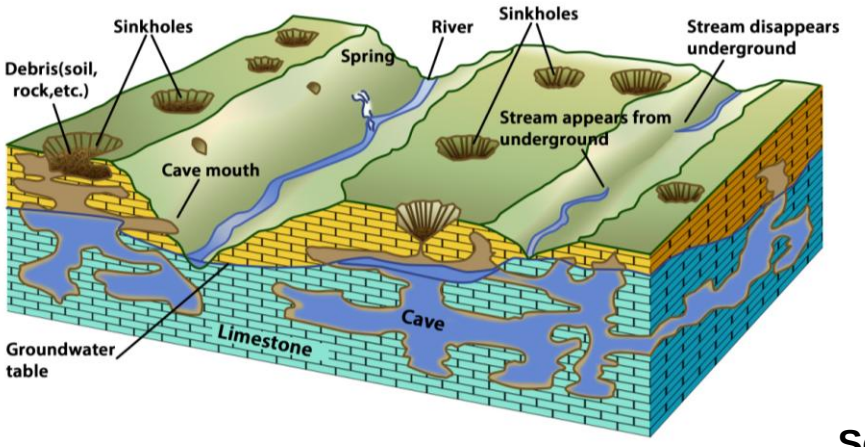
-incised valleys

-karst sinkholes and caves



Hunton Group (also Sylvan Shale, Viola Lm) with unconformity surface

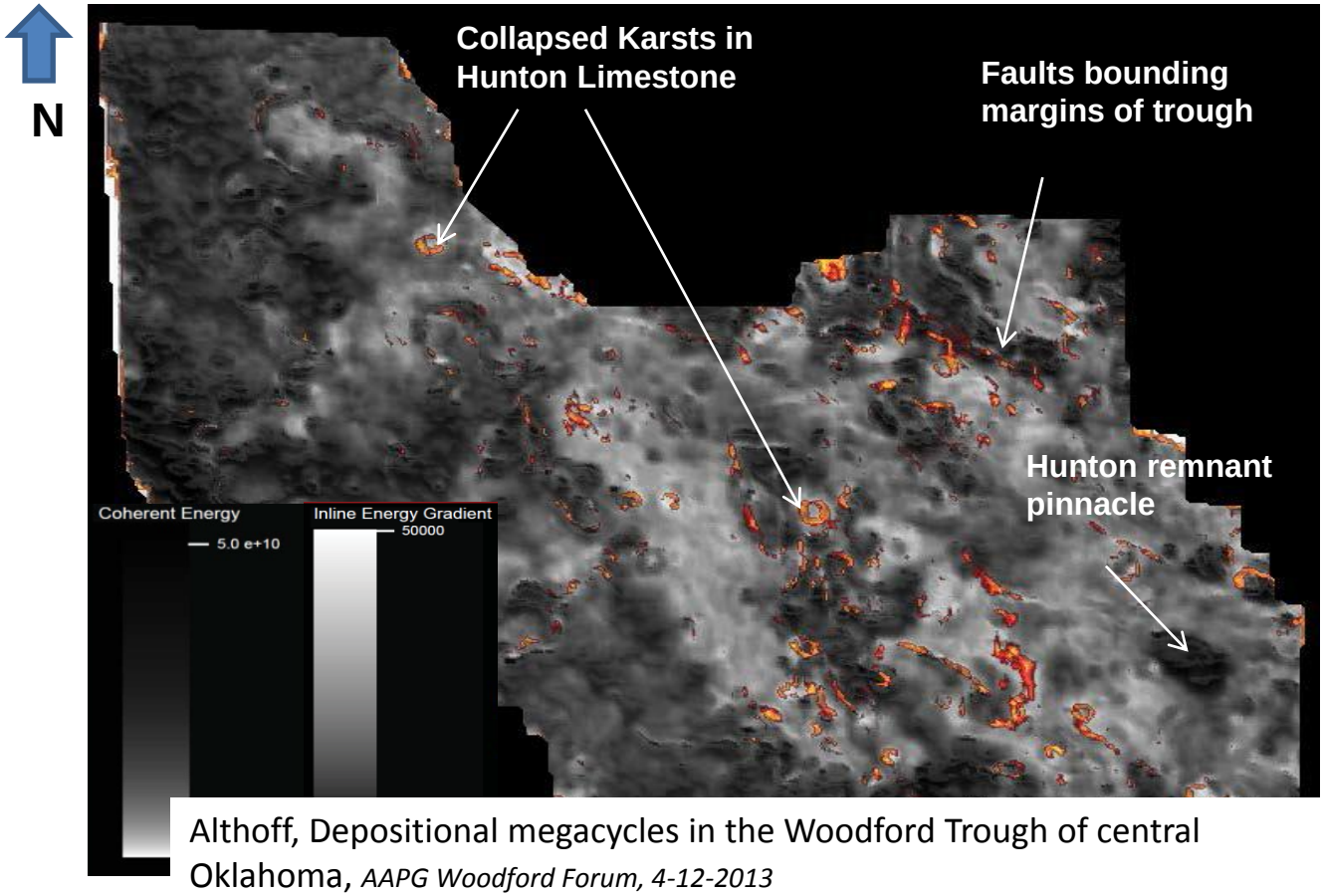
(Grotzinger and Jordan, 2010)



(Grotzinger and Jordan, 2010)

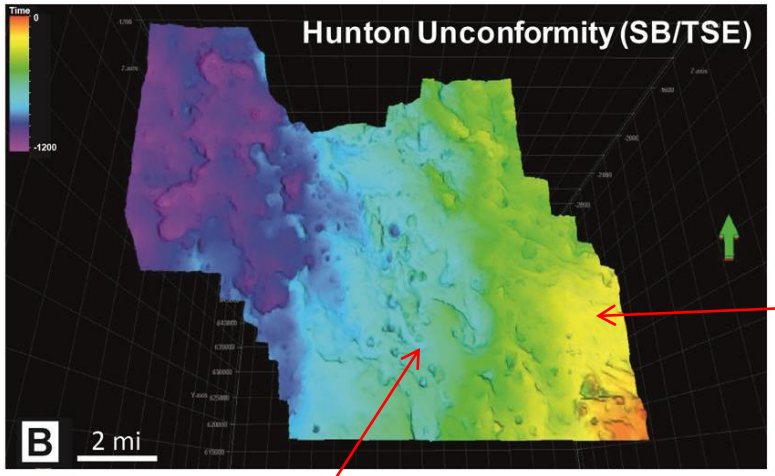
Florida sinkholes;Image courtesy of J. Breyer

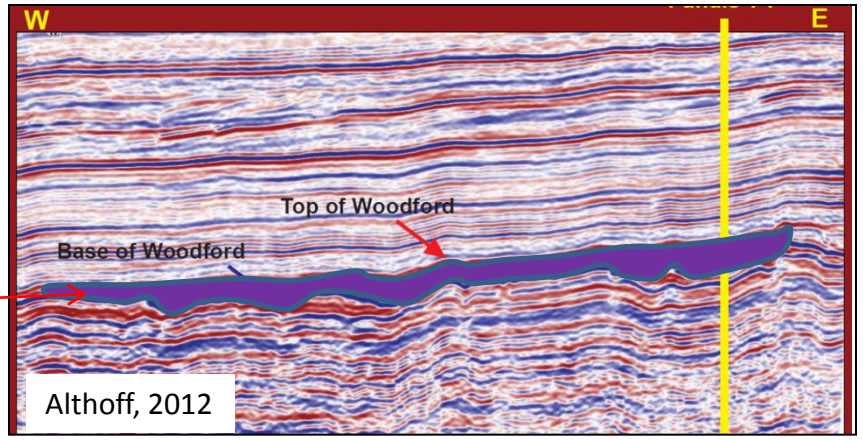
Seismically imaged Hunton surface

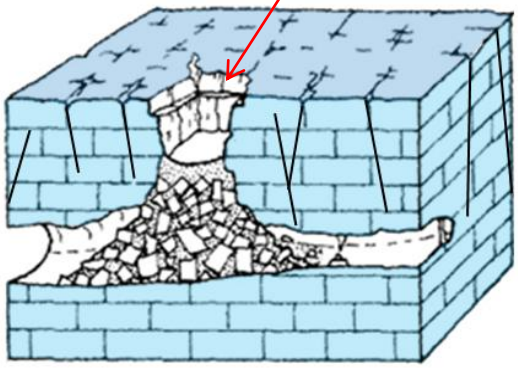


Althoff, Depositional megacycles in the Woodford Trough of central Oklahoma, *AAPG Woodford Forum, 4-12-2013*

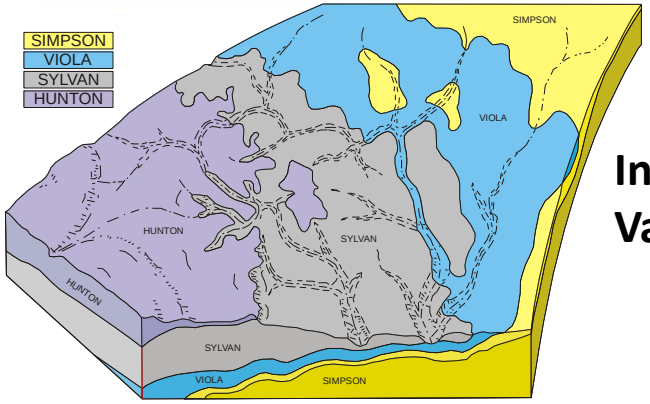
Woodford Incised valley fills and karst fills = potential sweet spots (greater thickness/organic-rich near base)



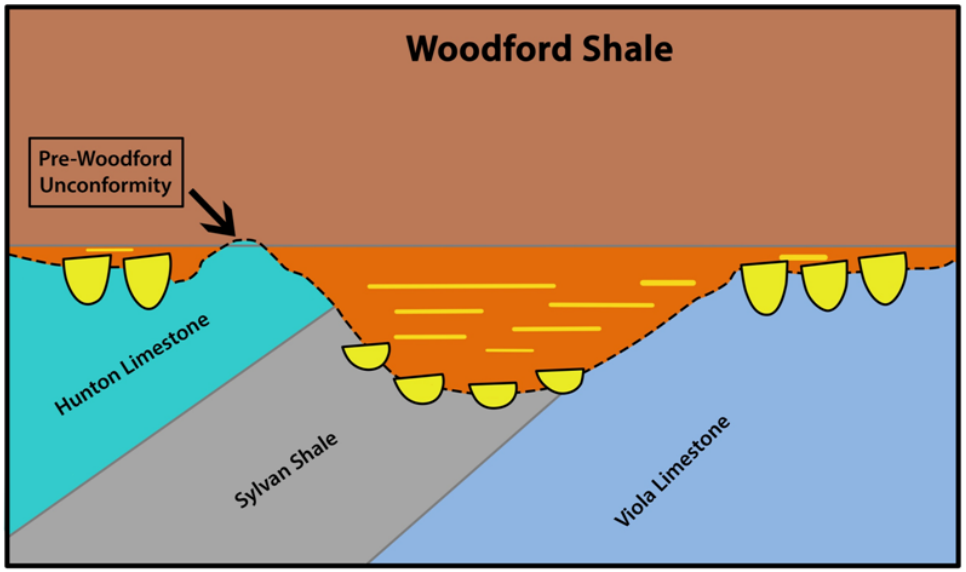




Karst

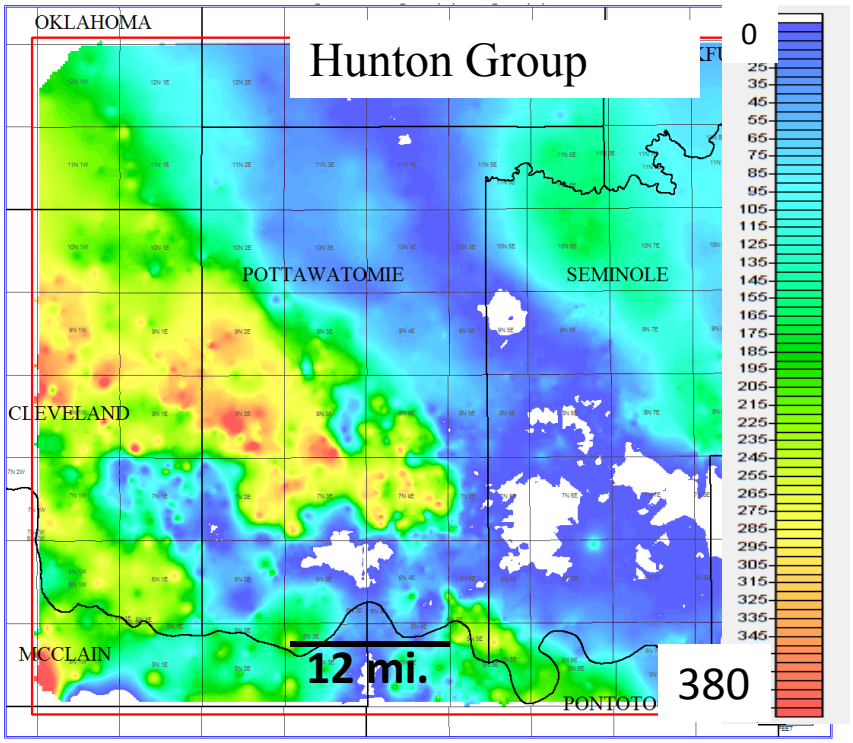


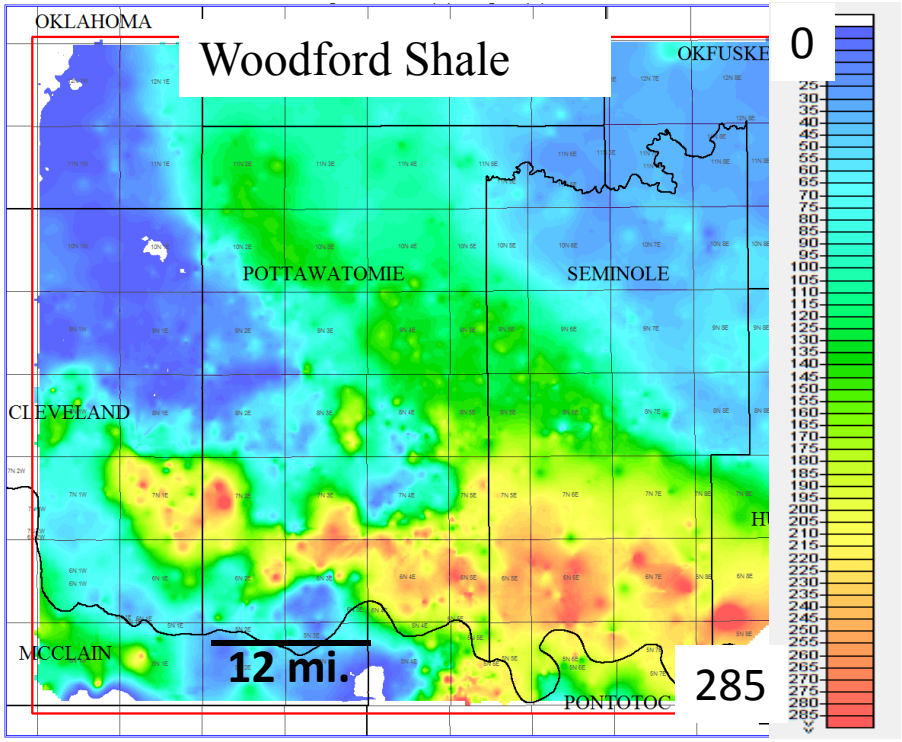
Incised Valley



Dutton, T., Longfellow Energy LP, Emerging Shale Plays Conference – April 25, 2013

Thicknesses of Hunton Group and overlying Woodford Shale

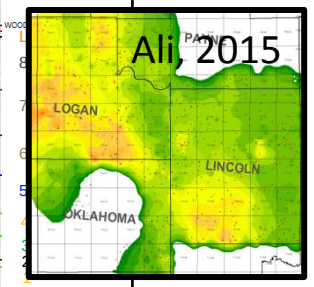


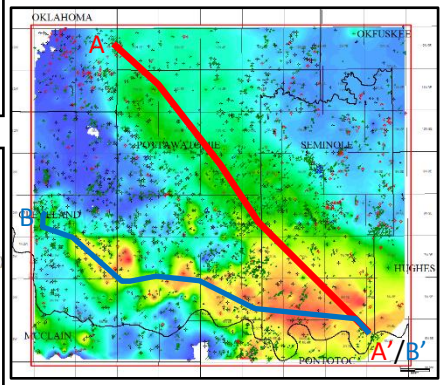


Woodford Incised Valley/karst fill

Valley fill (Woodford) is thin where underlying Hunton is thick and vice versa

A-A’ Shows clear termination (potentially onlap) of units 1-6 along a NW trajectory



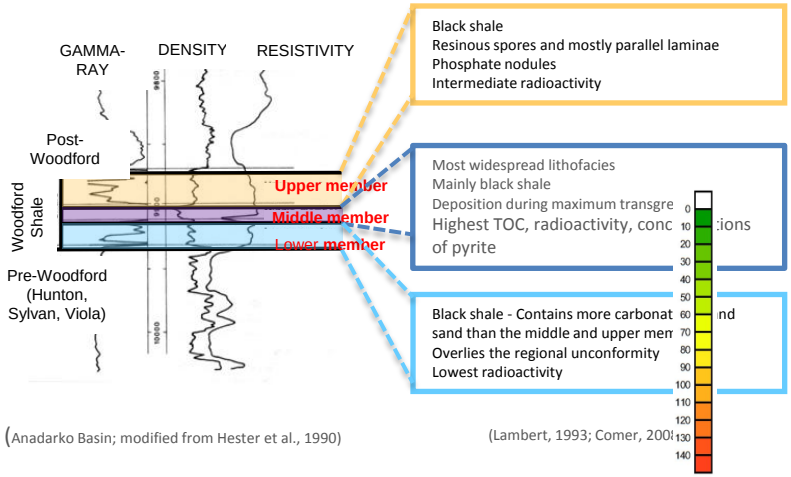


Unconformity surface

B-B’’ Shows Variations in thickness, especially in unit 9, also shows effects of anomalous paleotopography with respect to the Hunton Group.

Woodford Shale Stratigraphy

(Upper Devonian - Lower Mississippian)



(Anadarko Basin; modified from Hester et al., 1990)

(Lambert, 1993; Comer, 200

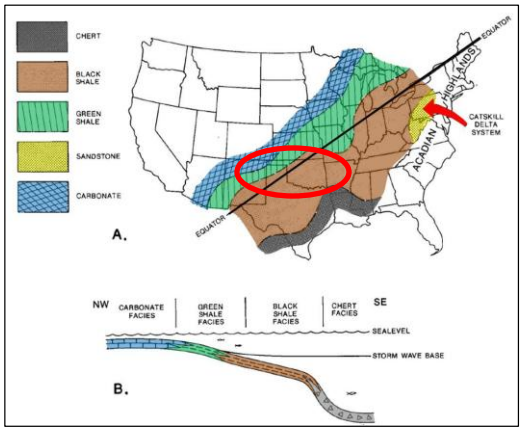
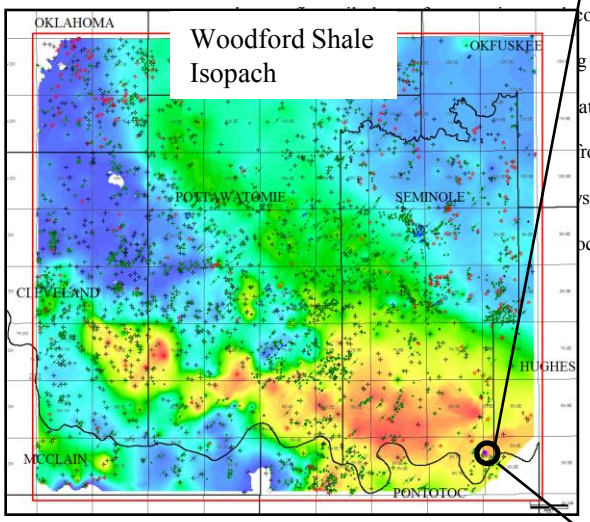
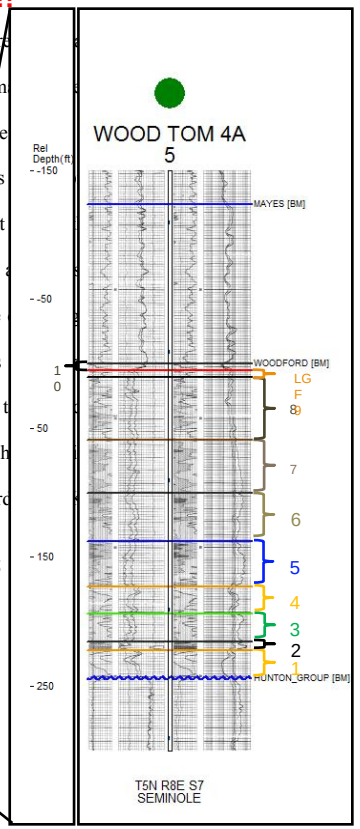


Figure 10. (A) Paleogeography and facies distribution in the Late Devonian. (B) Northwest-southeast schematic cross section showing the relation between facies and relative water depth (Modified from Kirkland et al, 1992).

Woodford deposition and resulting stratigraphy is much more complex than shown on this map!!

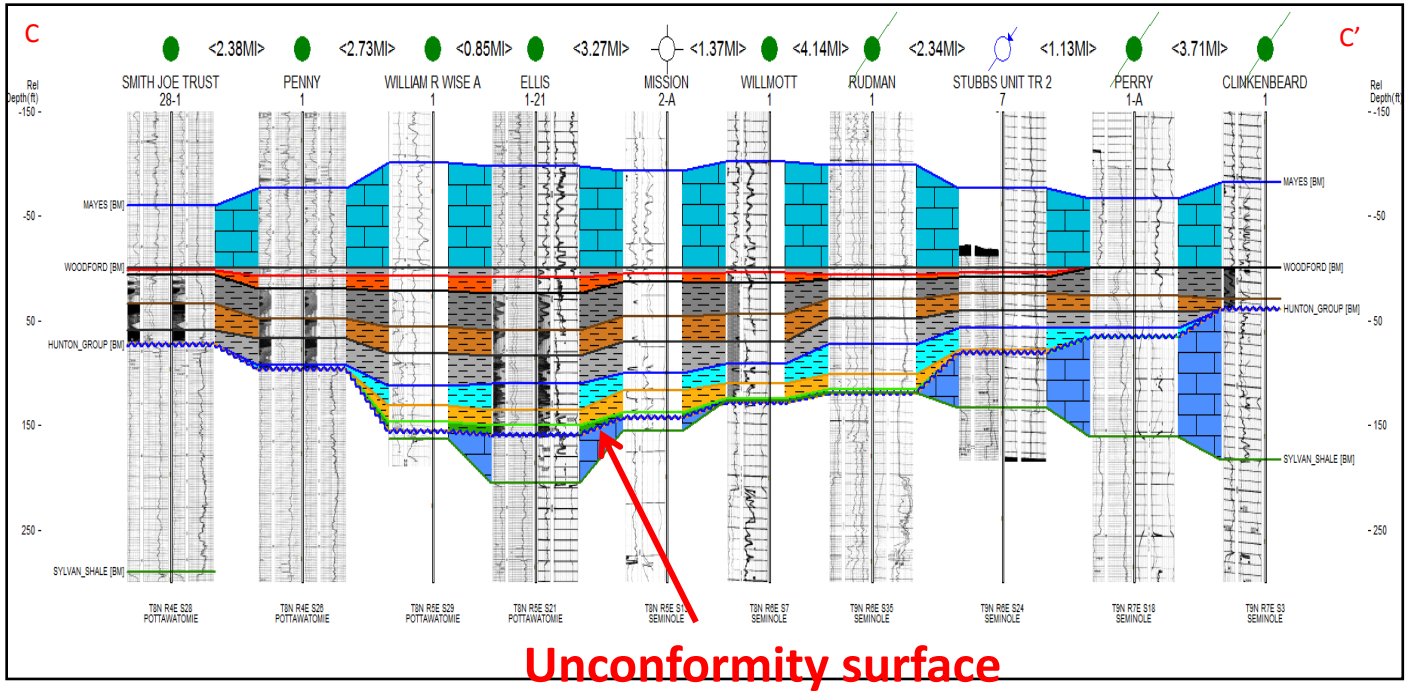
The Woodford Shale has been widely r
source rock, containing oil-generative organic m
kerogen) (Cardott, 2001; Comer, 2005). Howe
attractive target for unconventional oil and gas
source rock that is widely distributed throughout



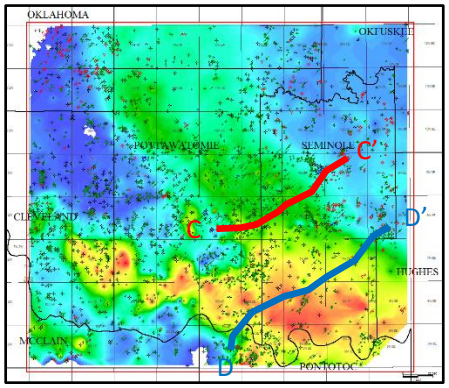


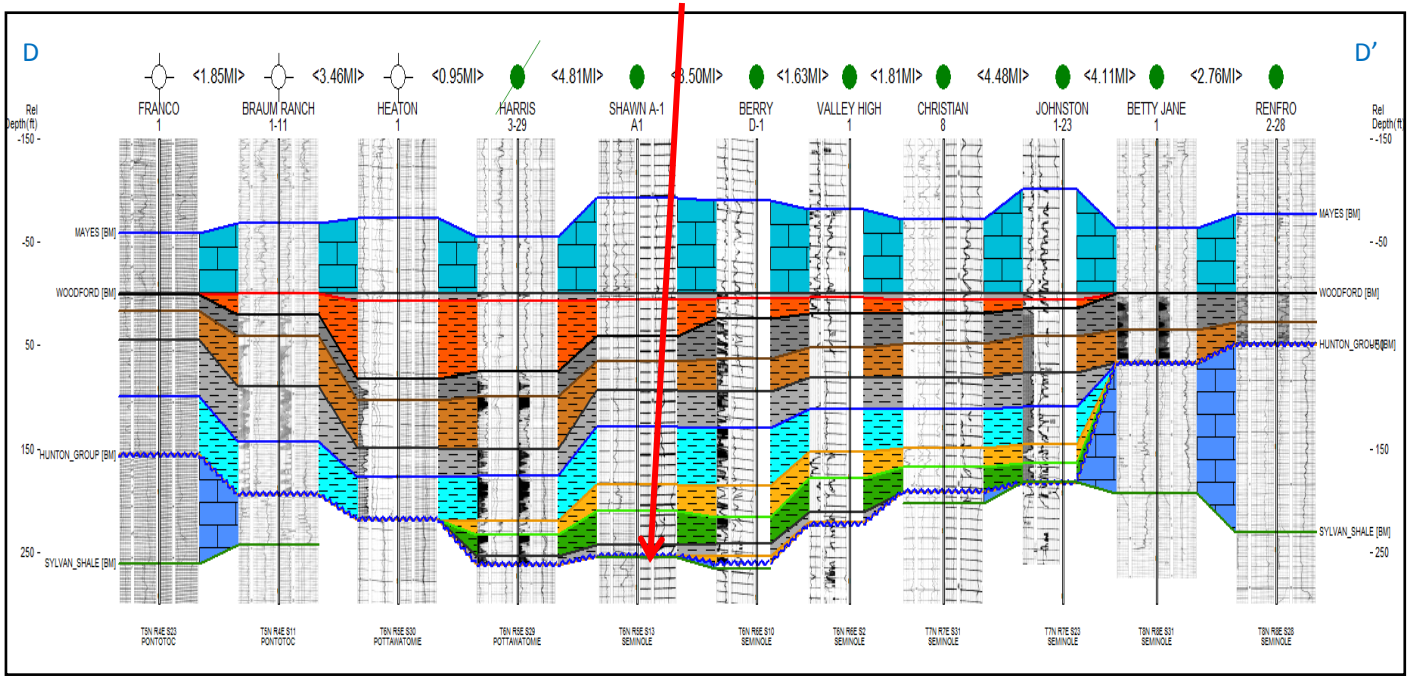
Correlation Standard on Cherokee Platform (from McCullough):

Woodford Shale subdivided into 10 units based on well log profiles (GR, Res, D/N); which we call high frequency cycles.



C-C' shows clear termination of units along both E and W edges. Maximum presence of units occurs in central area.

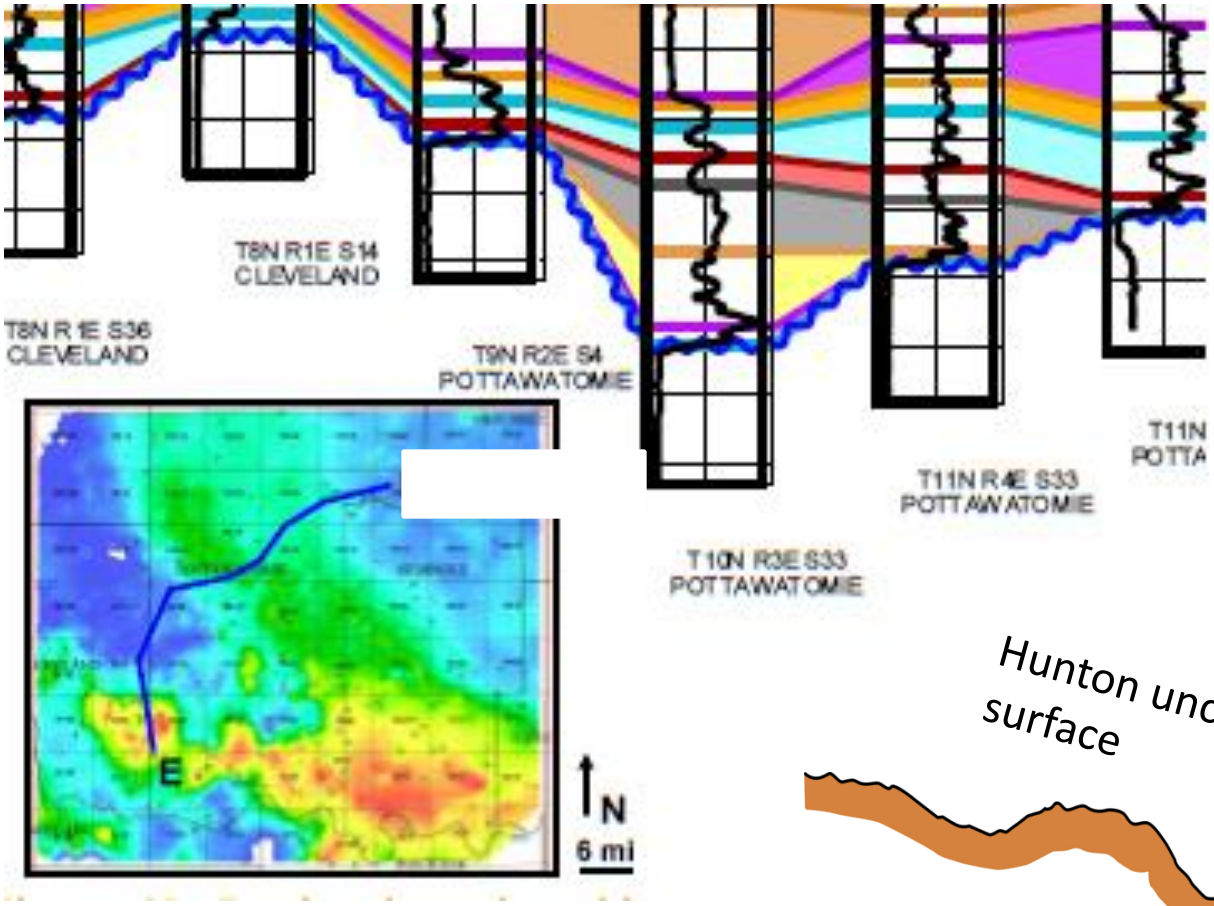


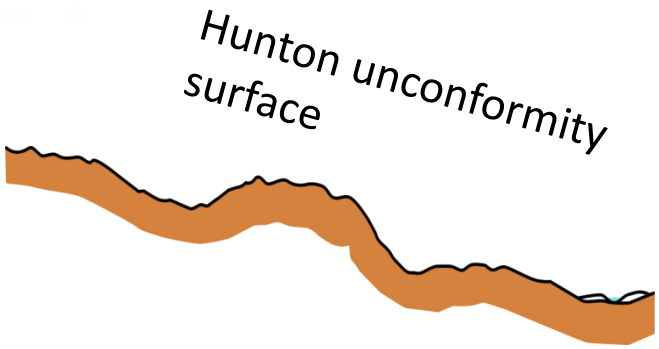


D-D' shows termination of units along both E and W edges. Maximum presence of units occurs in central area, however, some units also vary in thickness (unit 9).

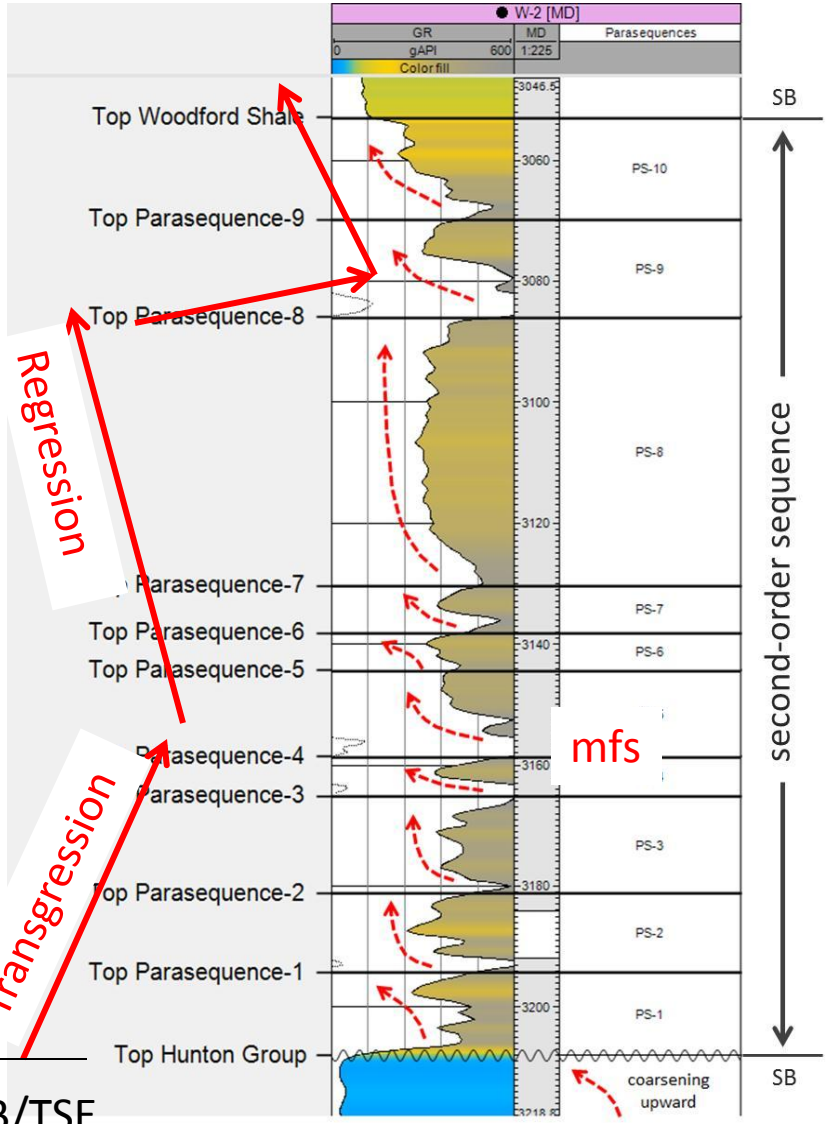
E

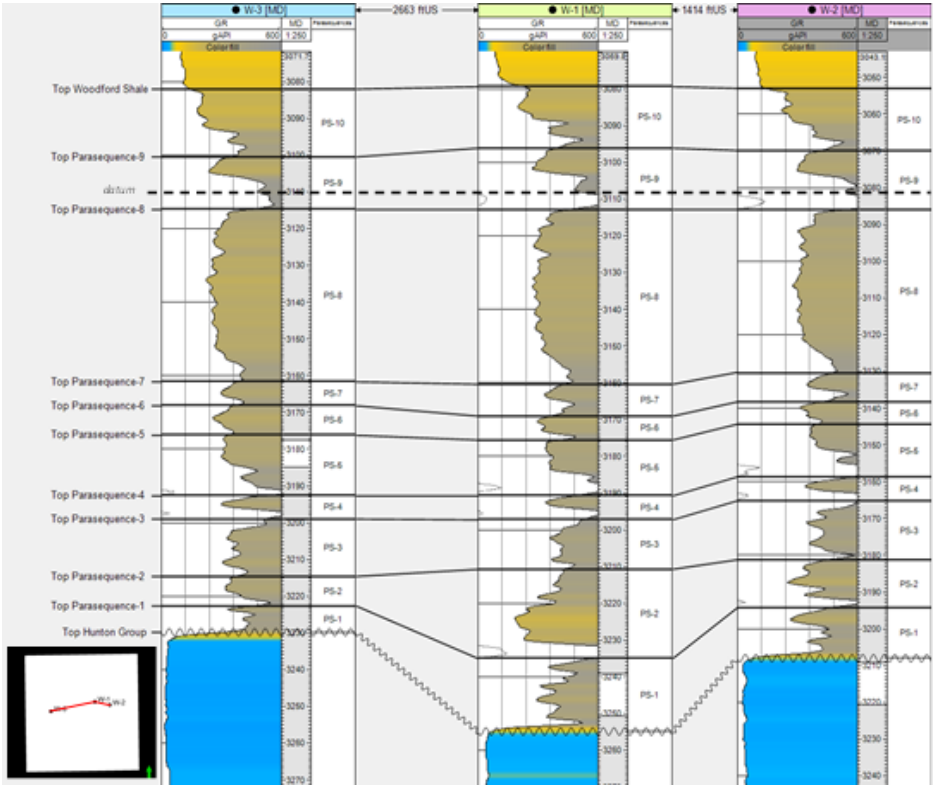
E’


T8N R1E S14
CLEVELAND
T8N R1E S36
CLEVELAND
T9N R2E S4
POTTAWATOMIE
T10N R3E S33
POTTAWATOMIE
T11N R4E S33
POTTAWATOMIE
T11N
POTTA
E
N
6 mi


Hunton unconformity surface

Gamma-ray log of well W-2 showing the second-order sequence boundaries (SB) of the Woodford Shale and superimposed 3rd order, higher-frequency sequences.

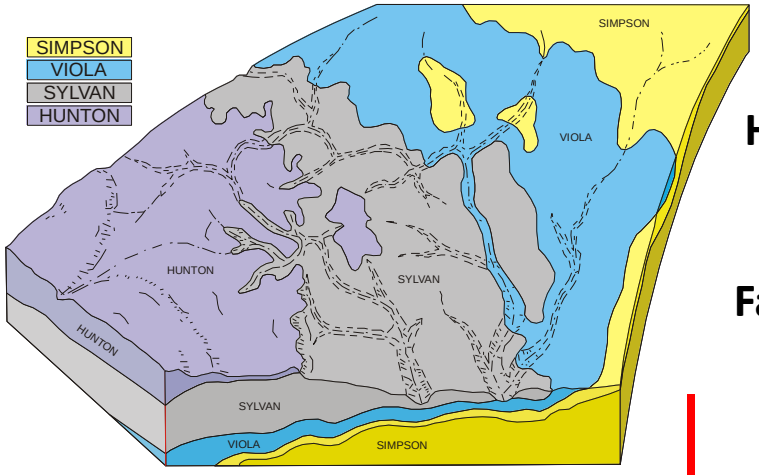




SB/TSE

Cardonas, 2014

Effect of erosional paleotopography on valley filling

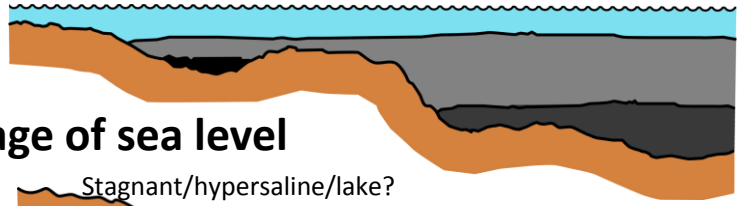


Modified from Althoff, 2012

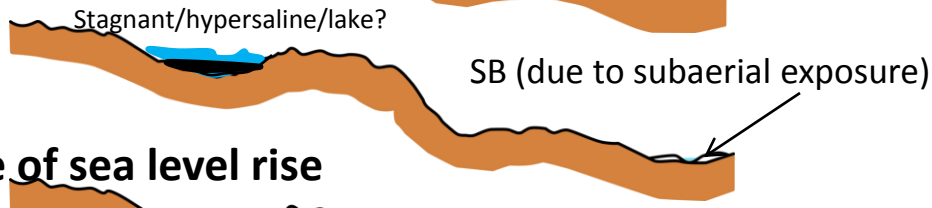
Less preserved TOC

Improved water circulation =

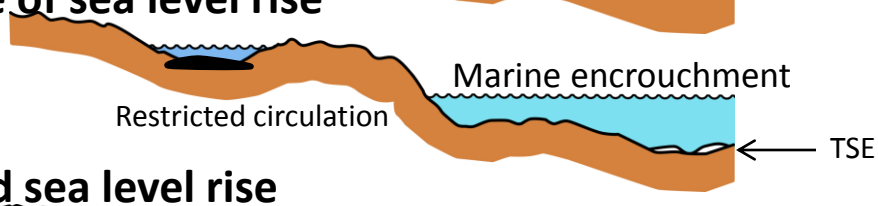
Highstand of sea level



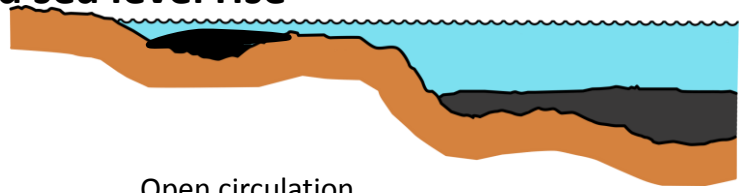
Falling stage of sea level

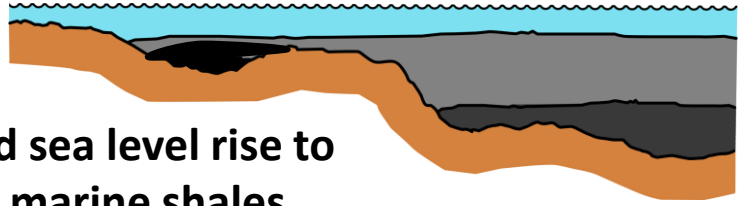


Early stage of sea level rise

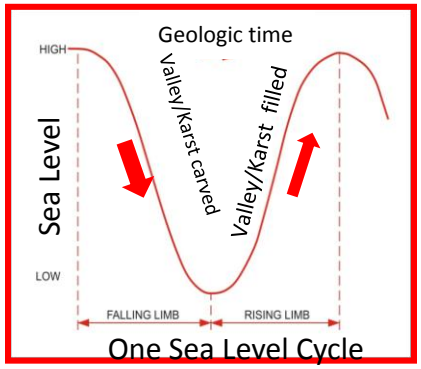


Continued sea level rise

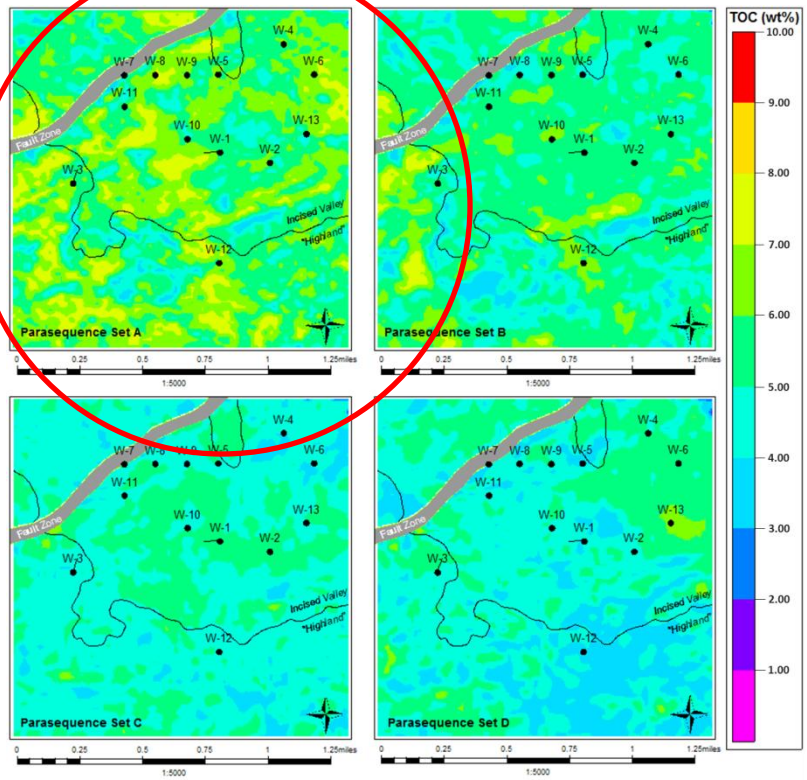




Continued sea level rise to give gray marine shales over black shales (Highstand of sea level = improved water circulation and oxygenation)



TOC from seismic inversion of Woodford 3D seismic volume

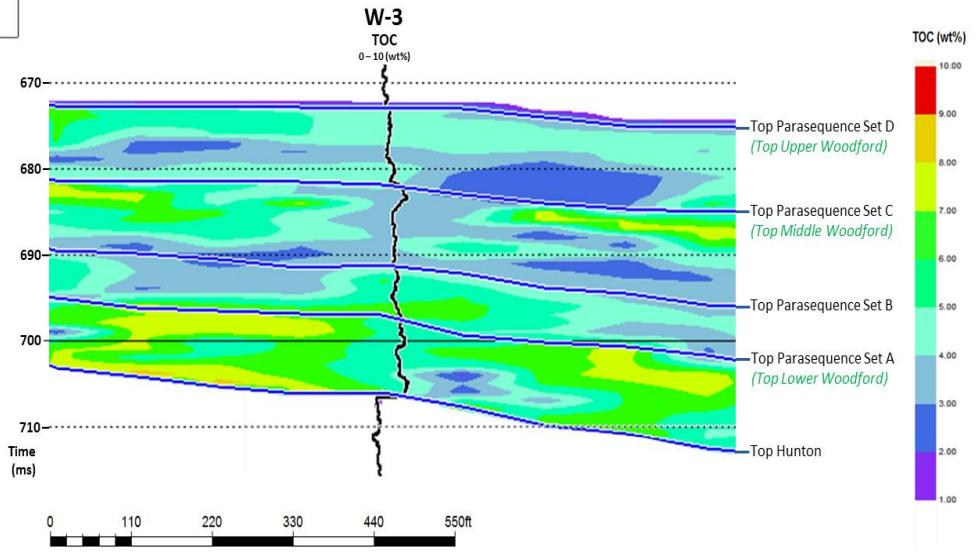


Total organic carbon (TOC) content maps for the Woodford Shale's parasequences sets in the study area. Dashed lines outline areas where this second-order sequence has more than 200 feet in thickness and are associated with pre-Woodford karsts or incised valleys

To note:

-more TOC near base WDFD

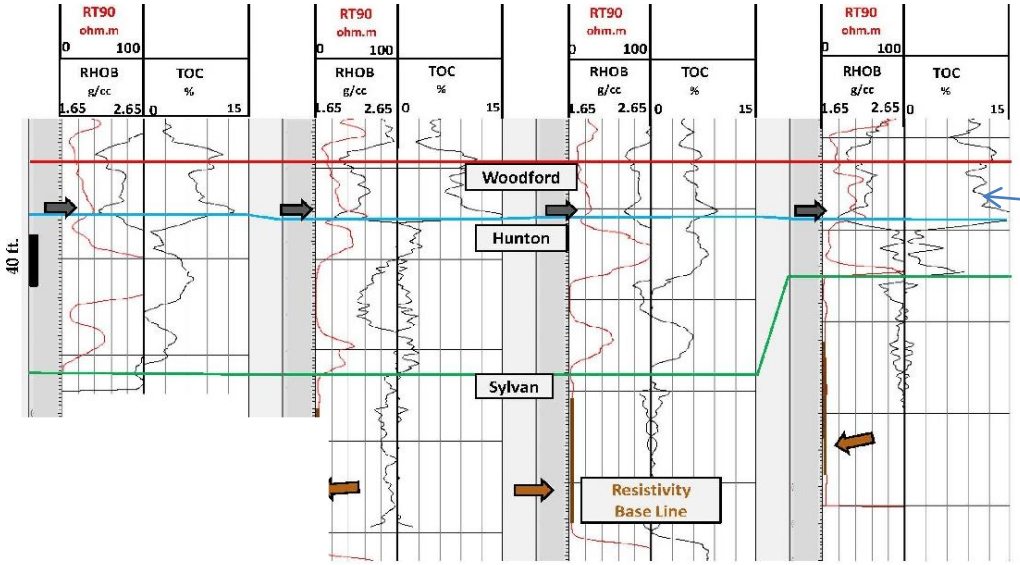
-Patchy distribution of TOC



Vertical section through the TOC section and its correlation with the calculated log in the well W-3

Cardonas 2014

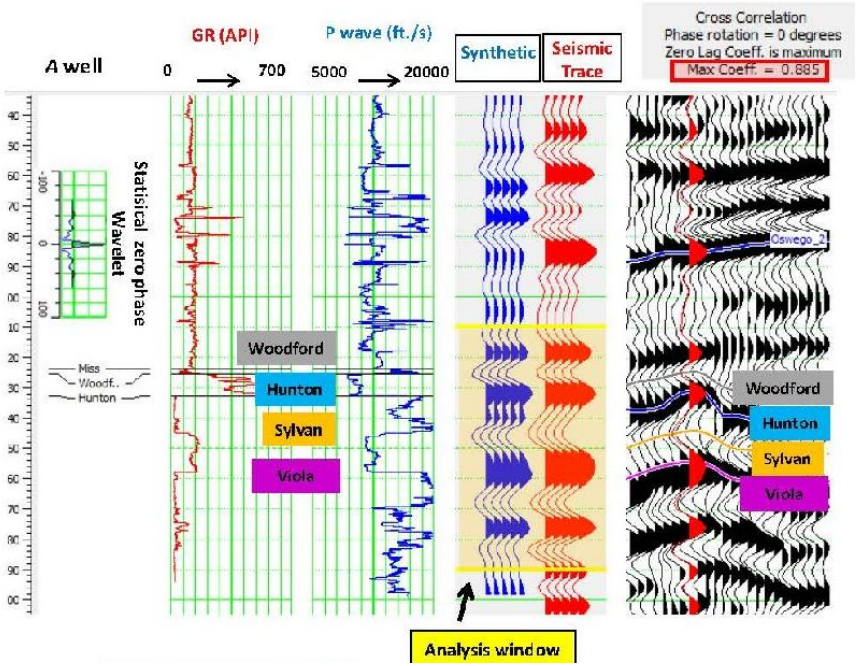
Cardonas, 2014



Calculated %TOC

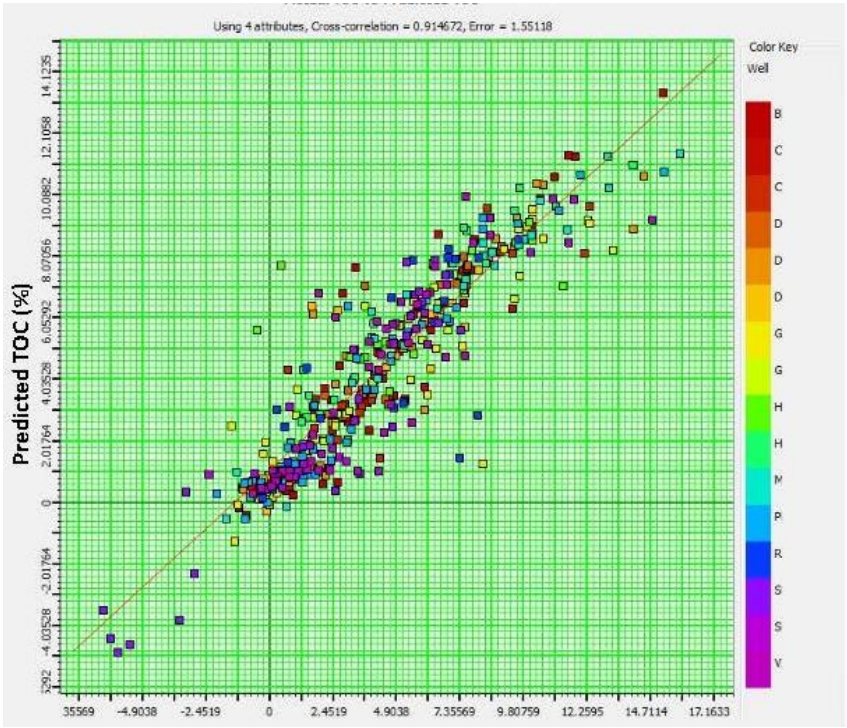
Passey calibration

Well-seismic tie

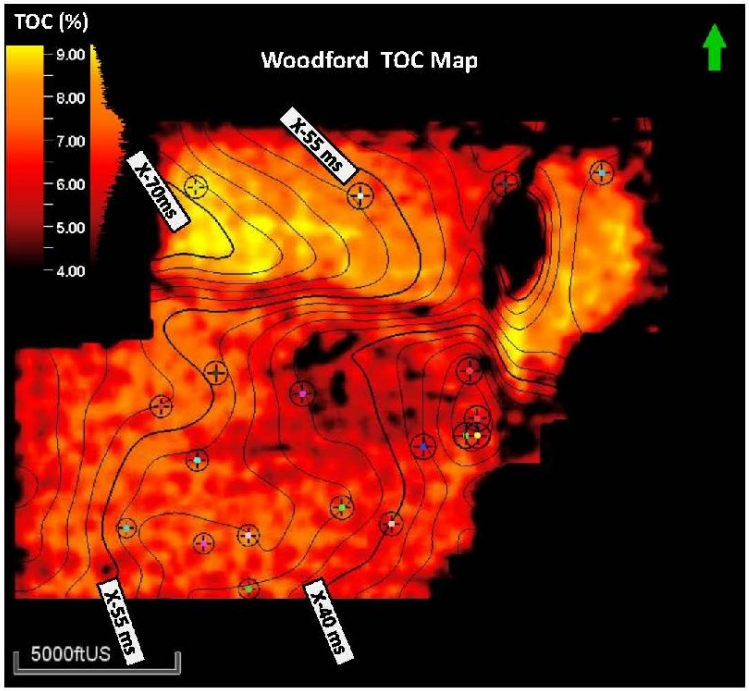


Infante, 2015

Seismically predicted TOC from inversion

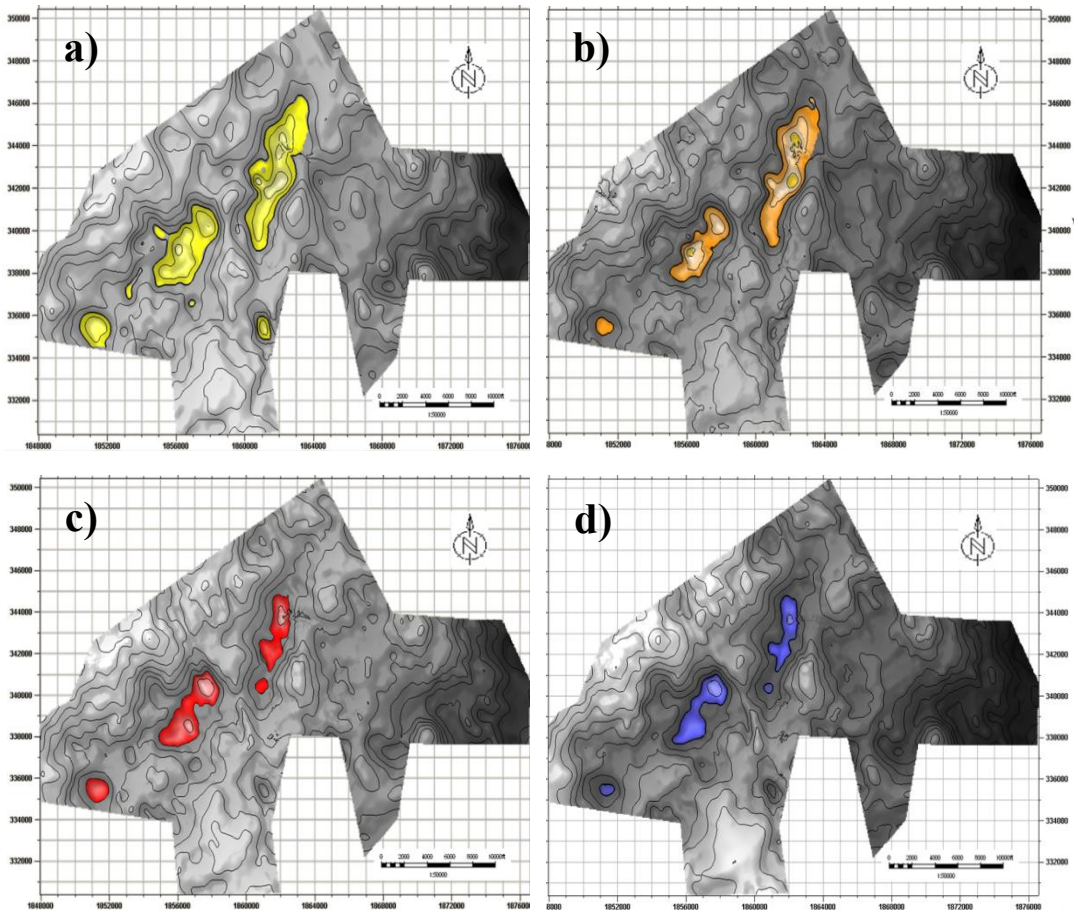


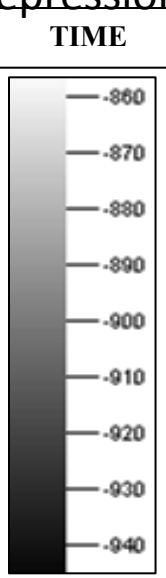
Passey-calculated TOC

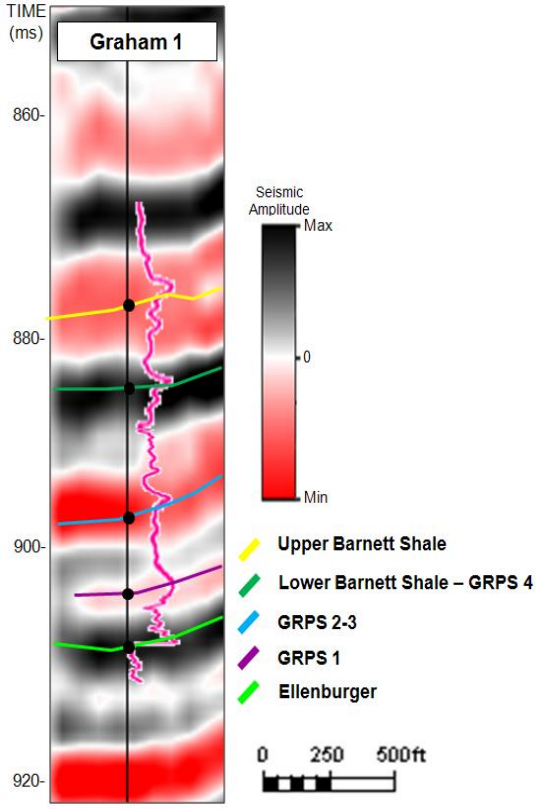


Infante, 2015

Barnett Shale 3D horizon slices showing Karst surface and depressions into the overlying Barnett







Areal distribution of karst topography on top of:

(a) GRPS 1,

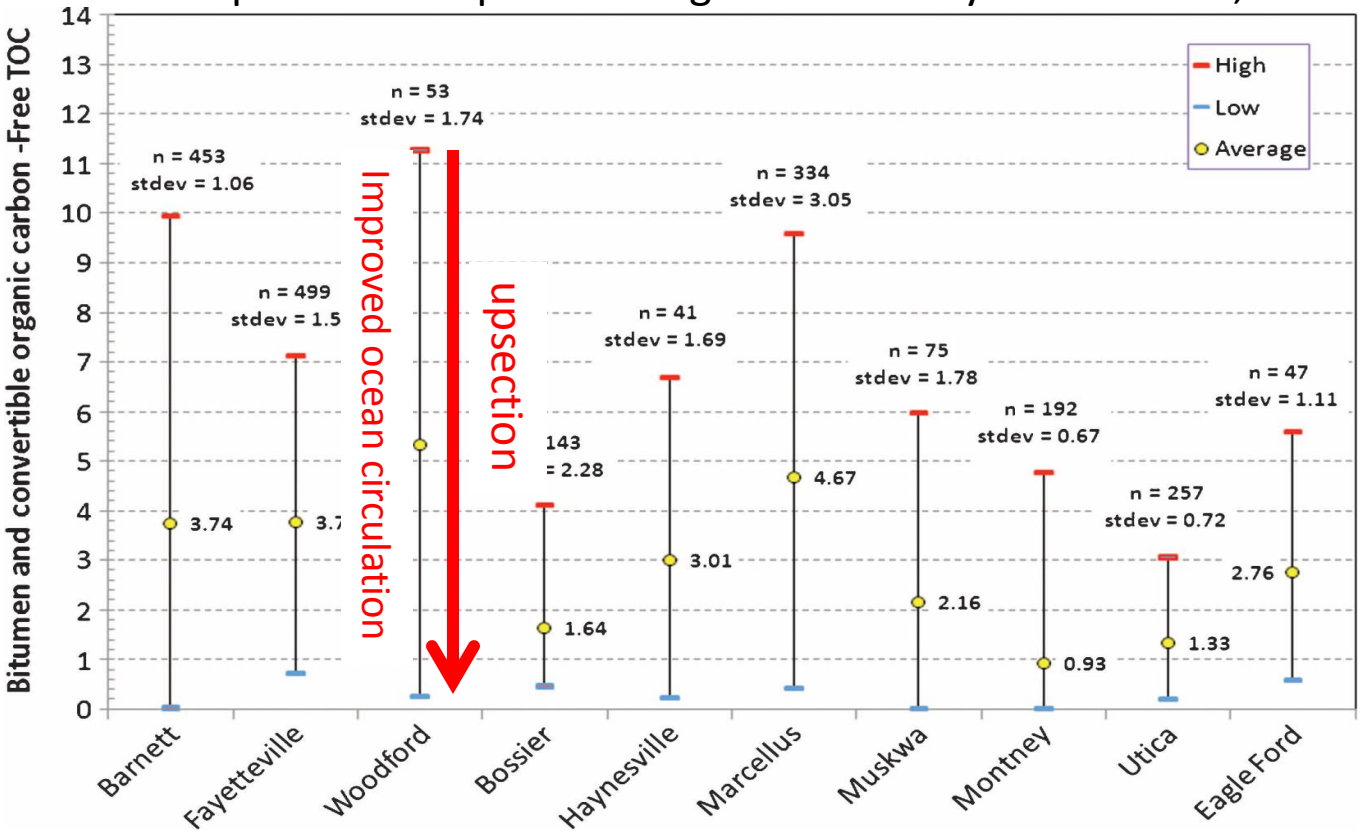
(b) GRPS 2-3,

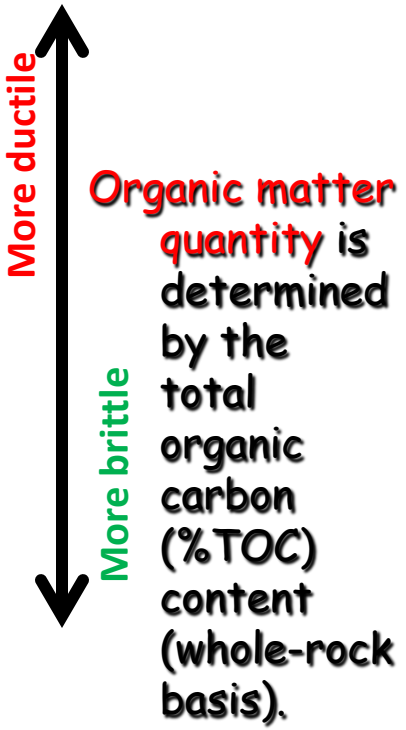
(c) Lower Barnett Sh,

(d) Upper Barnett Sh

Baruch, 2011

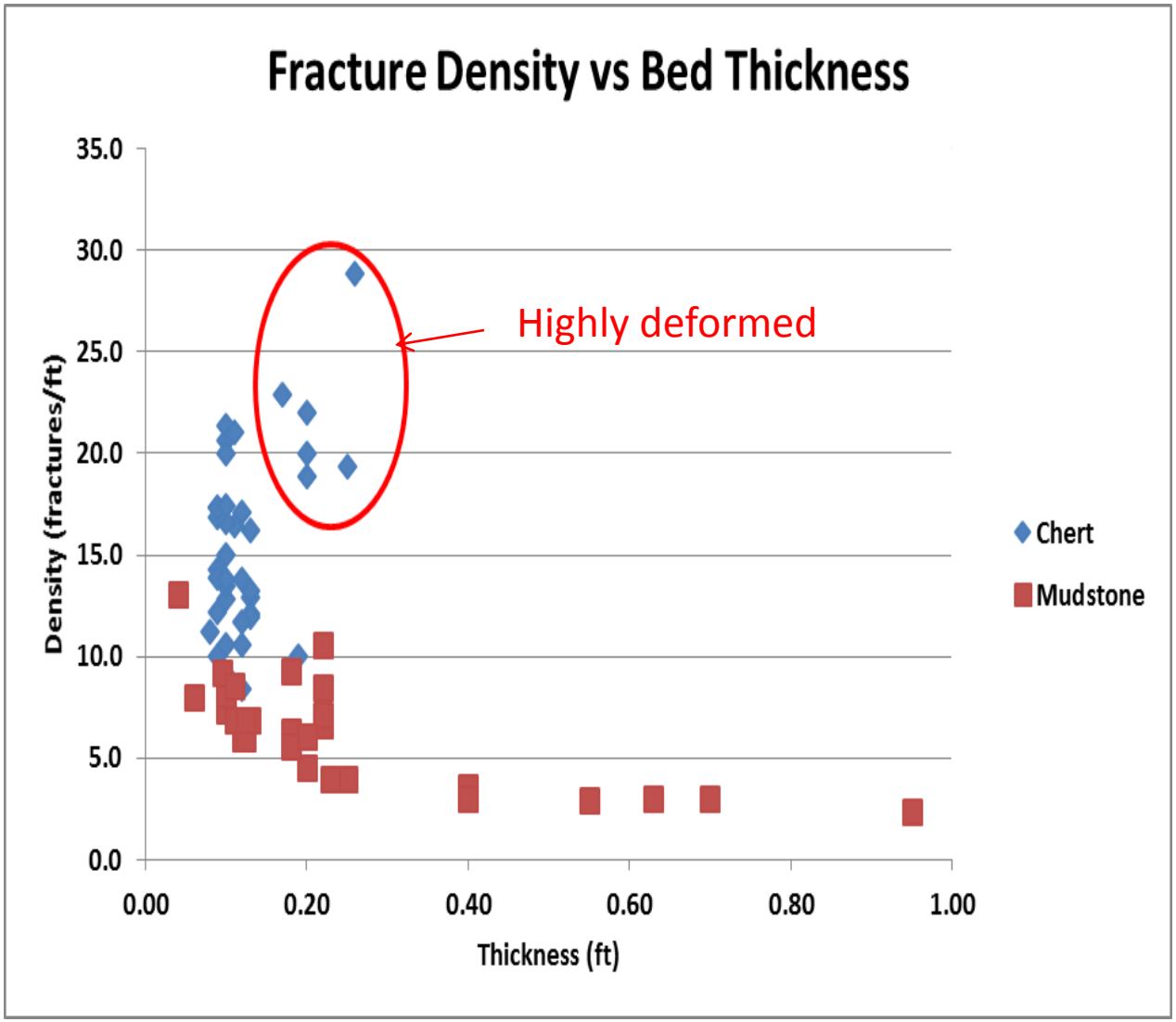
The TOCpd for the top 10 shale-gas resource systems. Jarvie, 2012



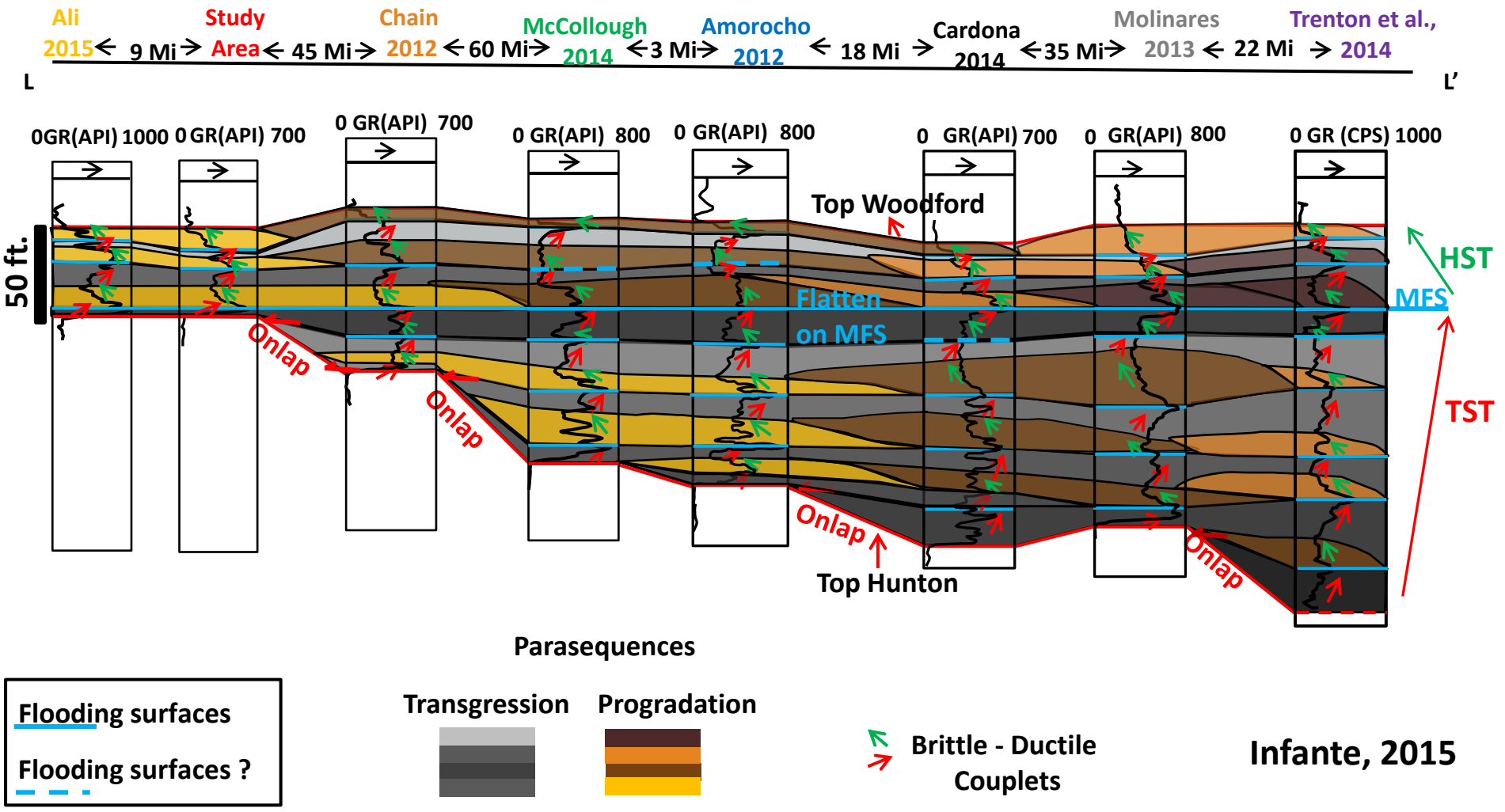


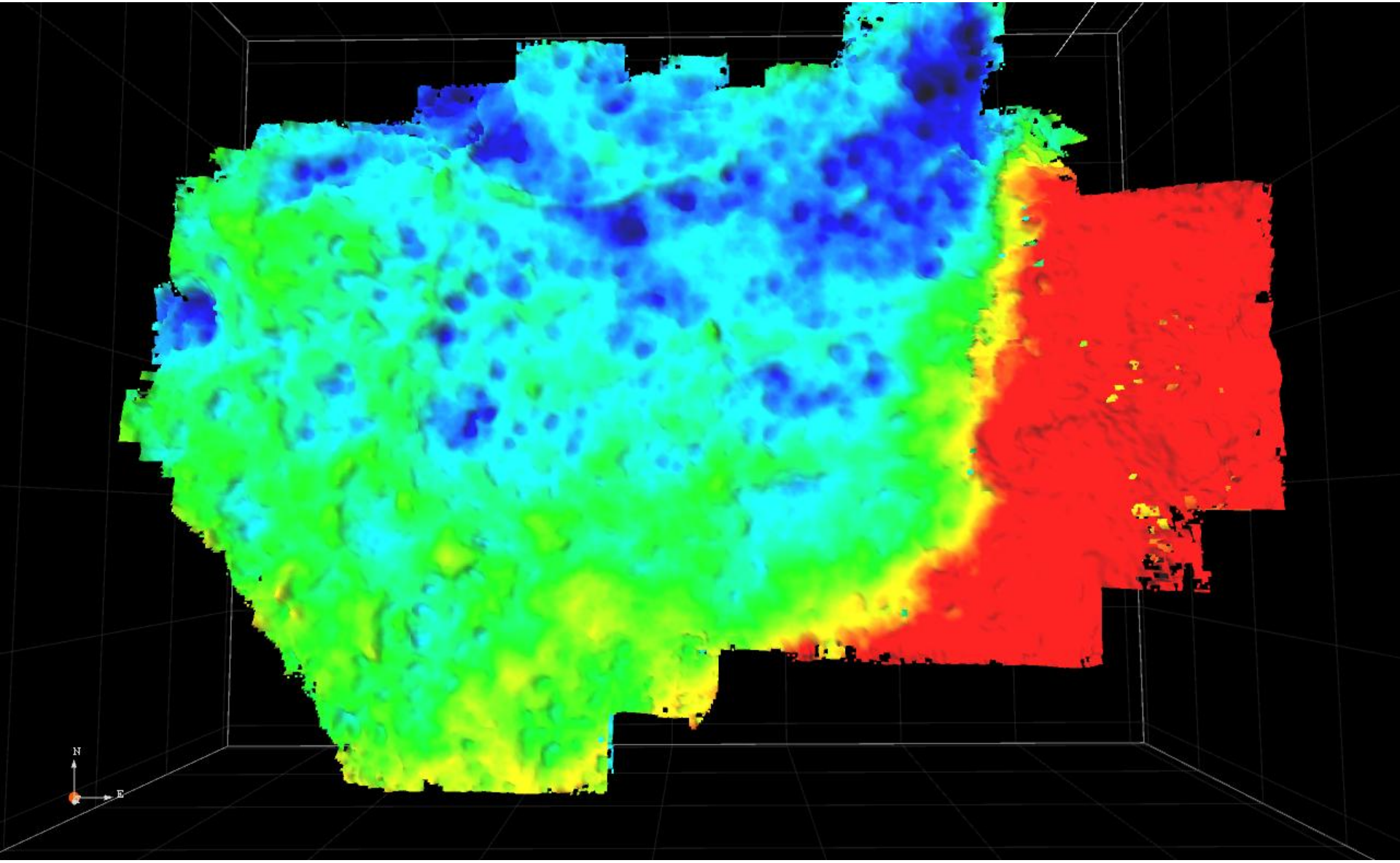
These data show the average TOCpd (present day) values for each system with the range of values, standard deviation, and number of samples. Given the high thermal maturity of these shales, these values are indicative of the nongenerative organic carbon (NGOC) values. TOCpd = present-day total organic carbon; stdev = standard deviation; n = number of samples.

Four locations along Woodford wall: by Ghosh, 2015



Regional Correlations





Mystery carbonate unconformity surface in 3D seismic area of Texas, which is overlain by carbonaceous shale