Oil Production From Low-Maturity Organic-Rich Shale: An Example from the Devonian New Albany Shale in the Illinois Basin, Breckinridge County, Kentucky *

Brandon C. Nuttall[1], Thomas M. Parris[1], Glynn Beck[1], Donna C. Willette[2], Maria Mastalerz[3], and Joan Crockett[2]

Search and Discovery Article #51196 (2015)**
Posted November 30, 2015

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Abstract

The Devonian New Albany Shale is recognized as the primary source rock for Illinois Basin oil and gas production. As a shale reservoir, the New Albany is historically a gas producer. In 2011, Endeavor Energy Resources LP drilled and completed four natural gas producers in the Grassy Creek Member at the top of the shale in Breckinridge County, Kentucky. In 2012, Endeavor filed new completion reports indicating these wells had transitioned to combined oil and natural gas producers. In 2013, Hard Rock Drilling completed two oil producers to the northwest of the Endeavor wells. In approximately 18 months, these six wells have produced 23,649 barrels of oil and 246 MMcf of gas.

Oil, gas, and well cutting samples were acquired from two Endeavor wells and the Kentucky Geological Survey No. 1 Blan well. Rock-Eval, isotopic, and chromatographic analysis indicates the New Albany is a good, early mature source rock with Type I and Type II oil-prone marine kerogen that was thermogenically altered to natural gas and oil. Low reservoir pressures and geochemical fingerprinting suggest that the hydrocarbons were generated in place or very locally with minimal migration. The low Tmax and high hydrogen index (from Rock-Eval), presence of wet gas, and a large fraction of light gasolines in the produced oils are not consistent with classic measures of thermal maturity, however. Additional study is needed to develop a better understanding of this production and realistically assess the oil and gas potential of the New Albany Shale.

Selected References

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Oil Production from Low-maturity Organic-rich shale: an Example from the Devonian New Albany Shale in the Illinois Basin, Breckinridge County, Kentucky

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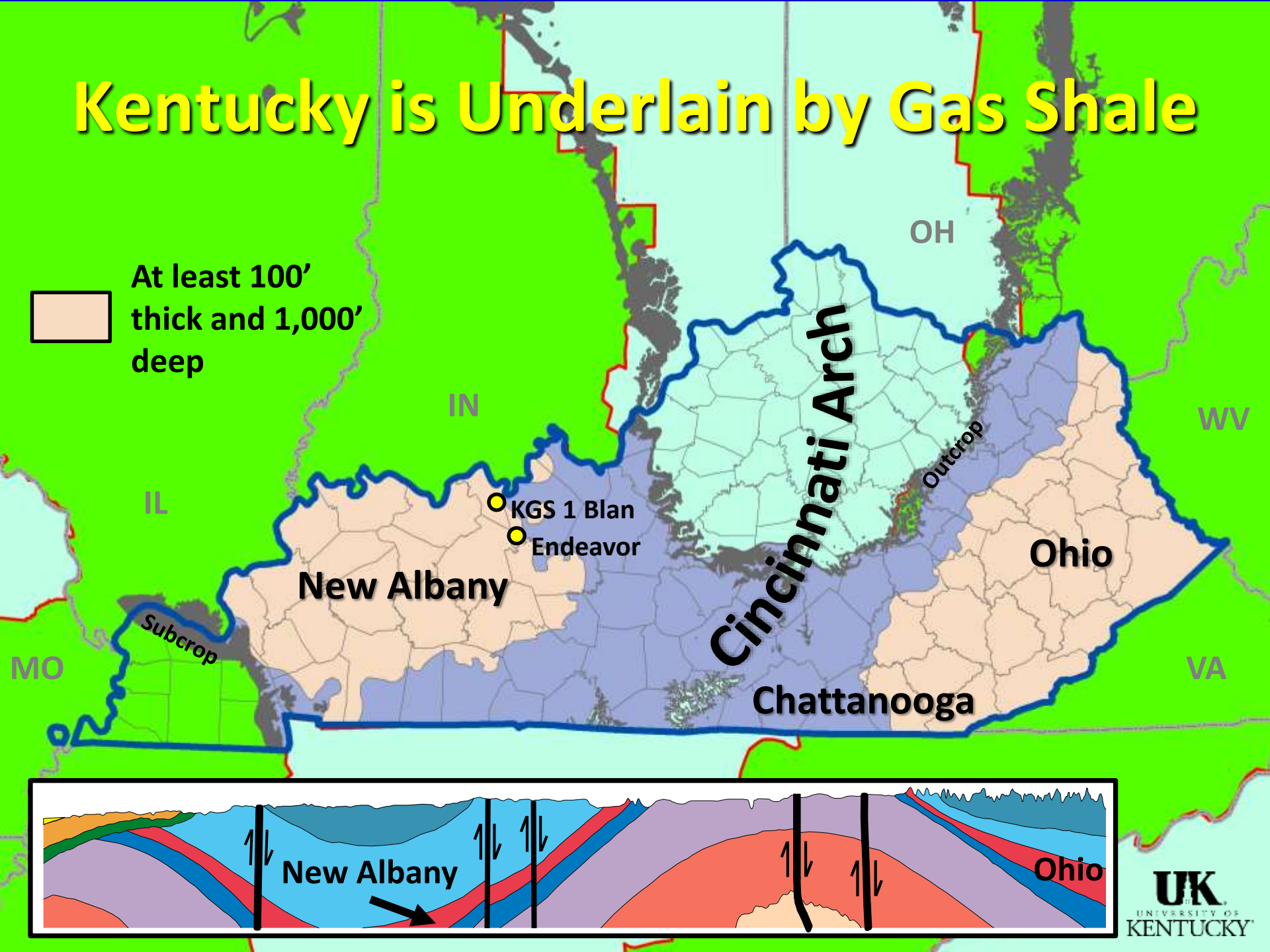
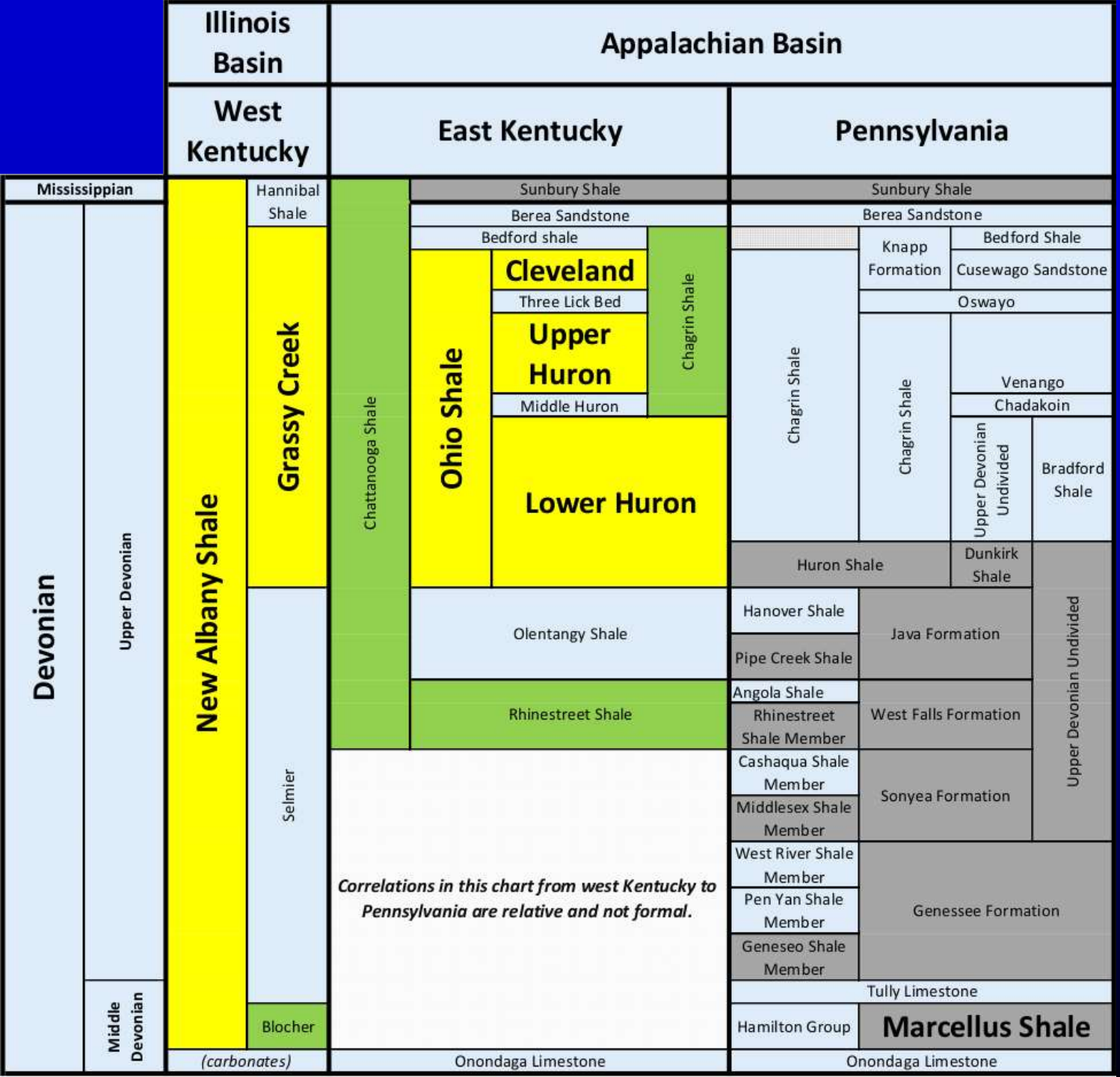
Eastern Section AAPG, Indianapolis, IN 21-Sep-2015

Kentucky is Underlain by Gas Shale





General Stratigraphy

Kentucky shale gas producer

Minor producer

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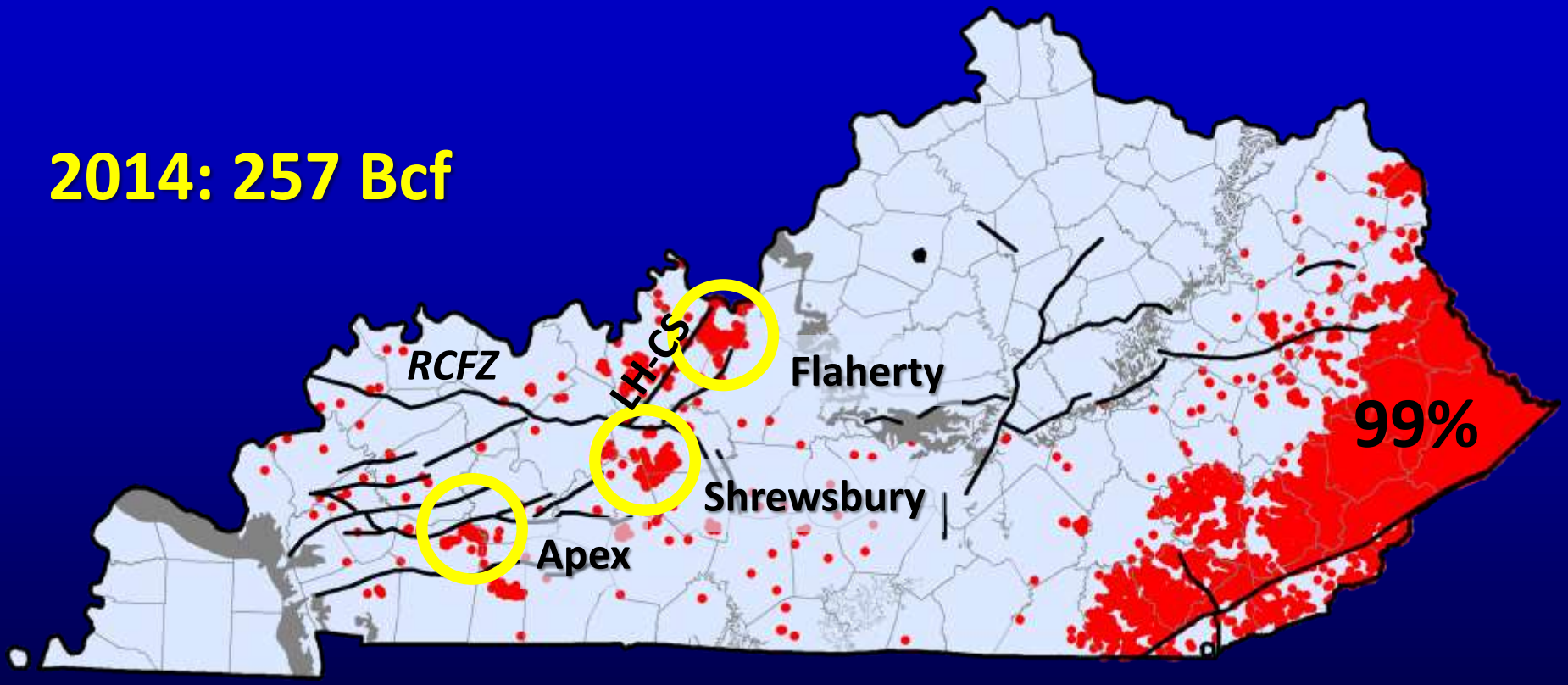
Kentucky Shale Gas Wells

2014: 257 Bcf



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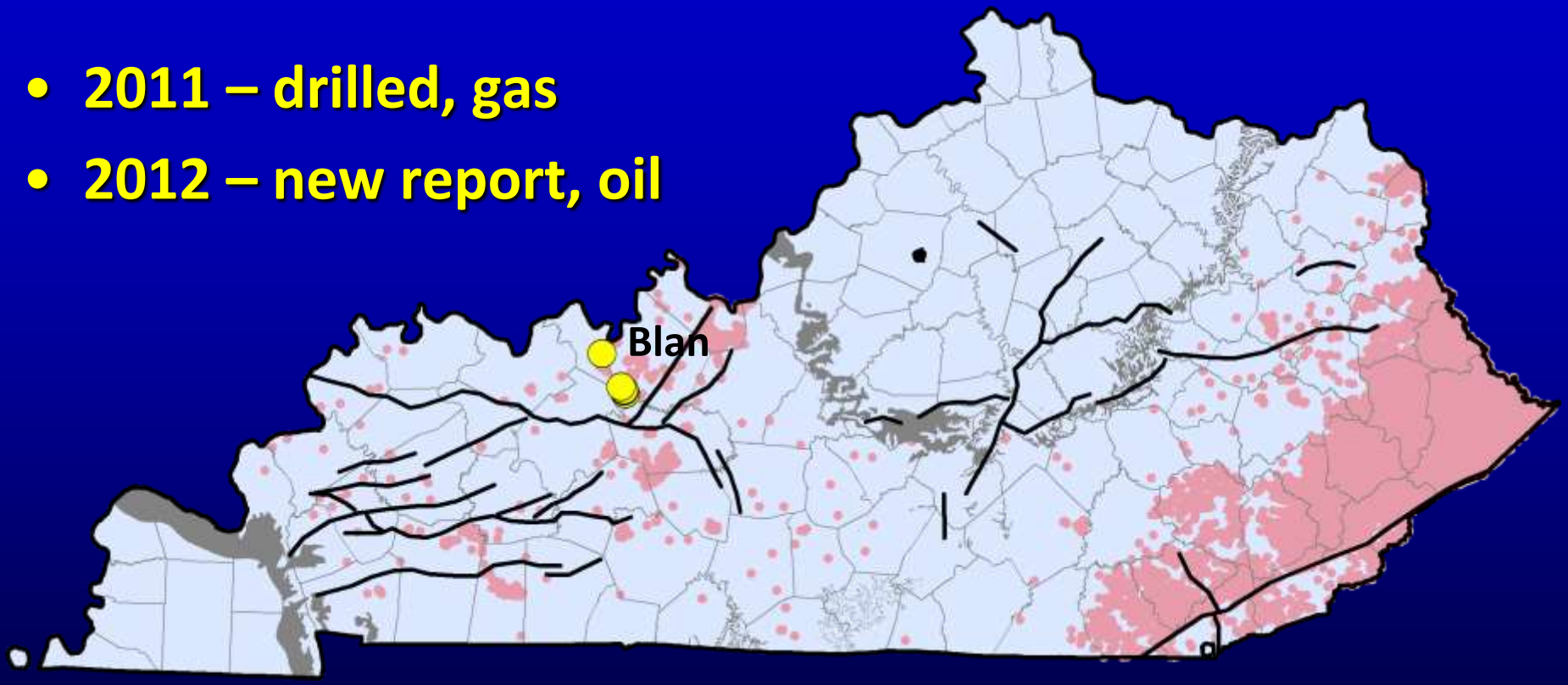
Endeavor Wells in Breckinridge Co.

- 2011 – drilled, gas
- 2012 – new report, oil



Initial GOR from 1.8 to 4

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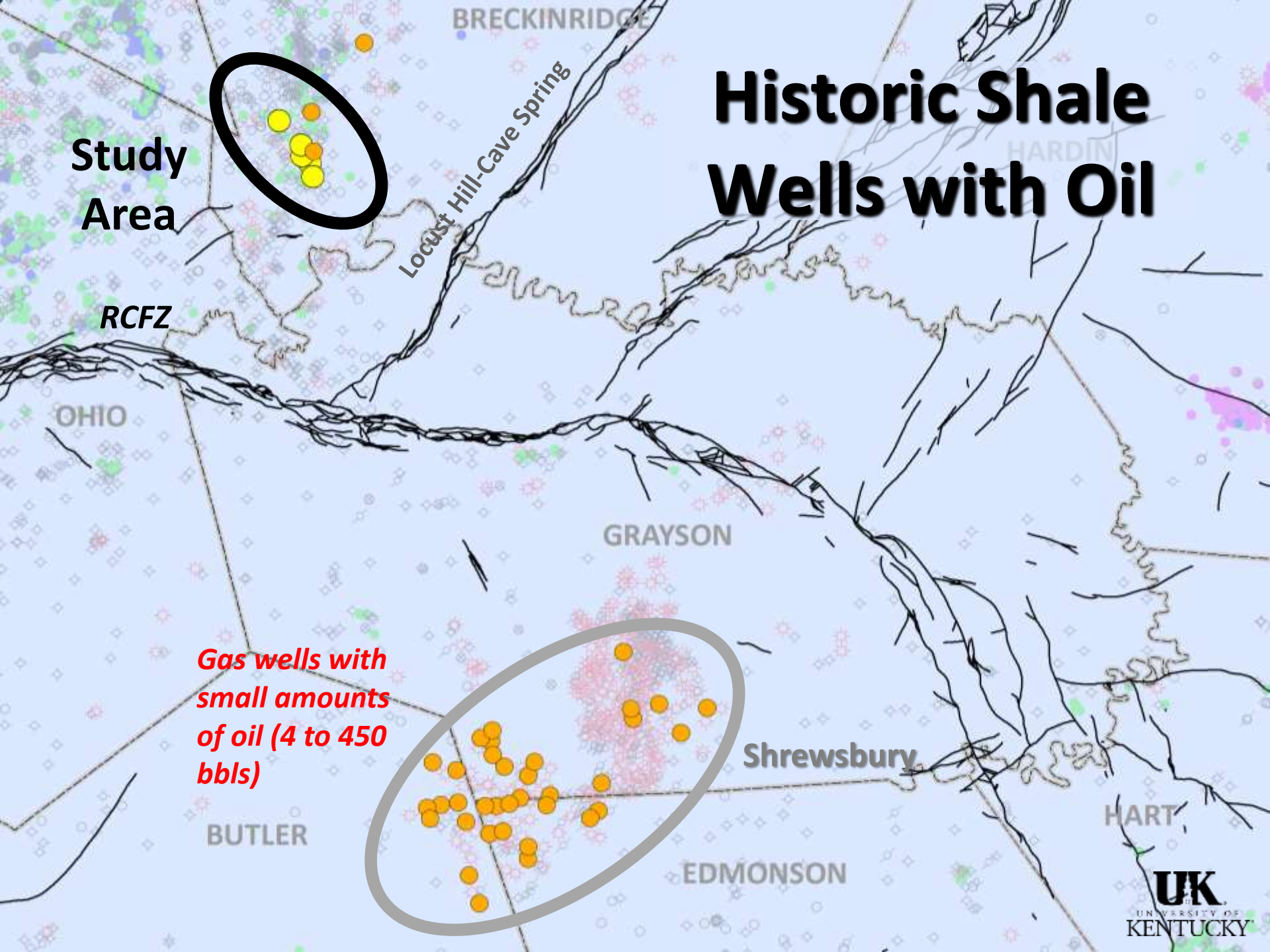
Historic Shale Wells with Oil
Study Area
RCFZ
Locust Hill-Cave Spring
BRECKINRIDGE
HARDIN
OHIO
GRAYSON
Gas wells with small amounts of oil (4 to 450 bbls)
Shrewsbury
BUTLER
EDMONSON
HART
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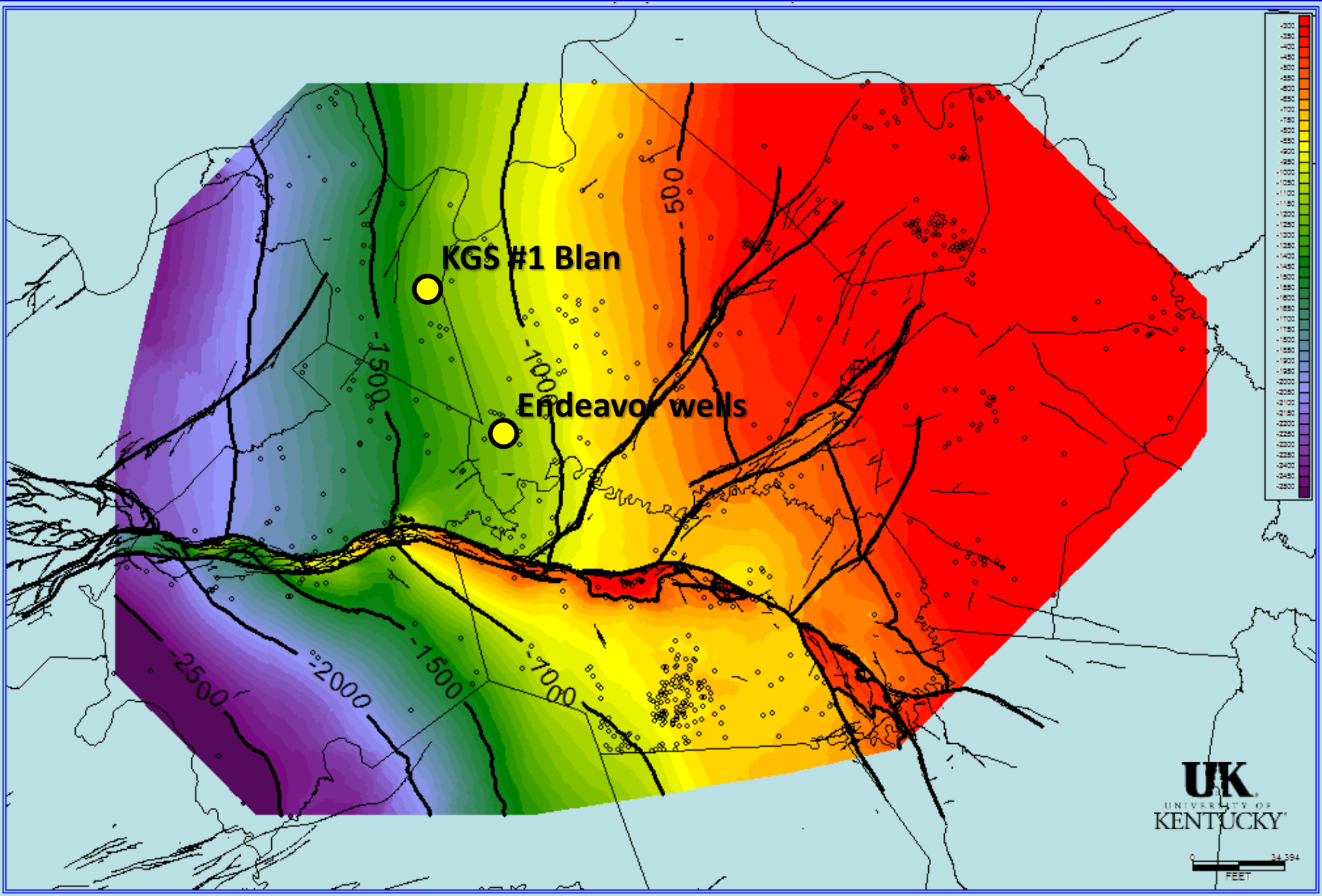
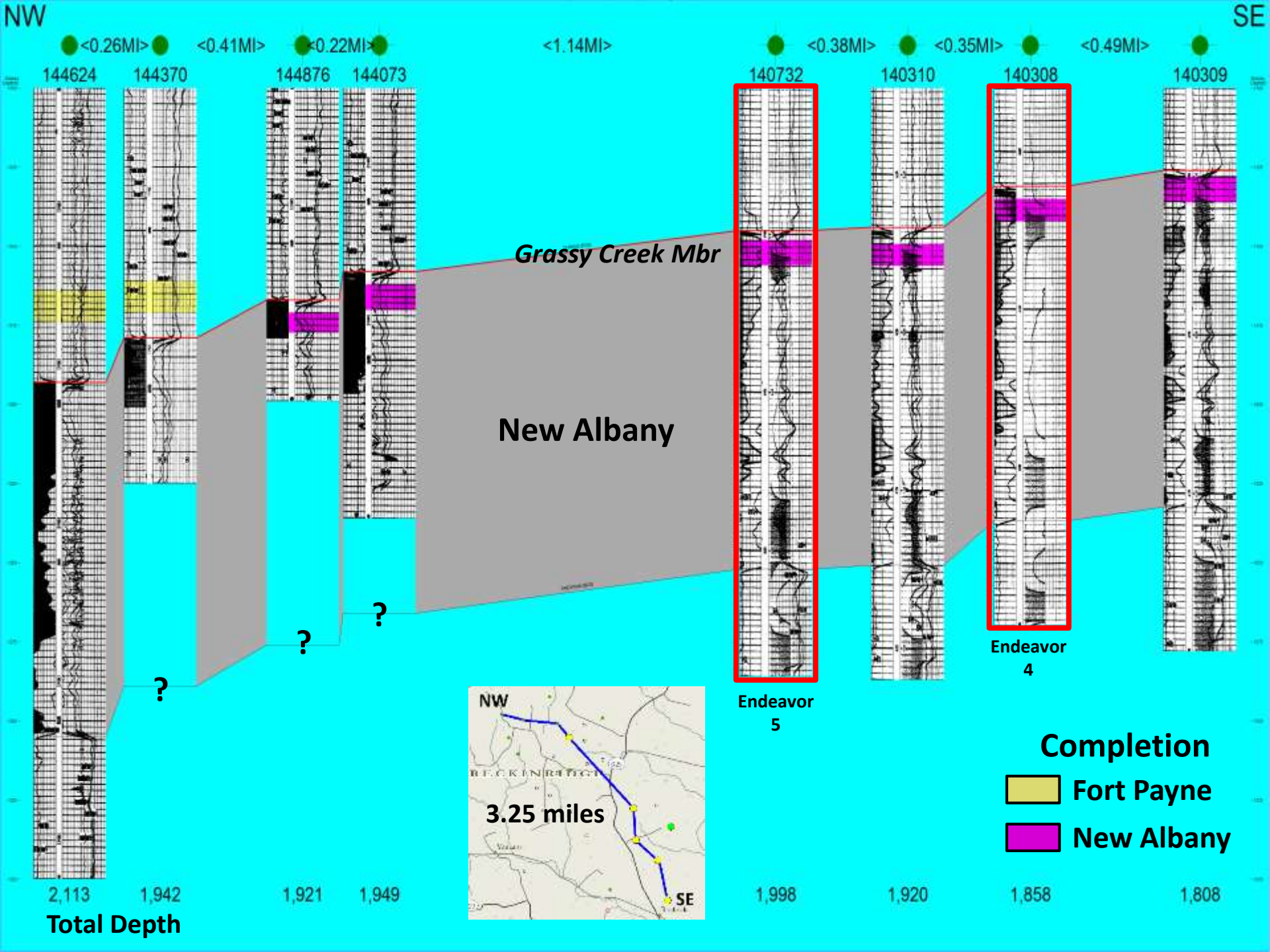
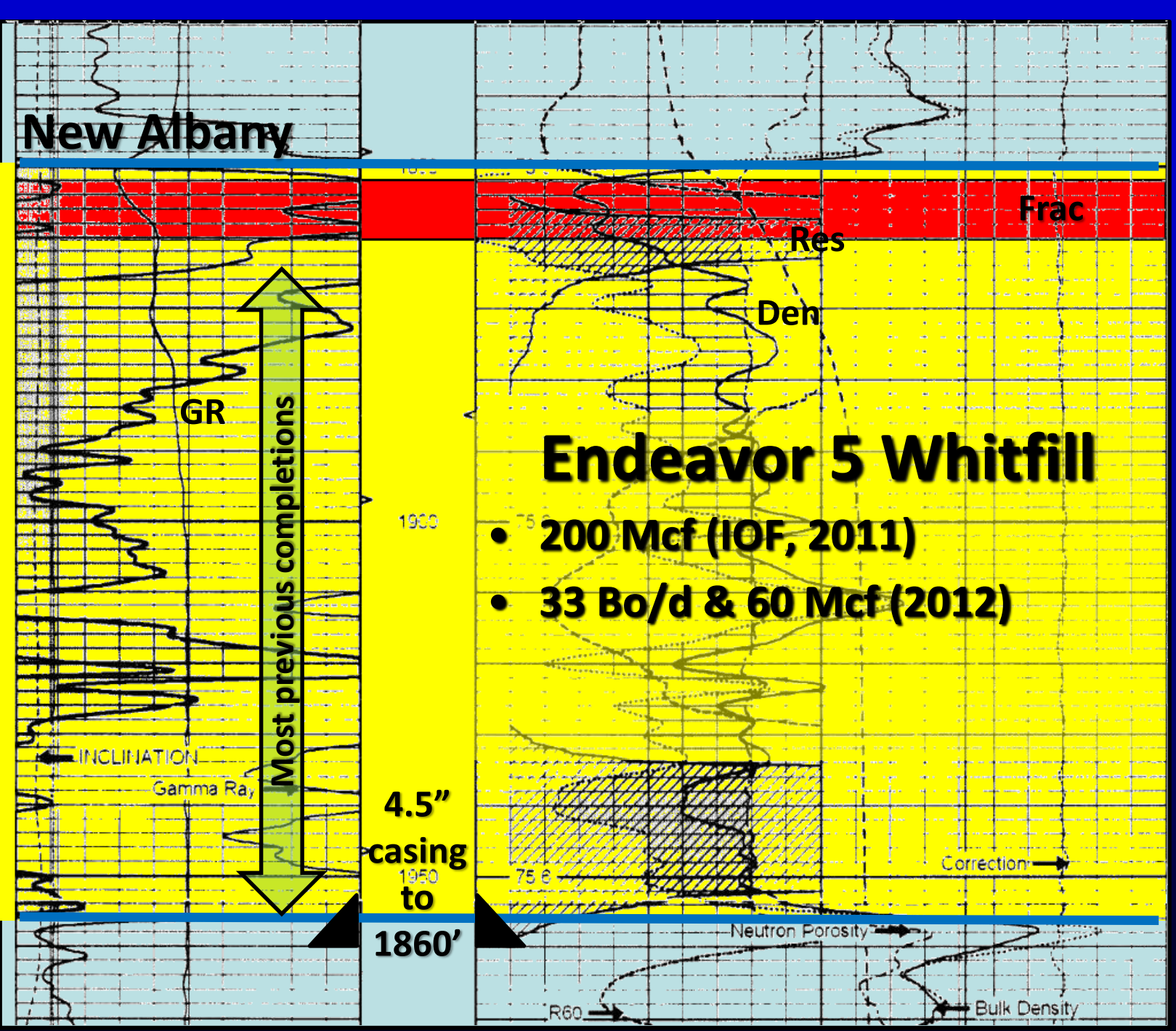
Top of New Albany Structure




NW
SE
<0.26MI>
<0.41MI>
<0.22MI>
<1.14MI>
<0.38MI>
<0.35MI>
<0.49MI>
144624
144370
144876
144073
140732
140310
140308
140309
Grassy Creek Mbr
New Albany
?
?
?
Endeavor 5
Endeavor 4
NW
3.25 miles
SE
Completion
Fort Payne
New Albany
2,113
1,942
1,921
1,949
1,998
1,920
1,858
1,808
Total Depth



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Endeavor #5 Whitfill

During visit:

- Estimated
  - 10-12 bo/d
  - 20 Mcf/d
- 400 psi backpressure
- Paraffin
  - AT 60 bo/d
  - Declines to 5 bo/d

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Preparing to
Sample Fluids
JENSEN
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Analyses & Data Sets

	Endeavor 4	Endeavor 5	KGS 1 Blan
Natural gas Composition Isotopes	✓	✓	Other data see Nuttall (2013) KGS RI 17
Oil Whole oil GC Isotopes MPLC	✓	✓	
Cuttings/Core Extract GC Aromatic GCMS Saturate GCMS MPLC	✓		✓

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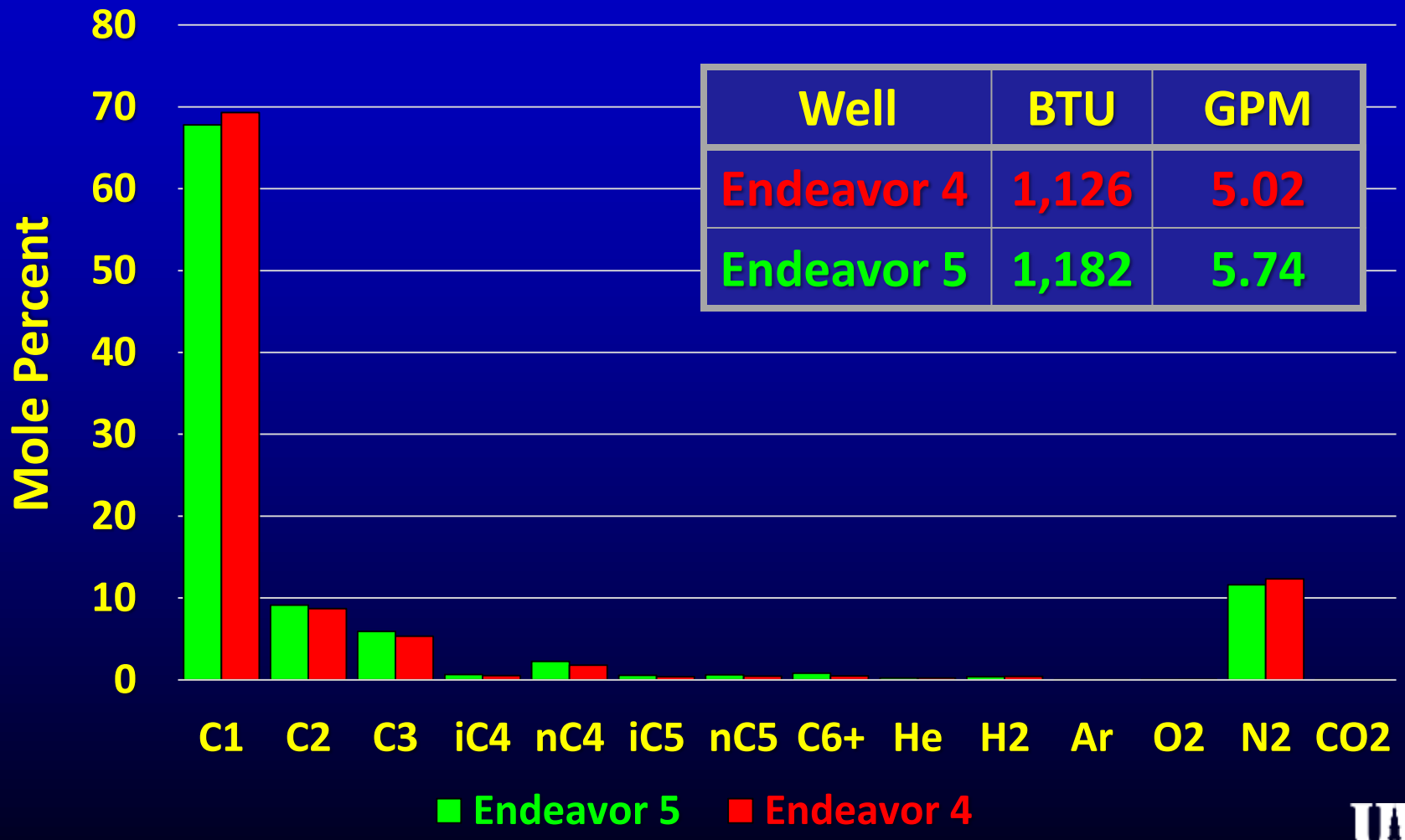
Gas Analysis



Well	BTU	GPM
Endeavor 4	1,126	5.02
Endeavor 5	1,182	5.74

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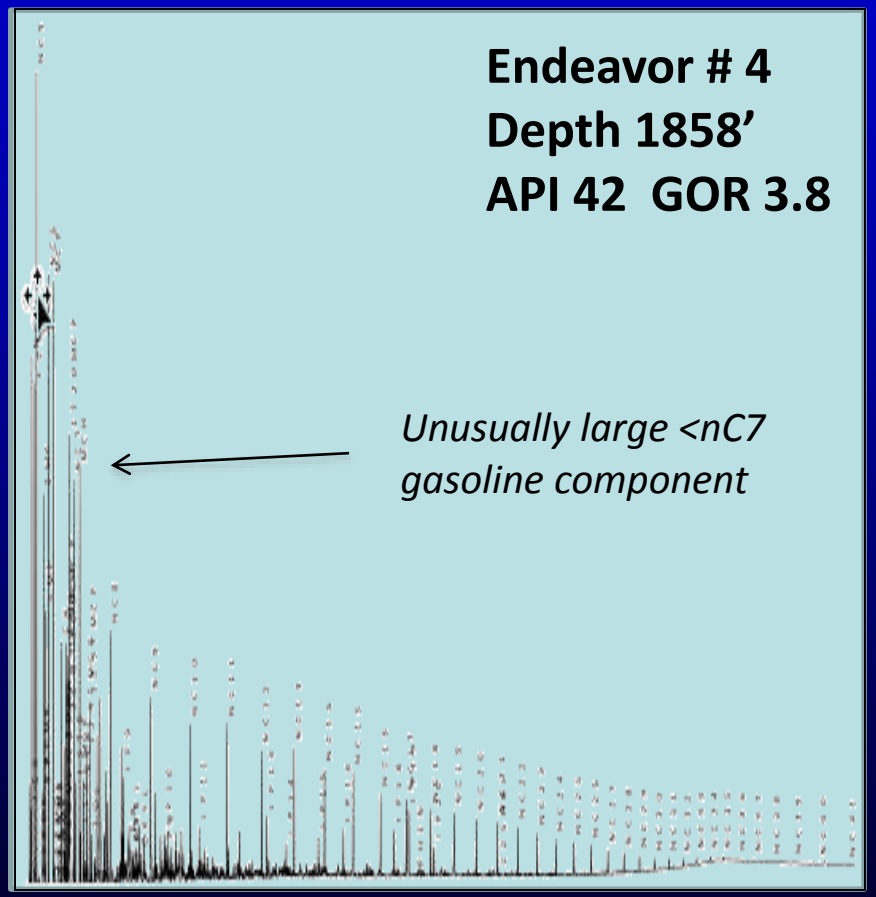
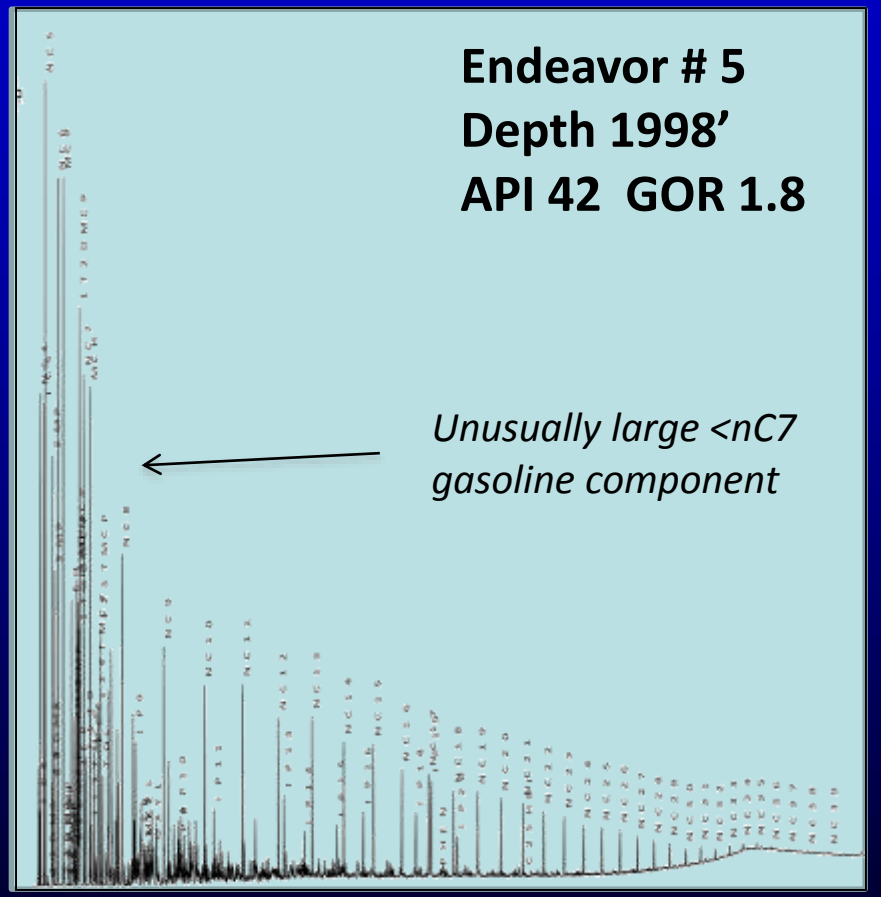
Gas Chromatograms of Whole Oil





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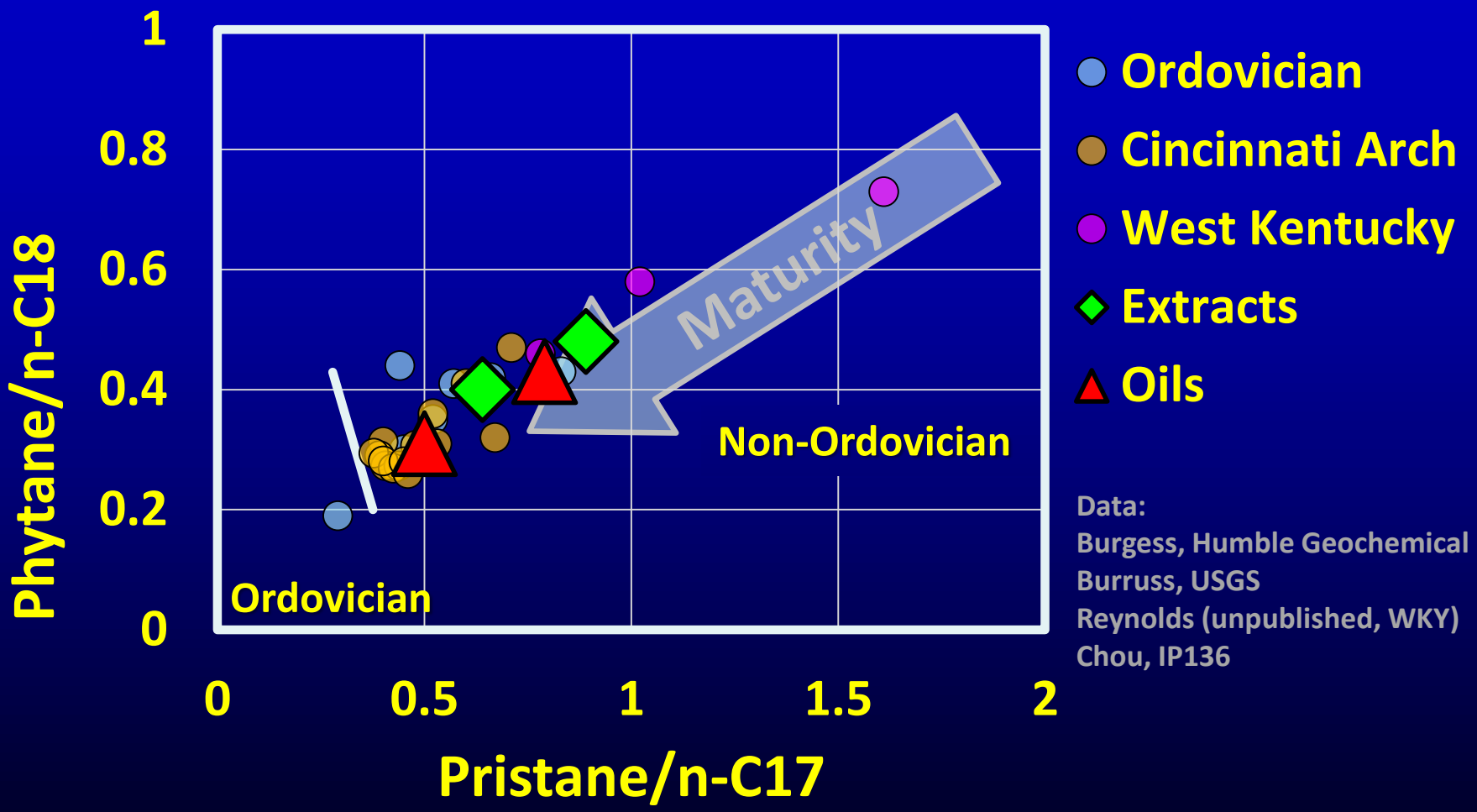
Oil & Extract Gas Chromatographs



Data:
Burgess, Humble Geochemical
Burruss, USGS
Reynolds (unpublished, WKY)
Chou, IP136

Modified from Hamilton-Smith (KGS unpublished)
Hunt (1995)

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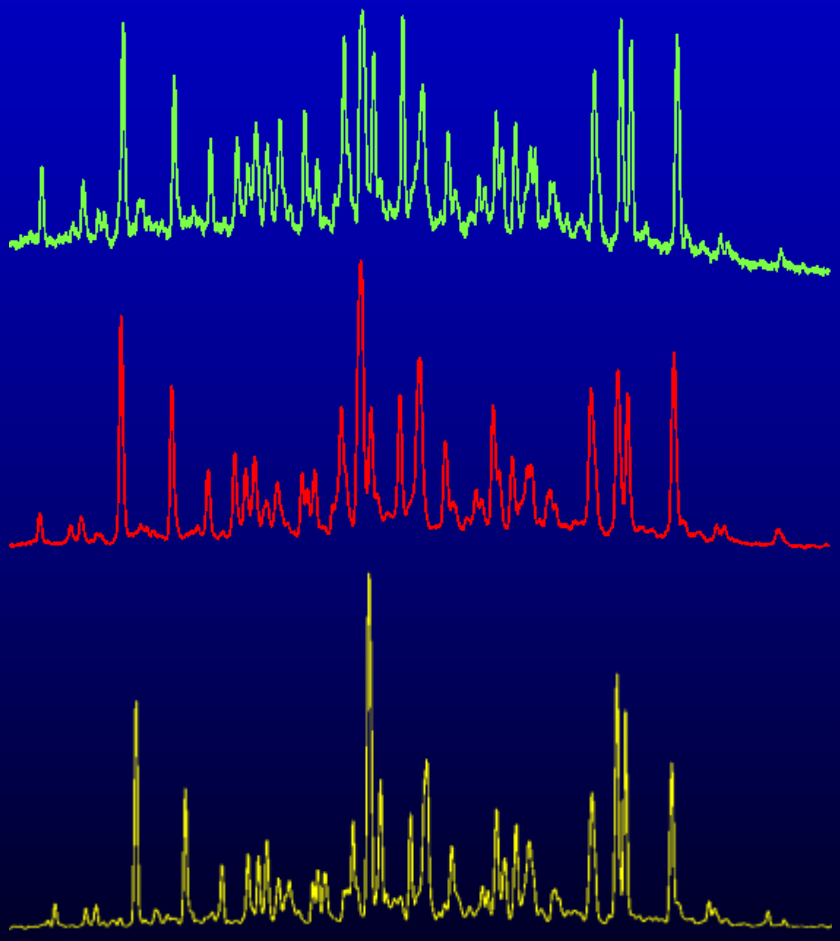
Not a Geochemist

Biomarkers: Sterane Distributions (GCMS)



Cuttings Extracts

Oil

Endeavor 4

KY0014 *Geomark*

(U. Devonian, distal marine shale, moderate maturity)

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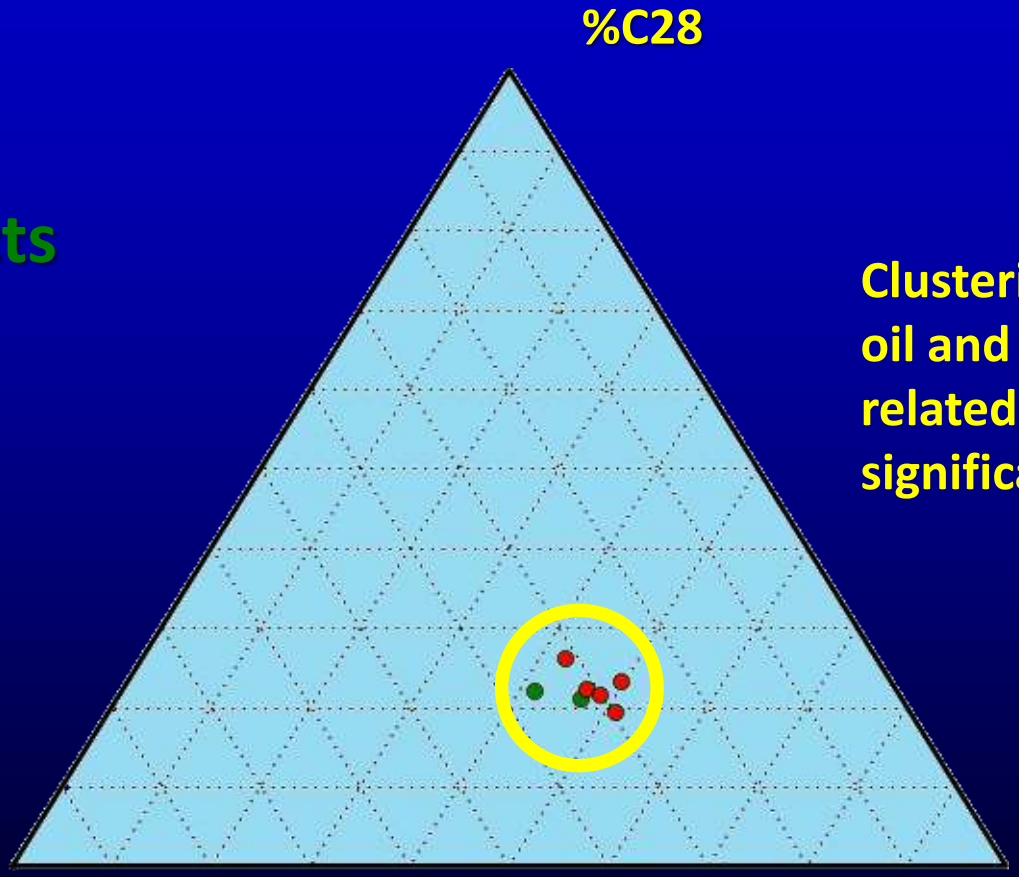
Oils and Extracts

Oils

Extracts



Clustering indicates oil and source are related (statistically significant)

Some data courtesy of Geomark

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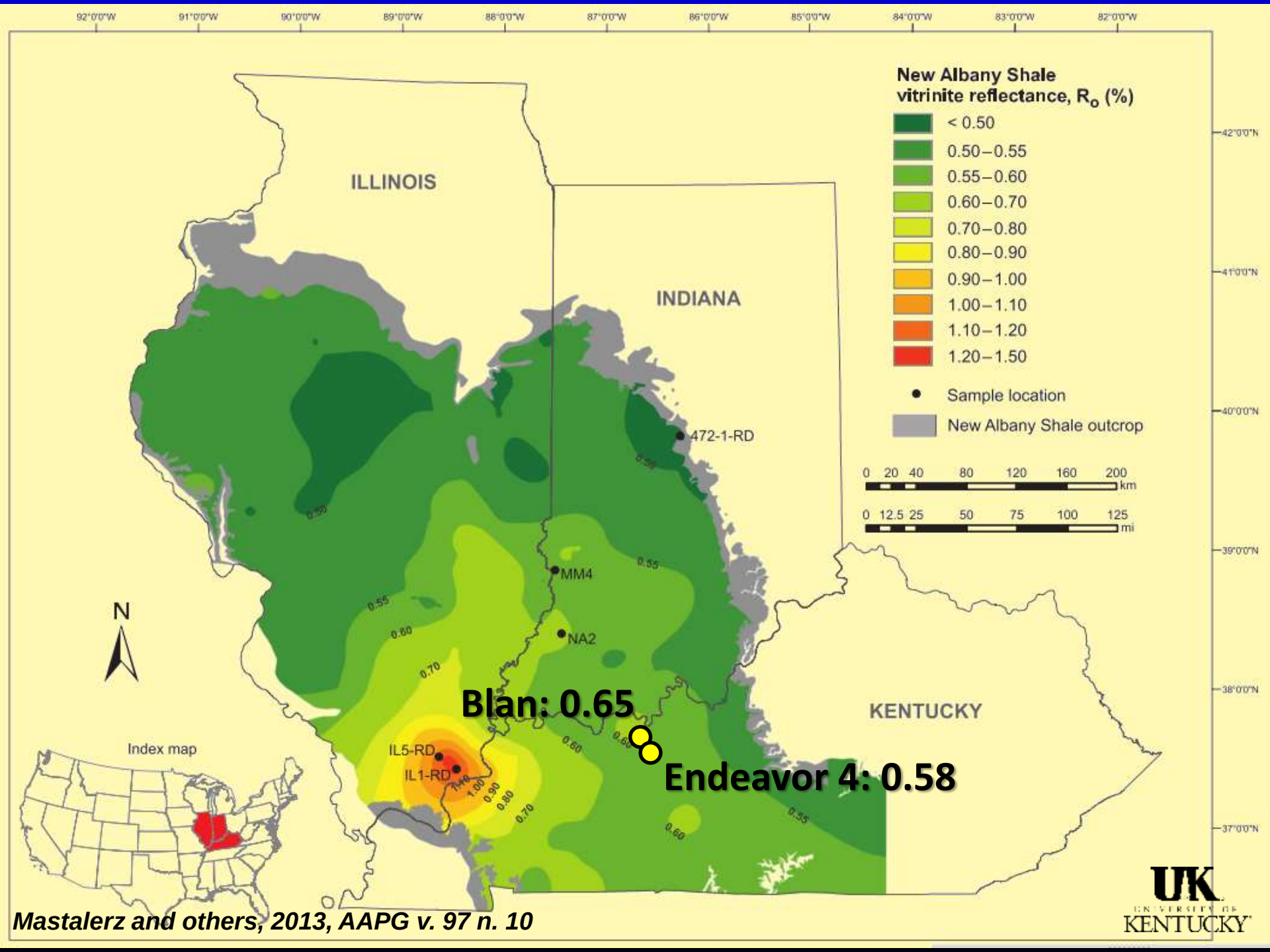

Mastalerz and others, 2013, AAPG v. 97 n. 10

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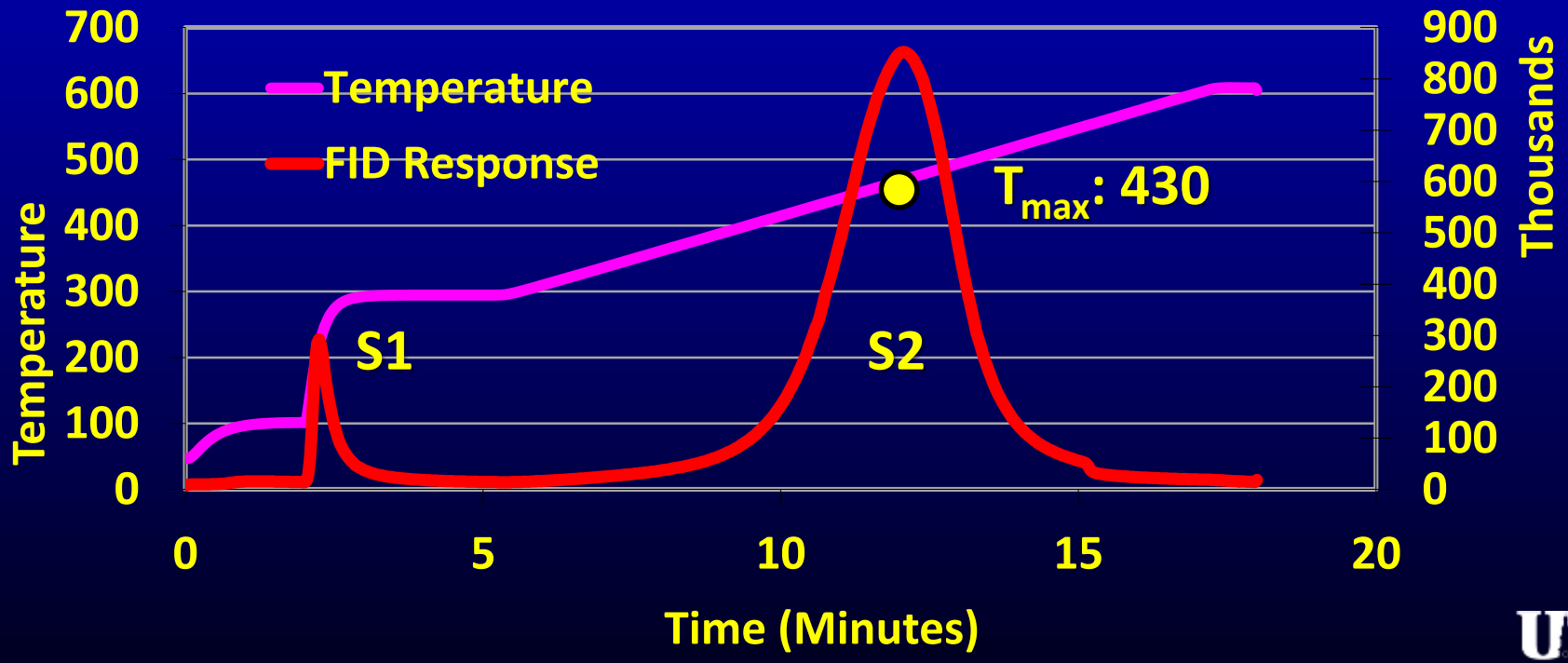
Endeavor #4 Pyrogram

- Organic-rich, early mature source rock
- Broad S2 indicates large capacity to generate hydrocarbons



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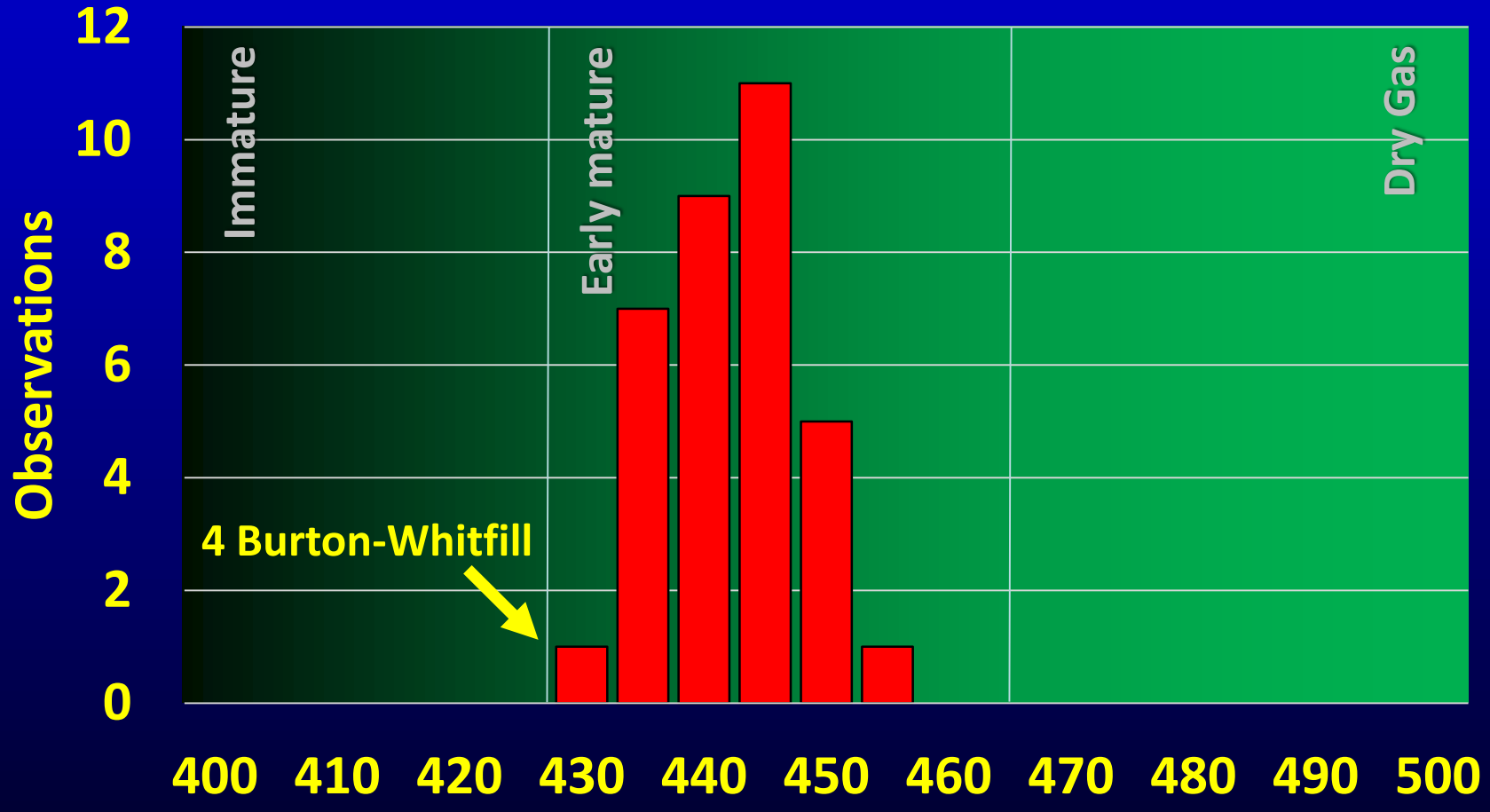
T_{max} (°C) – Max. Rate S2 Conversion



After Cole et al (1994)
Data from Endeavor 4, Blan, IP136, RPSEA

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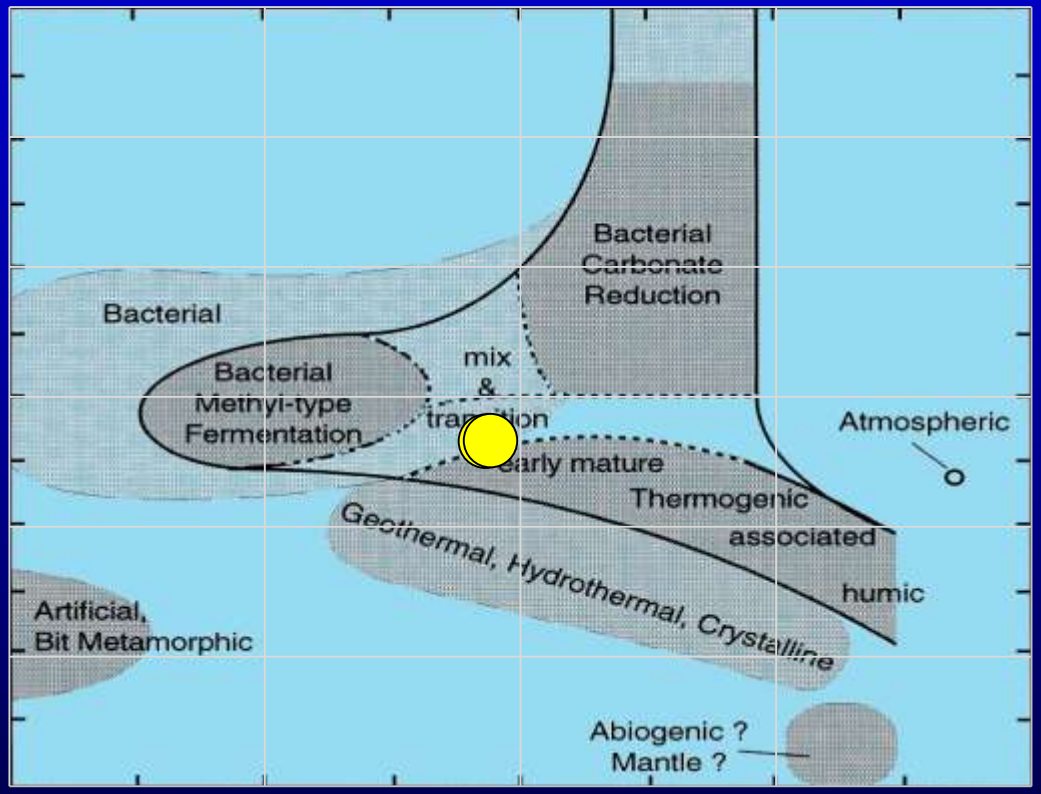
Methane Isotopes



-120
-100
-80
-60
-40
-20
0

$\delta^{13}C$

-450 -350 -250 -150 -50

δD_{C1}

Early mature thermogenic

Whiticar (1999)

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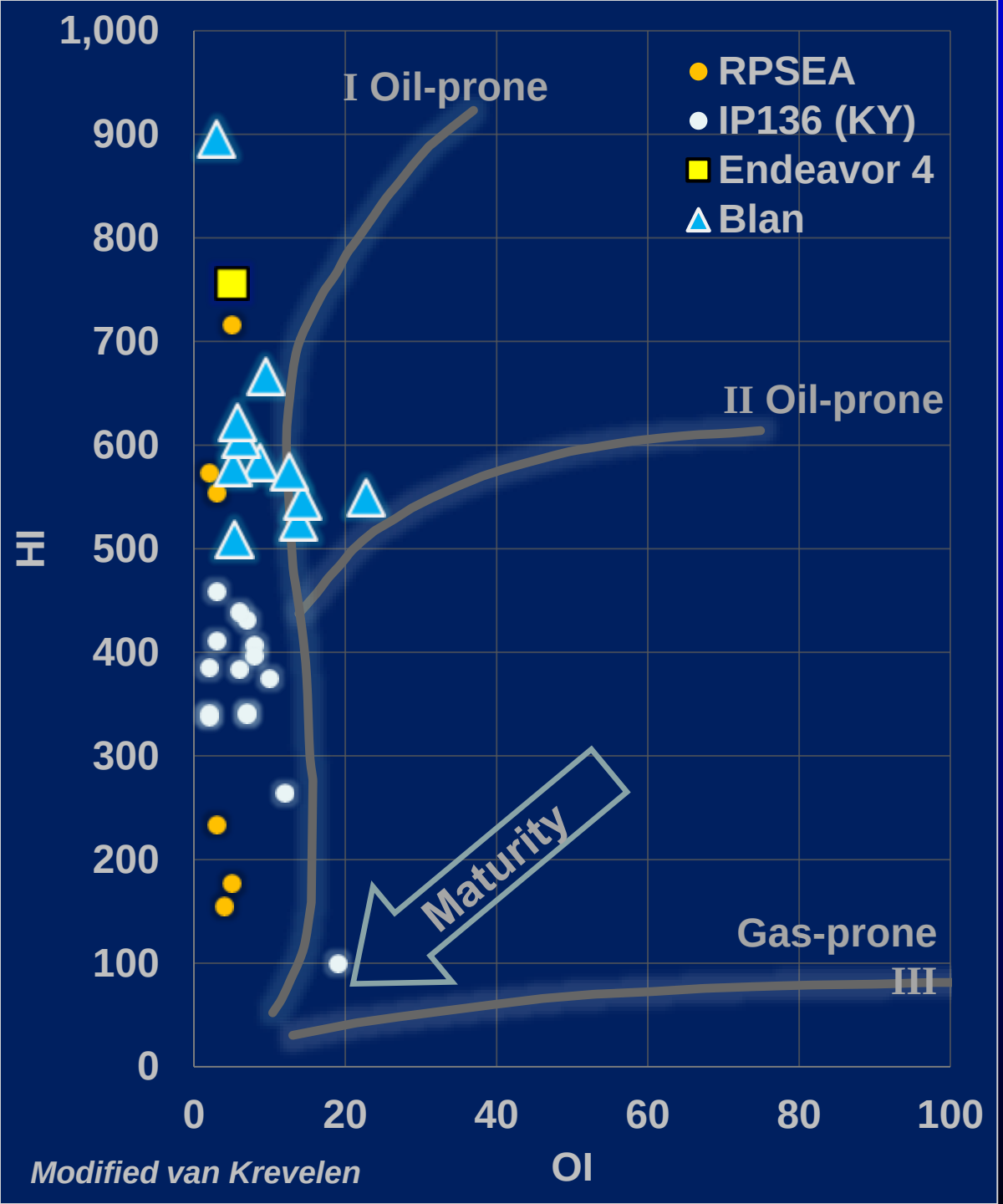

Rock-Eval

- Early mature
- Type I & II
- Oil prone
- Marine

Blan: Nuttall (2013) KGS Ser 12, RI 17

IP136: Chou and others, (1991)

RPSEA: Salehi and others, (2010) contract 07122-6

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Key Data Summary

		Endeavor 4	Endeavor 5	Blan 1
	Depth (ft)	1,858	1,998	1,876.5
Rock-Eval	TOC (%)	9.93		7.93
	HI	756		896
	S1	4.73		6.16
Oils	%Saturates (Oils)	61.69	62.95	
	%Aromatics (Oils)	28.43	26.84	
	Sat. $\delta^{13}C$	* -30.9	* -30.8	
	Arom. $\delta^{13}C$	* -29.8	* -29.8	
Extracts	%Saturates (Ext)	21.37		31.68
	%Aromatics (Ext)	17.57		19.72
	Sat. $\delta^{13}C$	* -29.2		* -29
	Arom. $\delta^{13}C$	* -29.1		* -29.1

Consistent with having been generated in place

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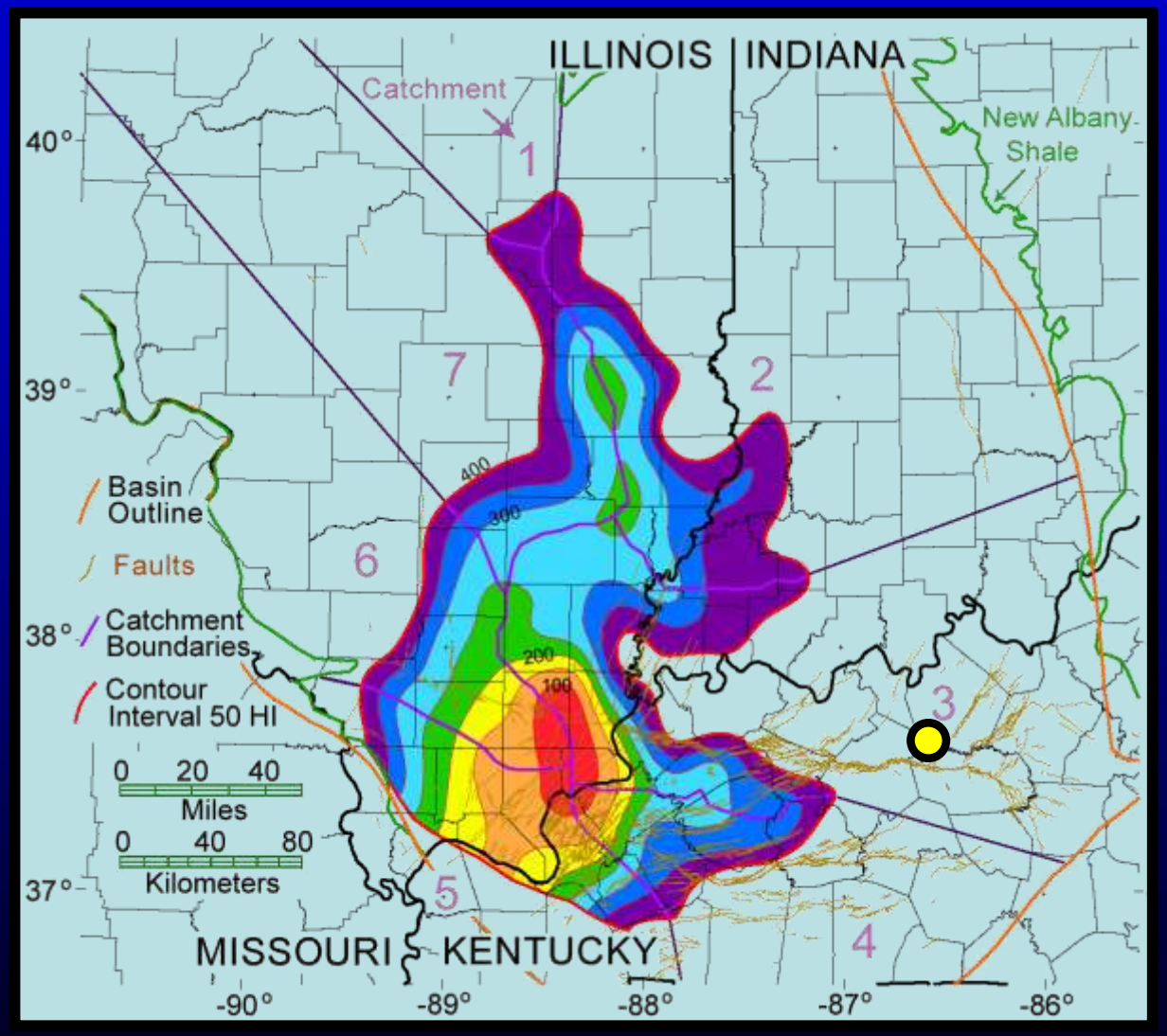
HI – Kerogen Conversion



New Albany Shale Petroleum System

Smaller HI indicates more conversion

Higley et al (2003) pubs.usgs.gov/of/2003/ofr-03-037/

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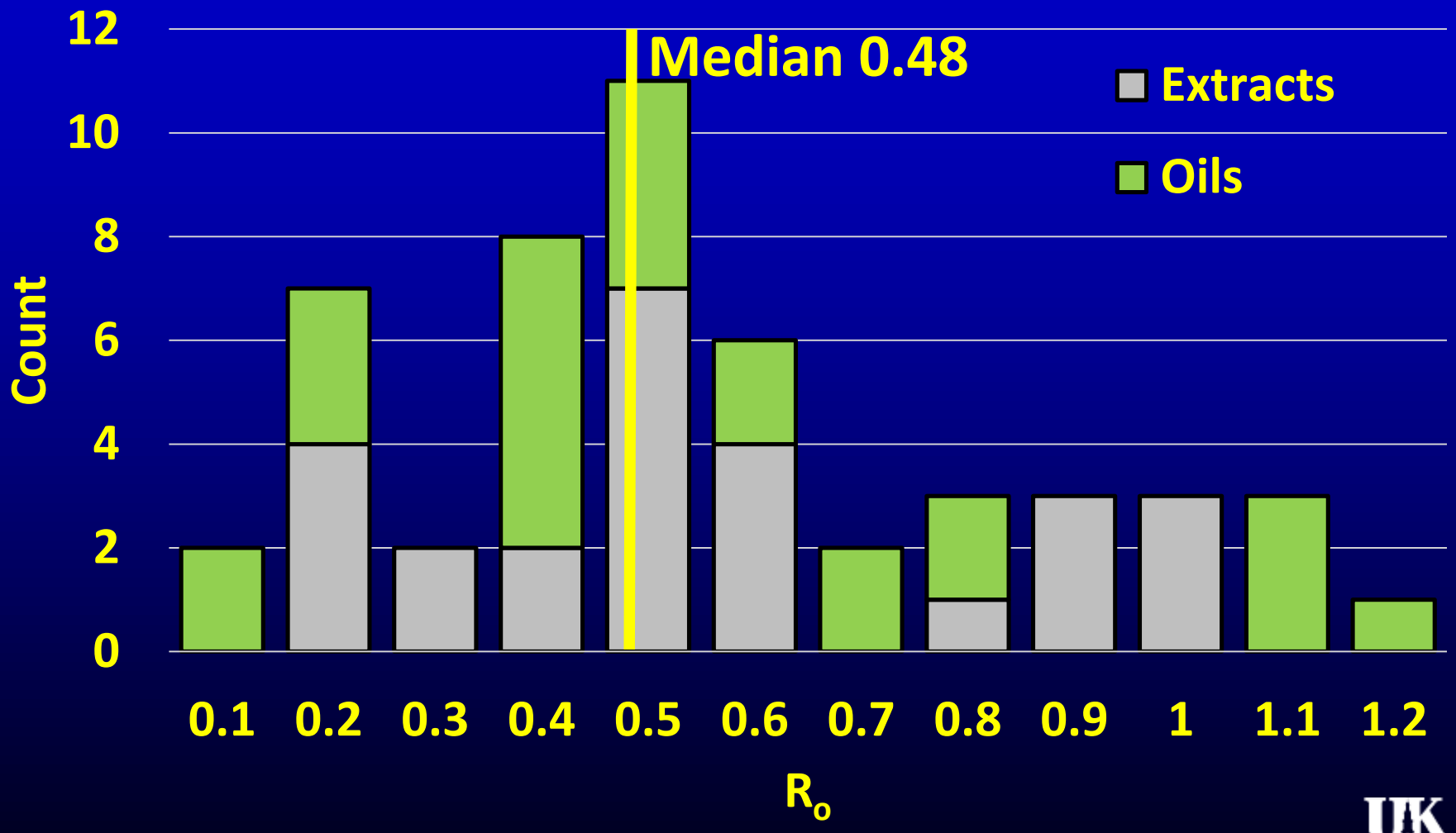
R_o Calculated from Biomarkers



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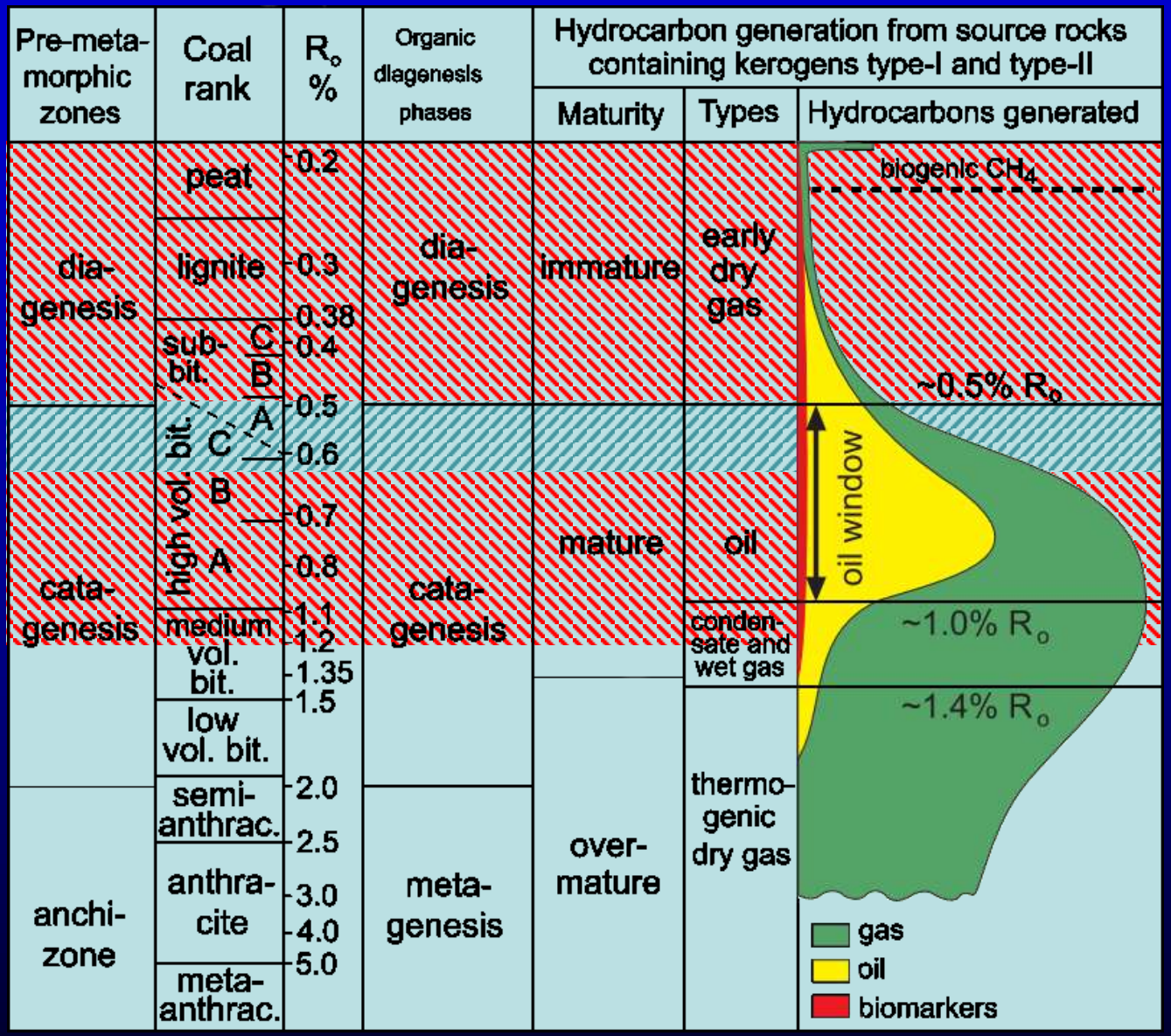
Maturity Summary



- Good source rock
- Early mature
- Type I & II
- Oil prone
- Marine
- Thermogenic

Modified from Mastalerz and others (2013) AAPG v. 97, n. 10

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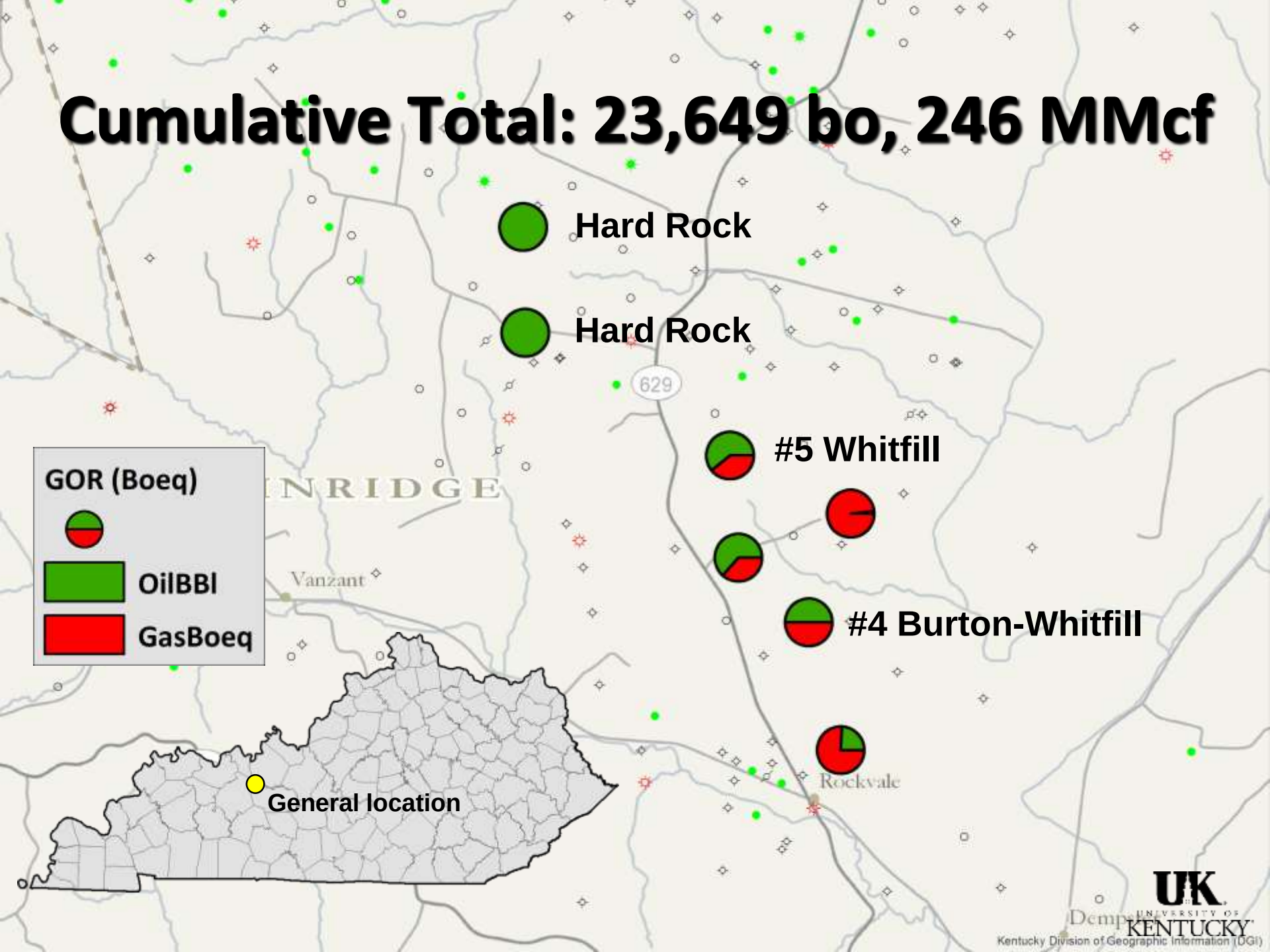
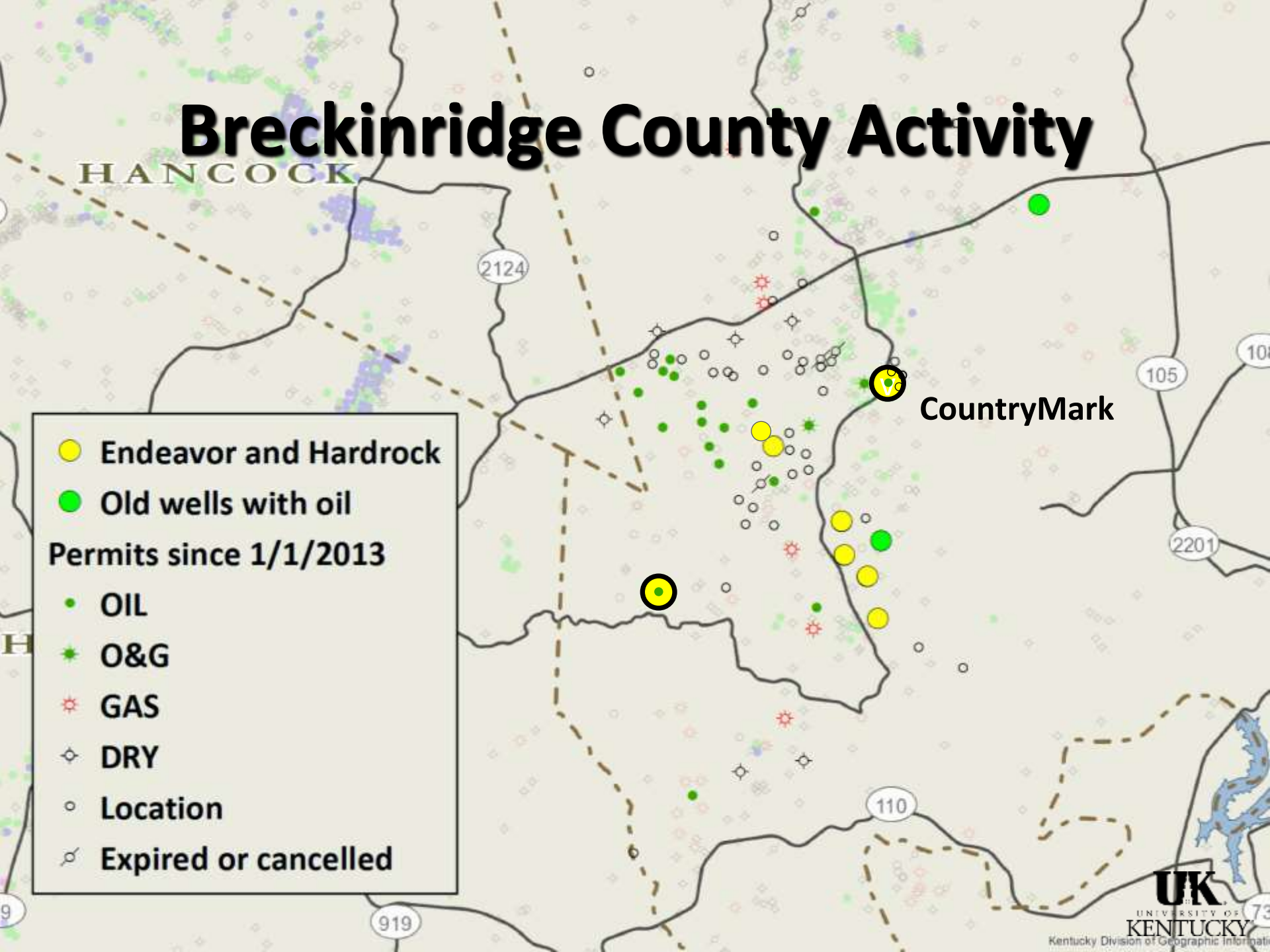
Cumulative Total: 23,649 bo, 246 MMcf



Breckinridge County Activity



Conclusions

- Early mature source rock (in oil window)
- Consistent with generation in New Albany
- Not consistent with classic measures of thermal maturity (T_{max}, $\%R_o$)
  - Wet gas
  - Higher than expected light gasoline fractions
- What does $\%R_o$ mean in a marine shale?

Takeaway

- Extremely limited data set
  - 4 data points with geochemistry does not make a play
- Potential for oil and NGLs
  - Down dip?
  - West of Locust Hill-Cave Spring Fault?
  - North of the Rough Creek Fault?
  - More mature in Rough Creek Graben?

Takeaway

- Extremely limited data set
  - 2 data points does not make a play
- Potential for oil and NGLs
  - Down dip?
  - West of Locust Hill-Cave Spring Fault?
  - South of the Rough Creek Fault?
  - More mature in Rough Creek Graben?

$ The current wellhead price of oil and gas!

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Acknowledgments

Ray Henning
Wally Dow
John Zumberge

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Thanks

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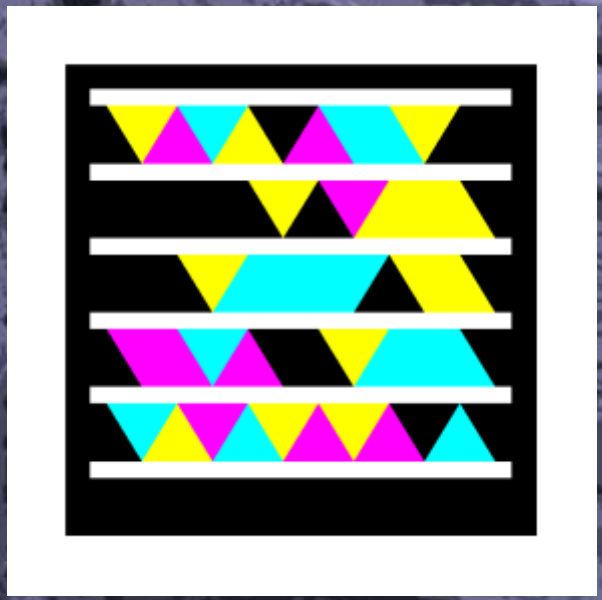

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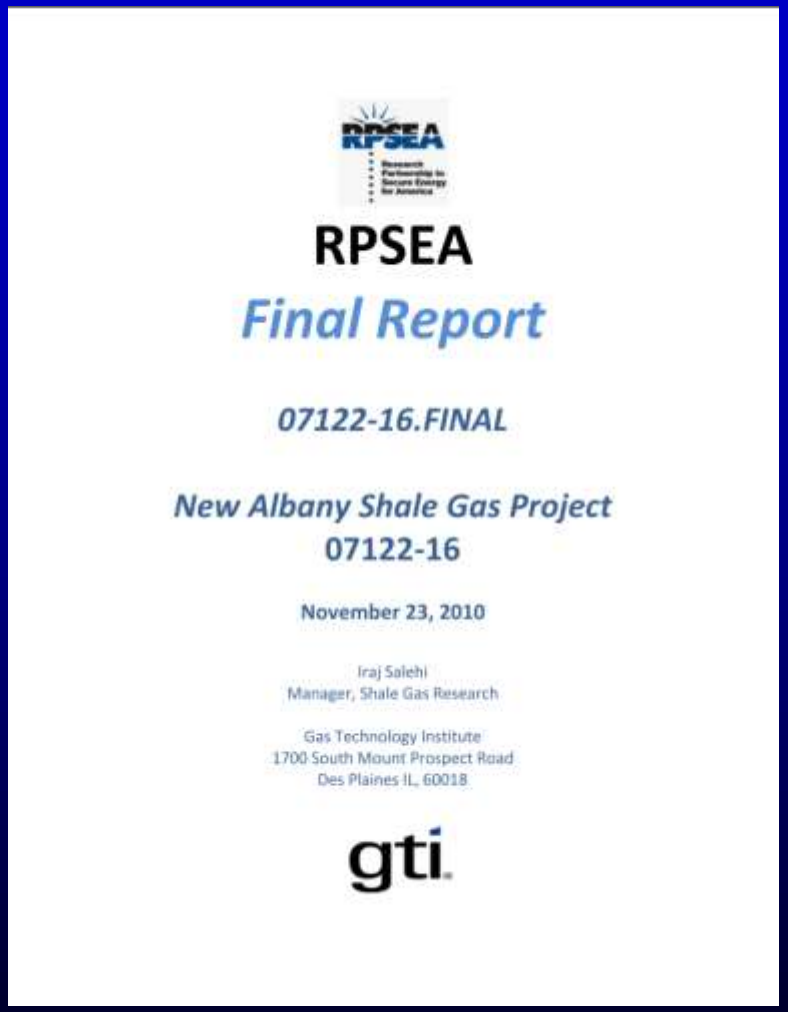
RPSEA Contract 07122-16


RPSEA

Final Report

07122-16.FINAL

New Albany Shale Gas Project
07122-16

November 23, 2010

Iraj Salehi
Manager, Shale Gas Research

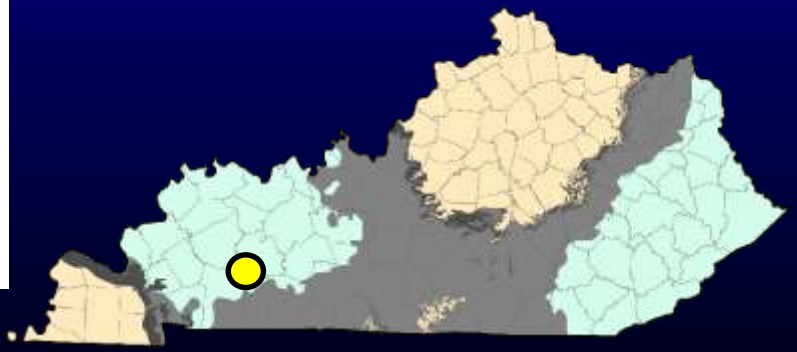
Gas Technology Institute
1700 South Mount Prospect Road
Des Plaines IL, 60018

gti

RPSEA/GTI, 2010

Detailed geochemical and geomechanical assessment of selected wells in Indiana and Kentucky

- **www.rpsea.org**
- **www.gastechnology.org**
- **www.isgs.Illinois.edu**



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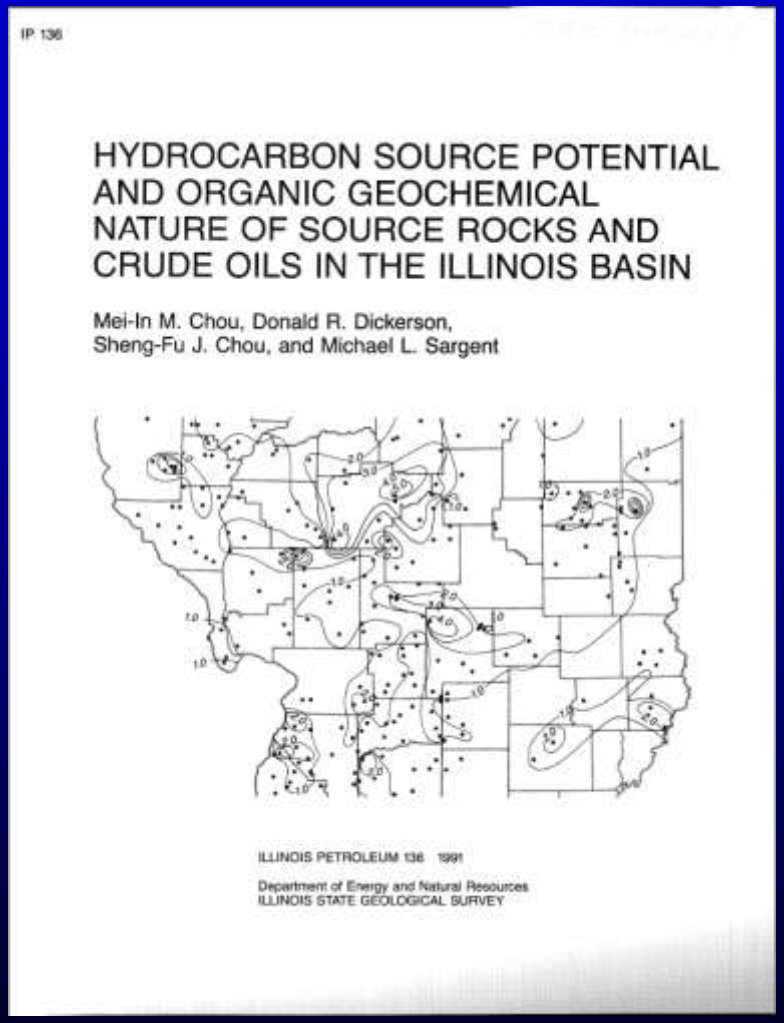
Chou and others, IP 136



IP 136

HYDROCARBON SOURCE POTENTIAL AND ORGANIC GEOCHEMICAL NATURE OF SOURCE ROCKS AND CRUDE OILS IN THE ILLINOIS BASIN

Mei-In M. Chou, Donald R. Dickerson, Sheng-Fu J. Chou, and Michael L. Sargent

ILLINOIS PETROLEUM 136 1991

Department of Energy and Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY

Rock-Eval pyrolysis and oil fingerprinting data for wells in Illinois, Indiana, and Kentucky (includes data other than New Albany Shale)

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KGS #1 Blan Publication

- TOC – 4.75% to 9.74%
- Oil to wet gas
  - TAI – 2 to 2.3
  - Ro_{max} – 0.45% to 0.55%
  - T_{max} – 431°C to 440°C
- k – 9.48×10^{-5} md

RI 17, 2013

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