Petroleum Potential of Cambrian Sediments within the Rome Trough

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Kentucky Geological Survey

University of Kentucky

Kentucky Oil and Gas Association

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Lexington, KY

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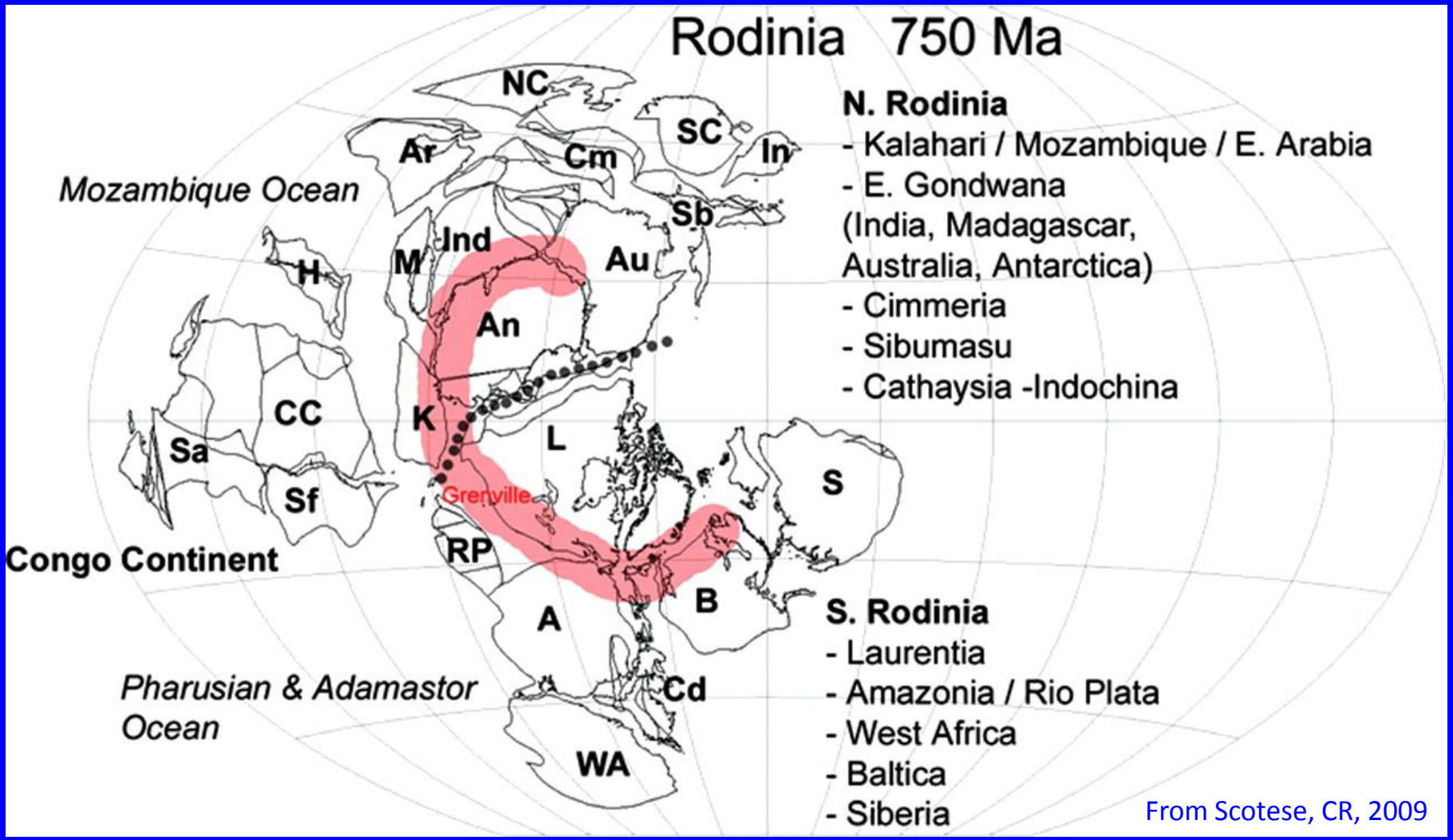
Unconventional Shale Resources

Regional Tectonic Setting:

Neoproterozoic - Late Cambrian

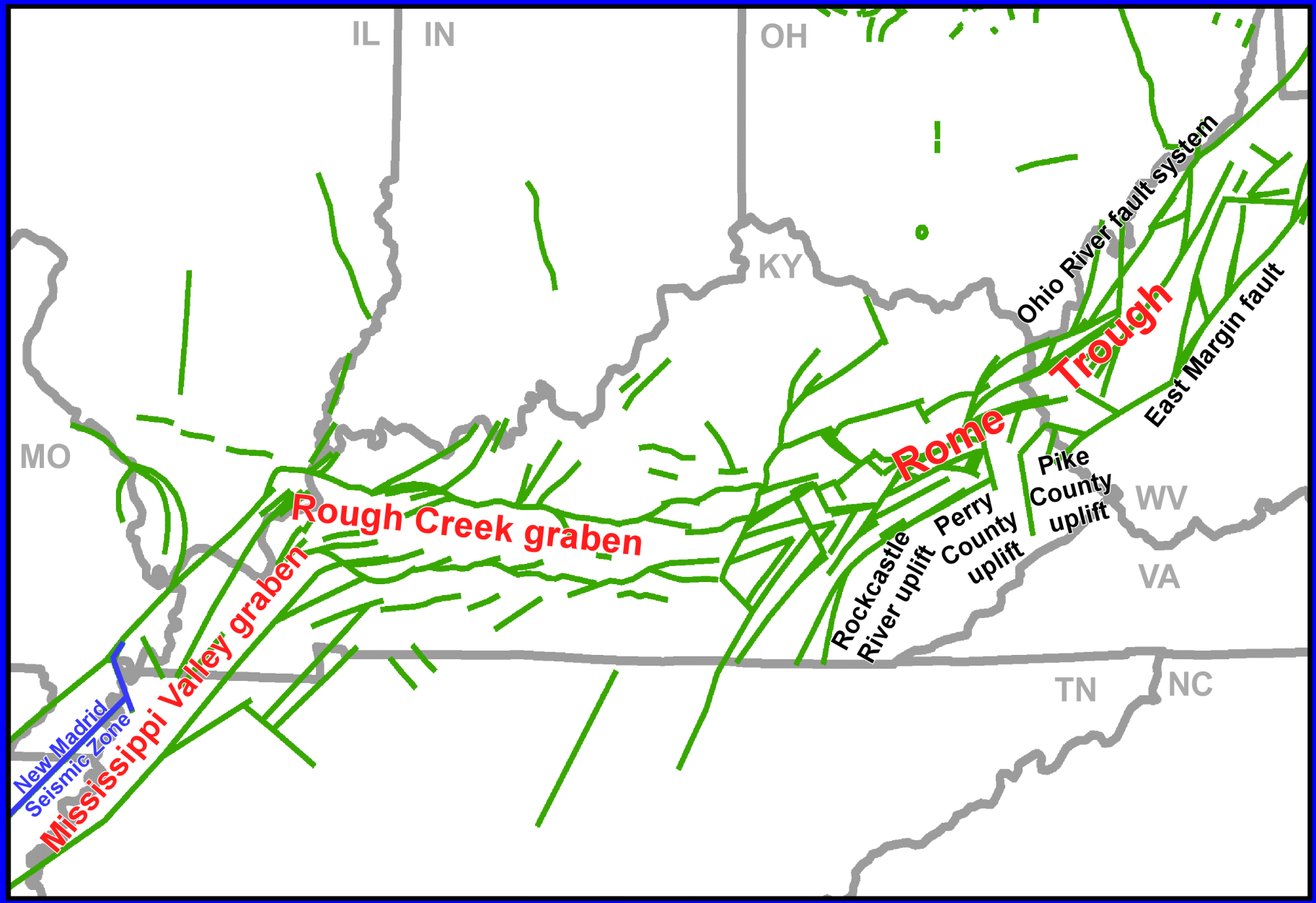
Breakup of Rodina Supercontinent

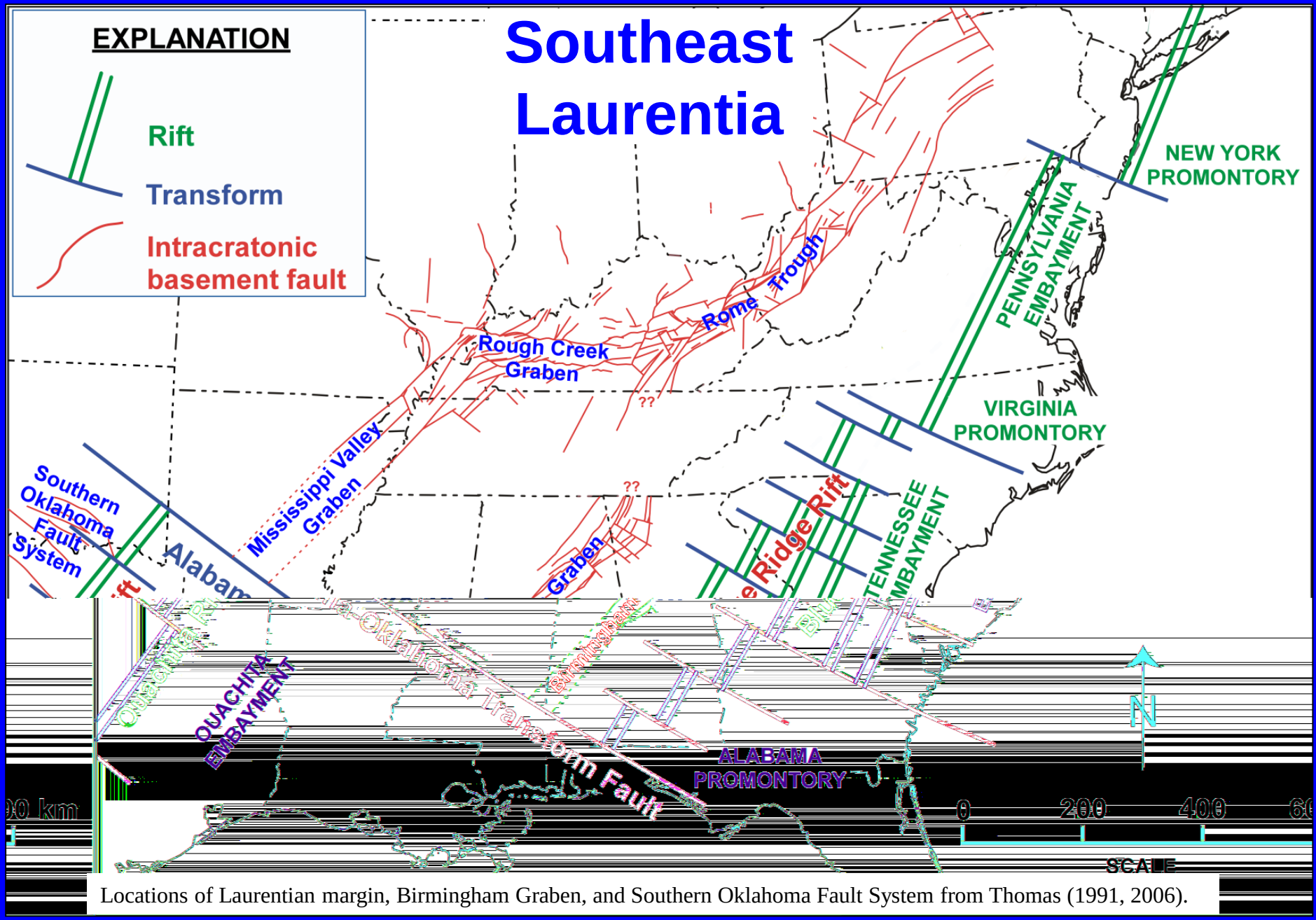


Eastern Interior Rift System

- Three contrasting regional features, all part of one “failed” rift:
  - Rome Trough
  - Rough Creek Graben
  - Mississippi Valley Graben
    (a.k.a. Reelfoot Rift)

Subsurface Features

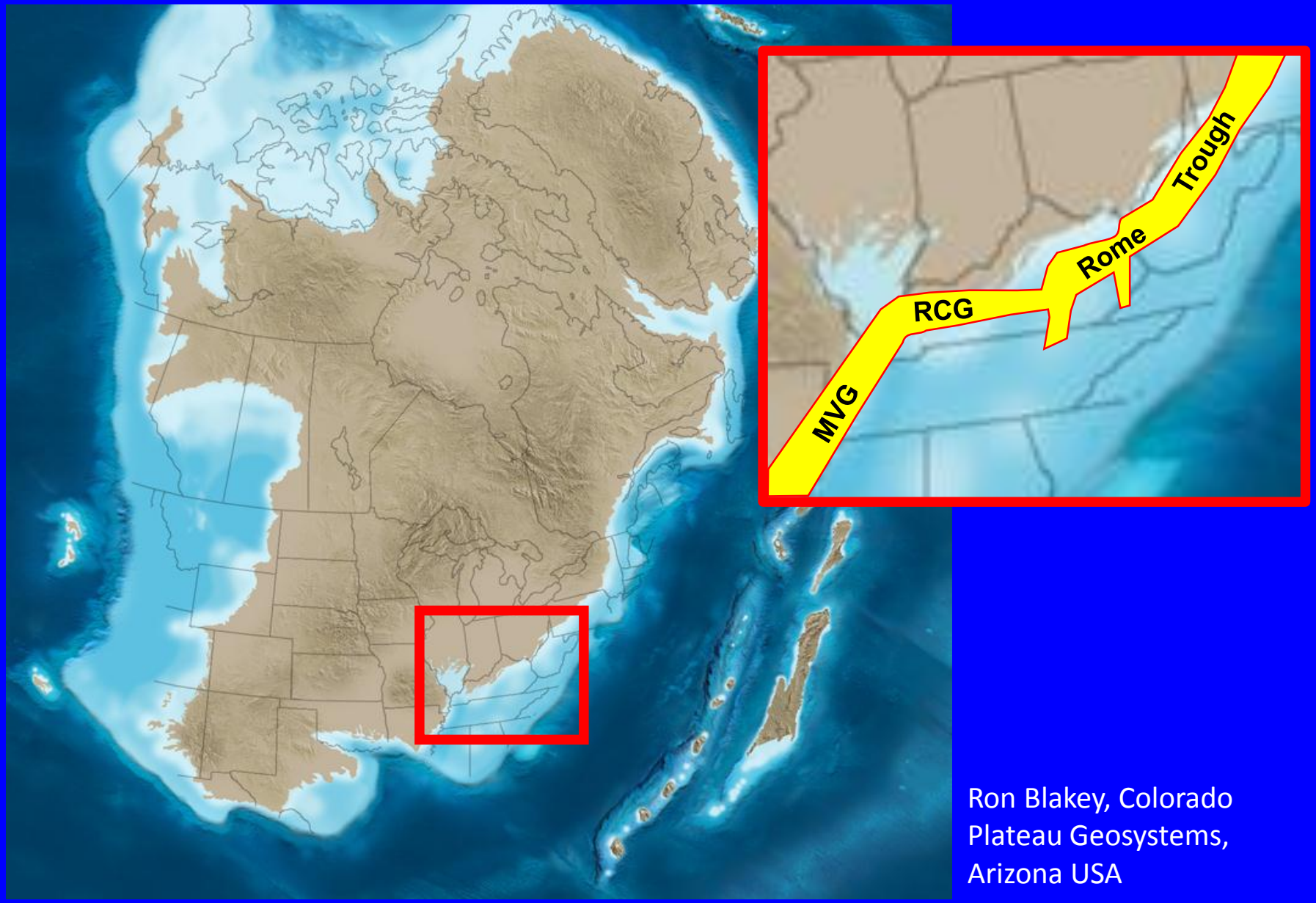




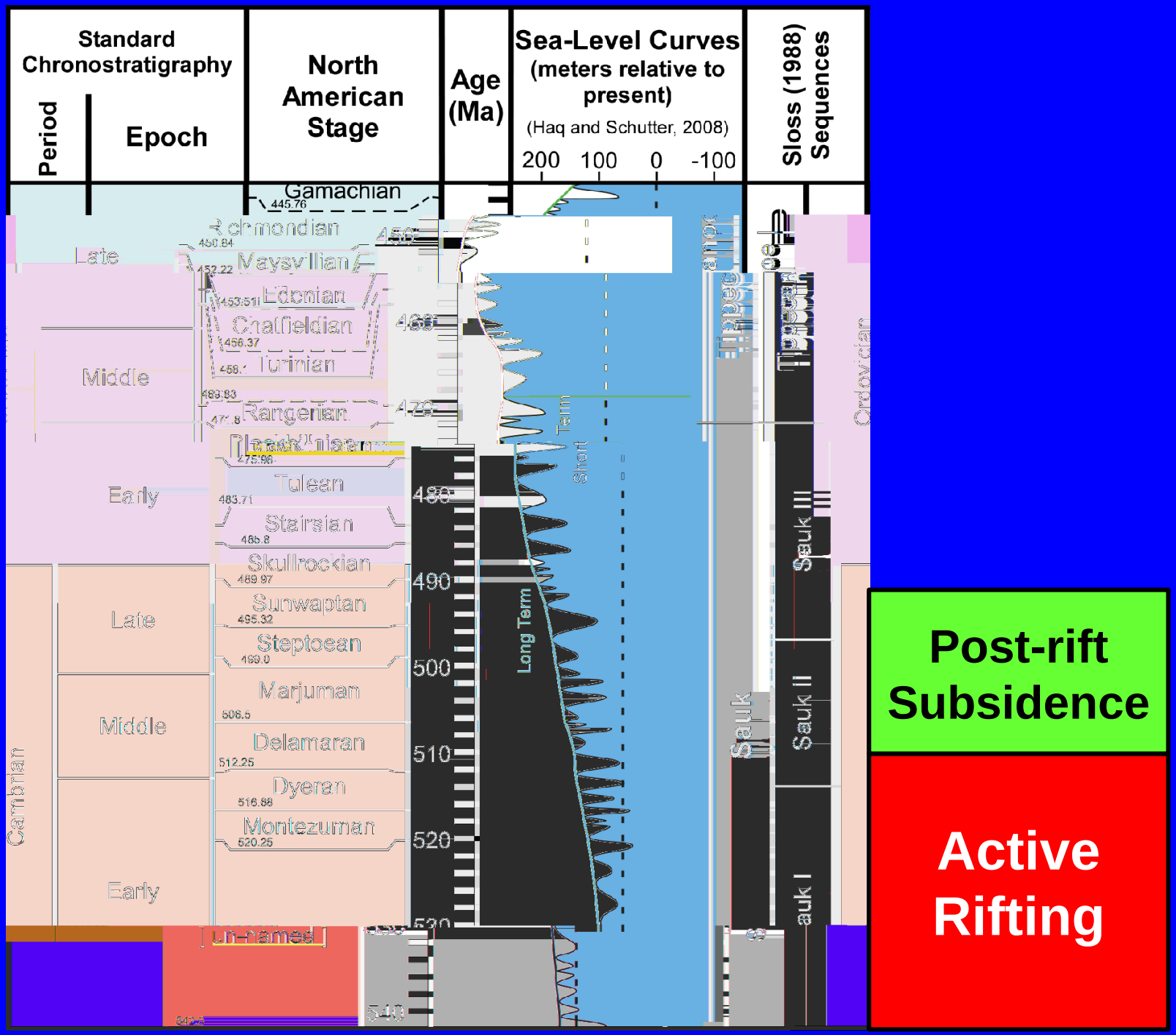
Locations of Laurentian margin, Birmingham Graben, and Southern Oklahoma Fault System from Thomas (1991, 2006).

Cambrian Stratigraphy and Deposition

Middle Cambrian Paleogeography

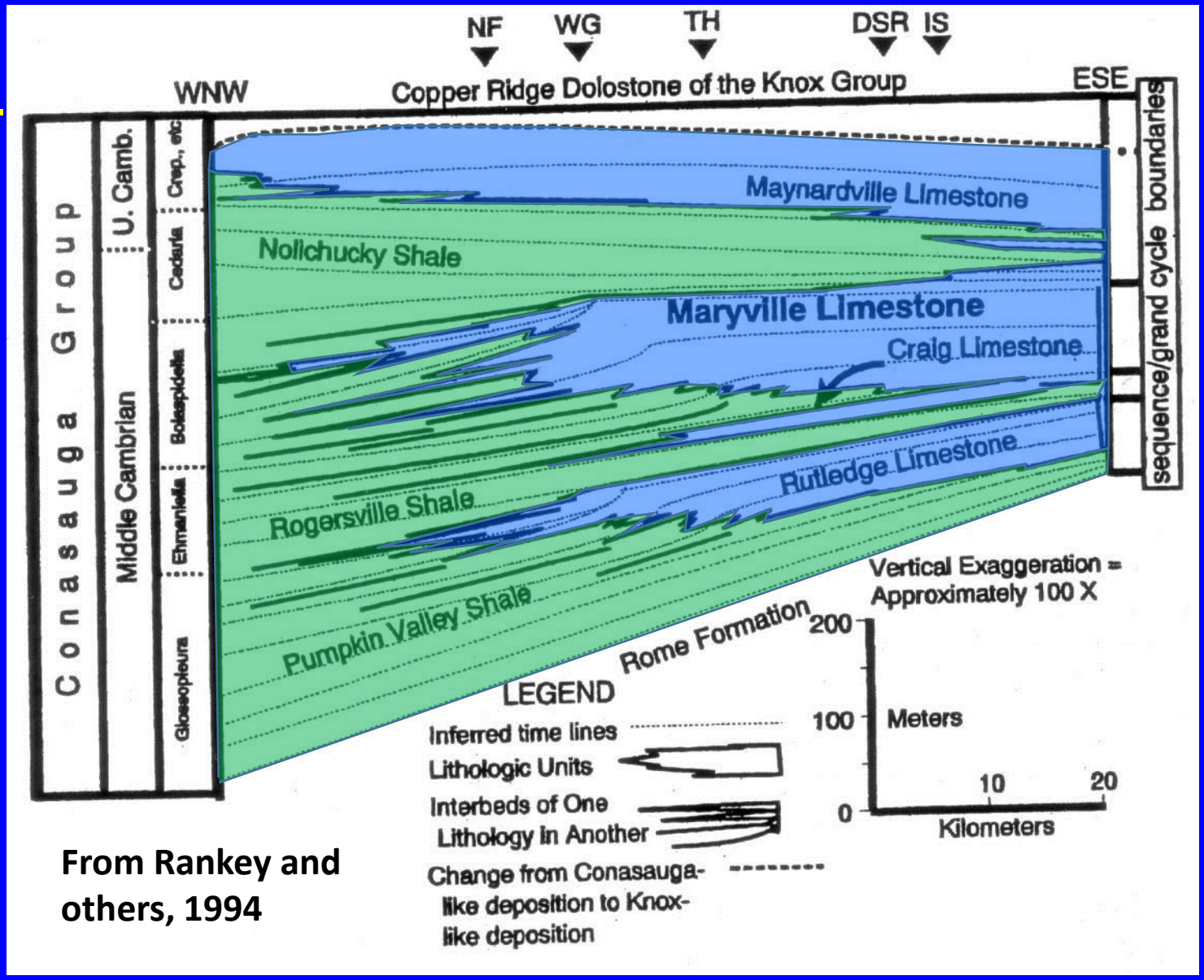


Ron Blakey, Colorado Plateau Geosystems, Arizona USA


Standard Chronostratigraphy
Period
Epoch
North American Stage
Age (Ma)
Sea-Level Curves (meters relative to present)
(Haq and Schutter, 2008)
200 100 0 -100
Sloss (1988) Sequences
Gamachian
445.76
Richmondian
450.84
Late
Maysvillian
452.22
Edenian
453.511
Chatfieldian
456.37
Middle
Turinian
458.1
Rangerian
469.93
Blackhillsian
Tulean
Early
483.71
Stairsian
485.8
Skullrockian
489.97
Late
Sunwaptan
495.32
Steptoean
499.0
Marjuman
Middle
506.5
Delamaran
512.25
Dyeran
516.88
Montezuman
520.25
Early
Cambrian
[un-named]
540
Ordovician
Upper
Tippecanoe
Sauk III
Sauk II
Sauk I
Sauk
Long Term
Short Term
Post-rift Subsidence
Active Rifting

Conasauga Trangressive-Regressive Cycles

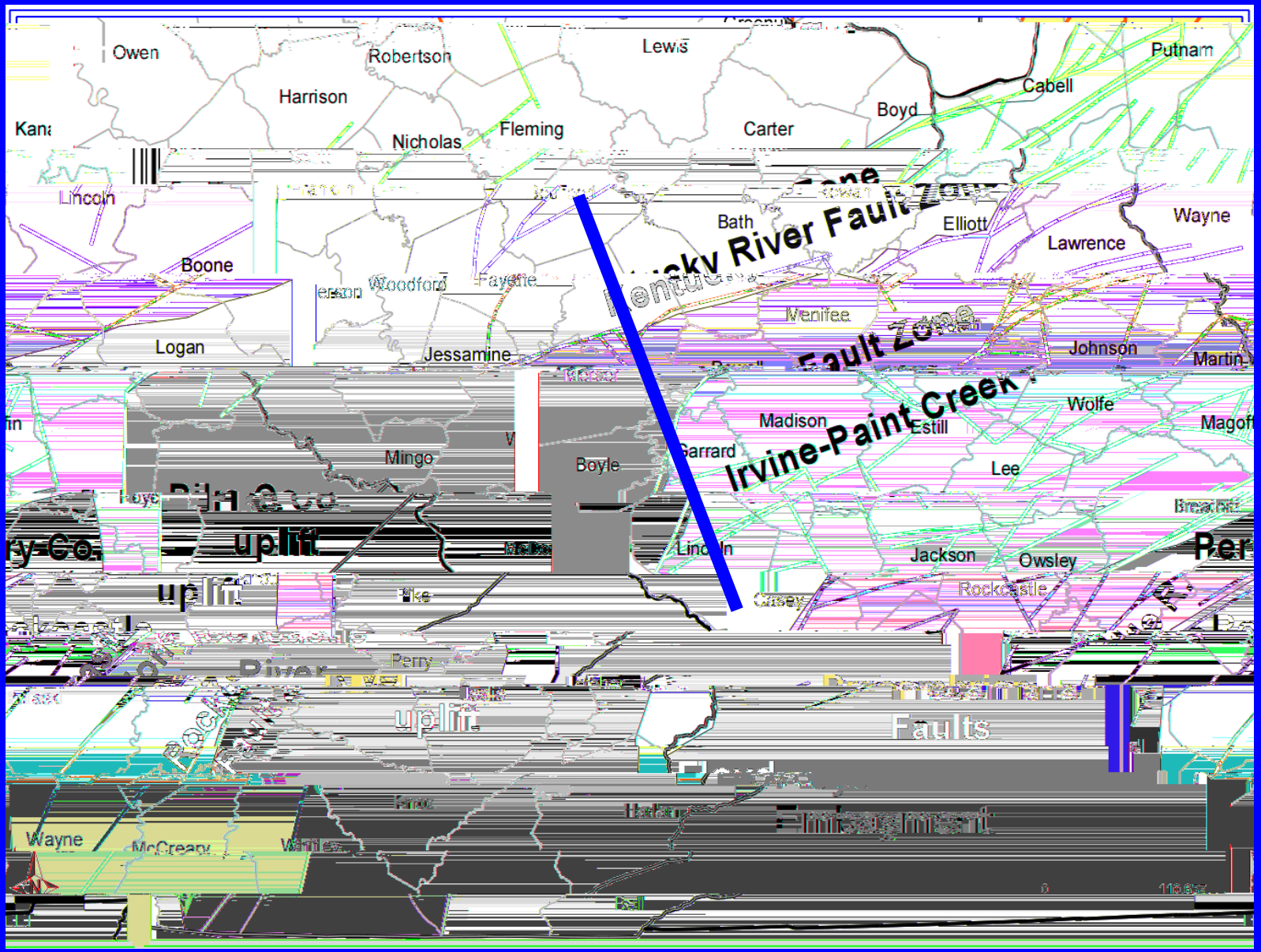
Eastern Tennessee Outcrops



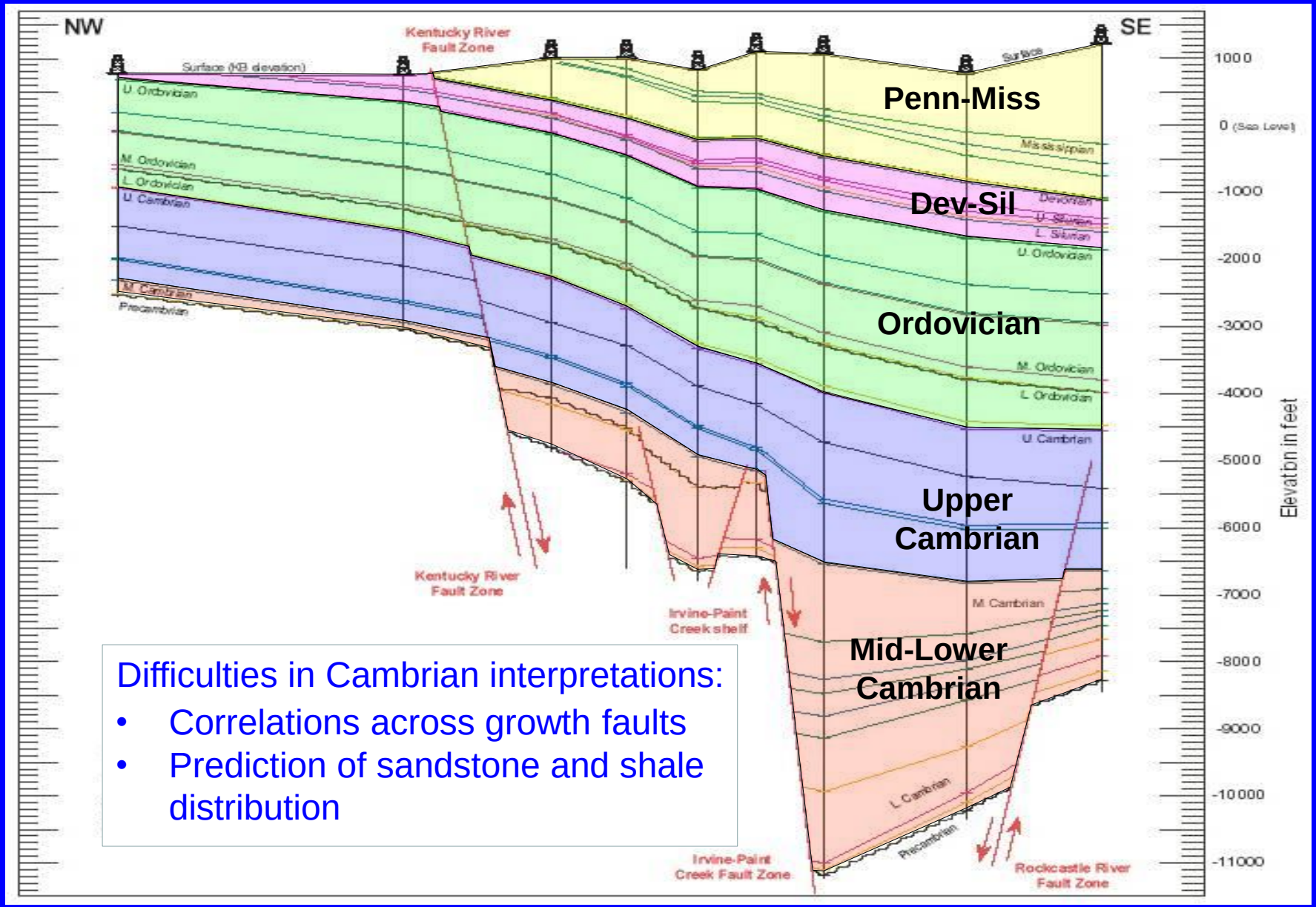
From Rankey and others, 1994

Rome Trough, Appalachian Basin

Rome Trough Structure



Simplified E. KY Cross Section

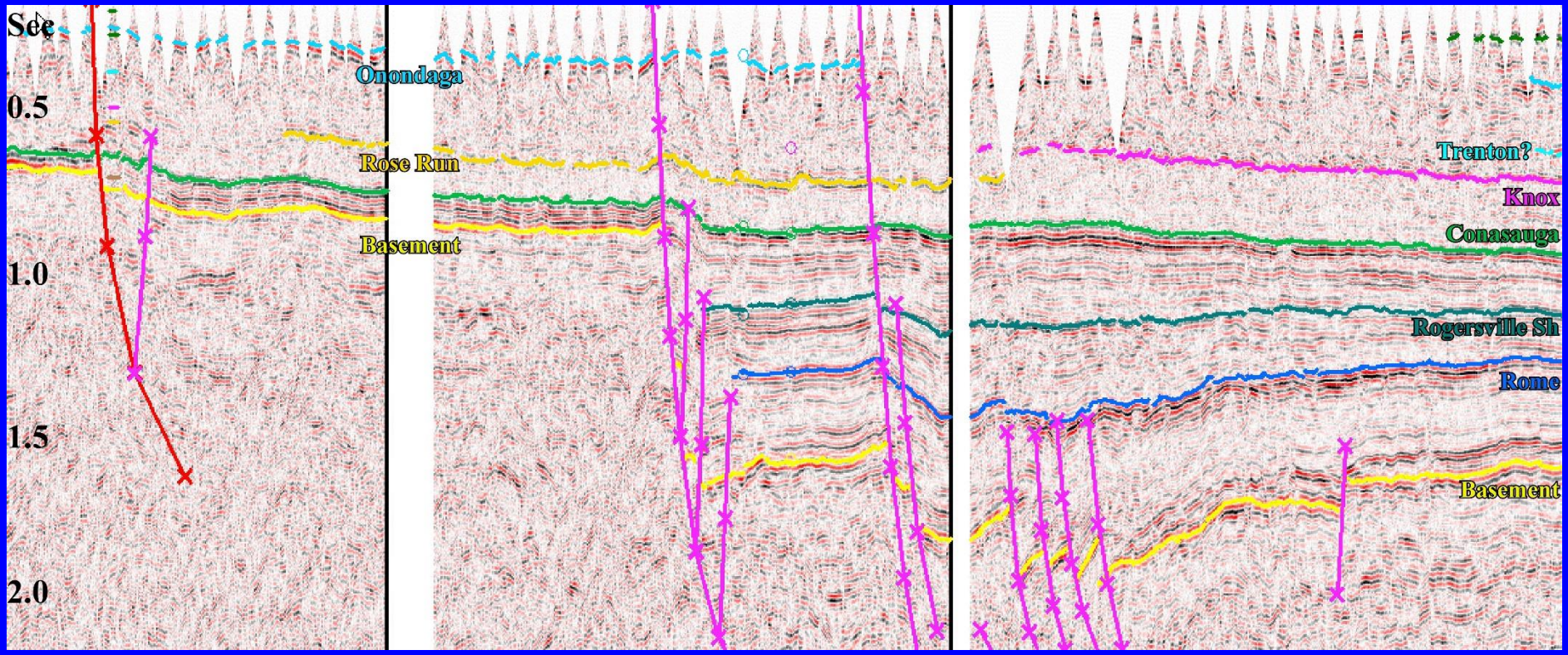


Difficulties in Cambrian interpretations:

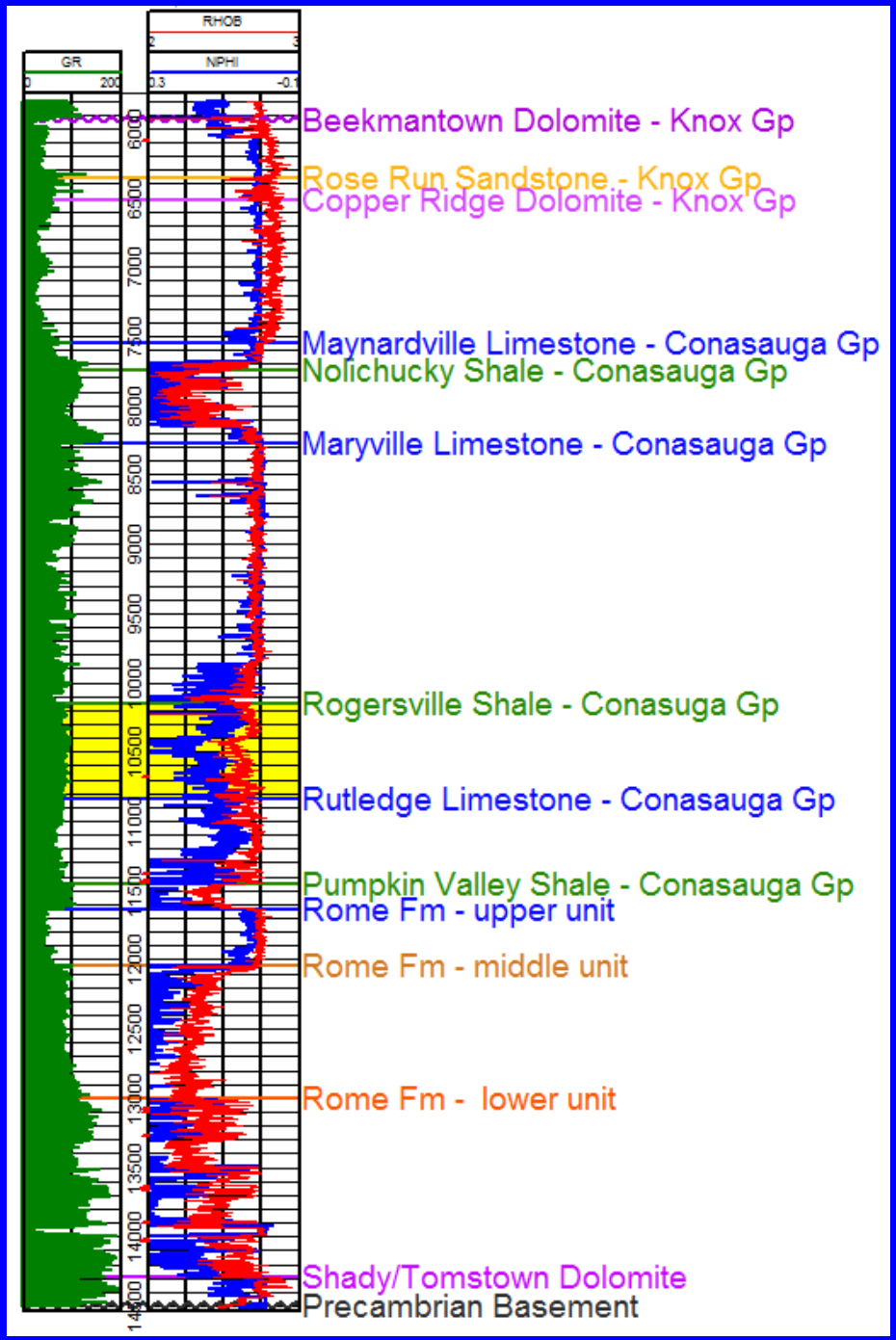
- Correlations across growth faults
- Prediction of sandstone and shale distribution

Eastern Kentucky Regional Seismic Example

NNW — Morgan to Magoffin County, KY — SSE



Approximate length of section is 49 miles.



Precambrian - Early Ordovician Stratigraphy within Rome Trough

U.S. Signal #1
Elkhorn Coal
Johnson Co.
Kentucky

Rogersville Shale Source Rock Quality and Thermal Maturity

All Cambrian wells, to date

- Pre-1960 wells
- 1960's wells
- 1970's wells
- 1980's wells
- 1990's wells
- Early 2000's wells
- New Rogersville Shale tests (2014-'15)

Most deep wells have hydrocarbon shows, however, almost all are not sustainable or repeatable.

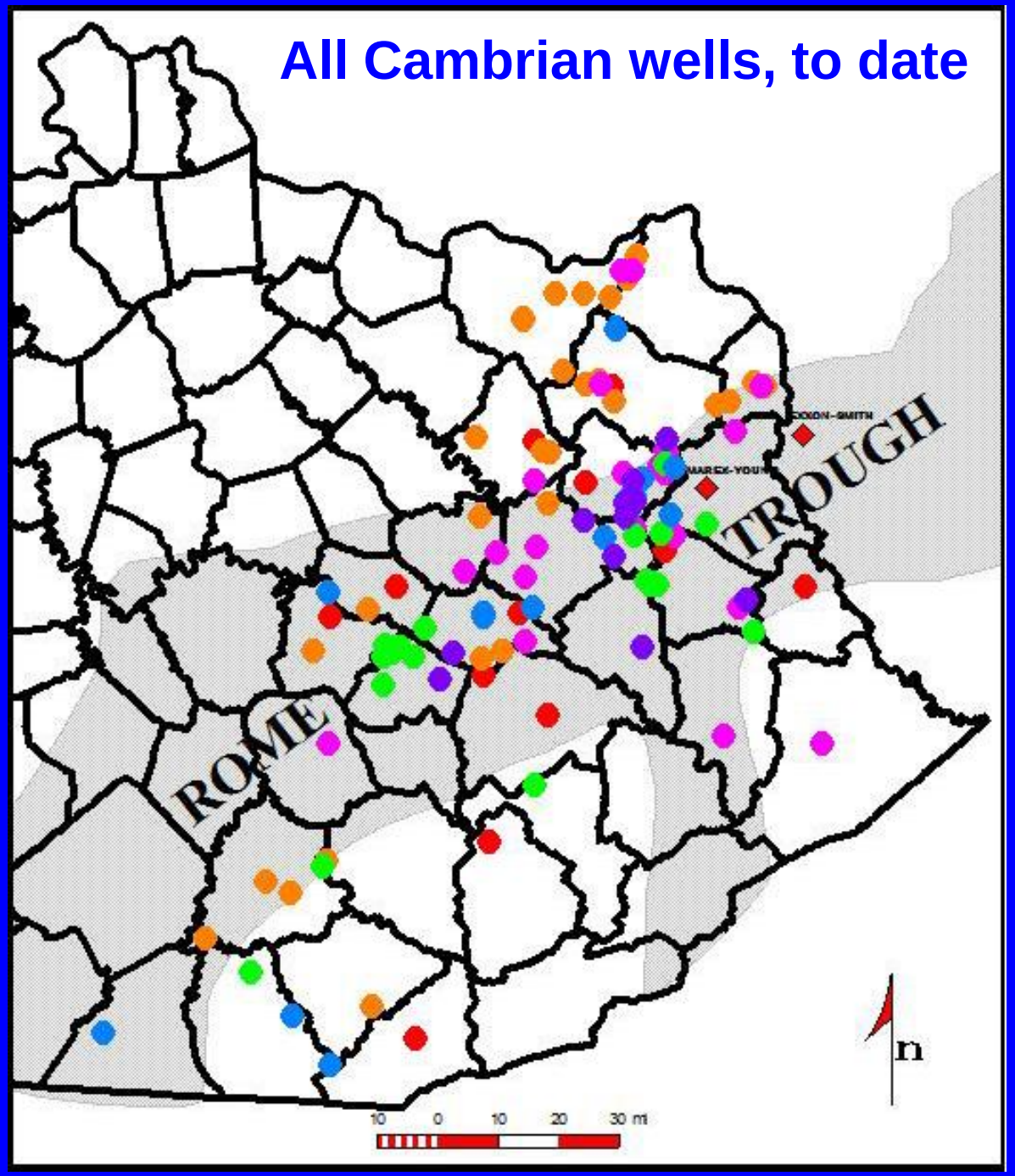
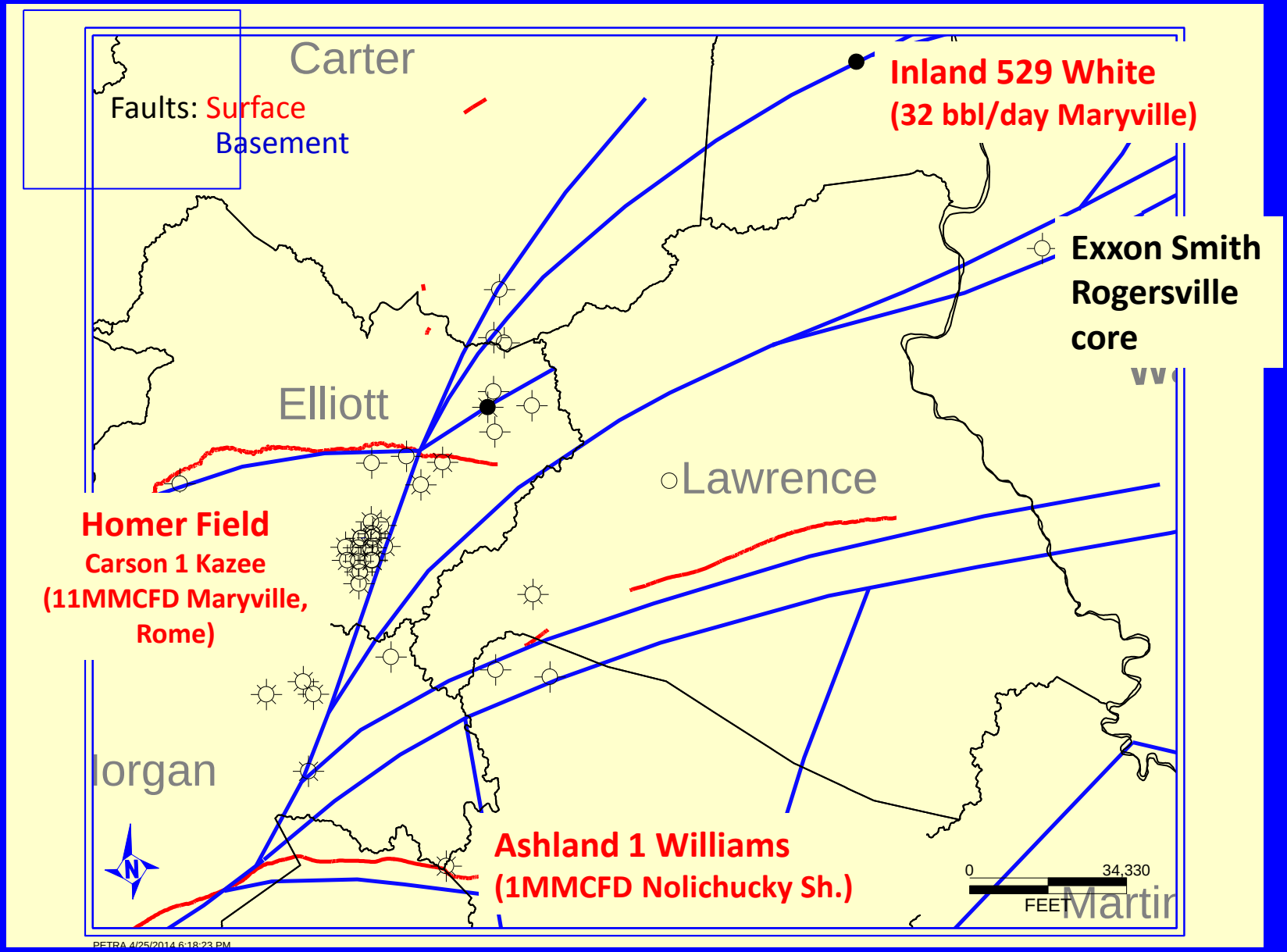
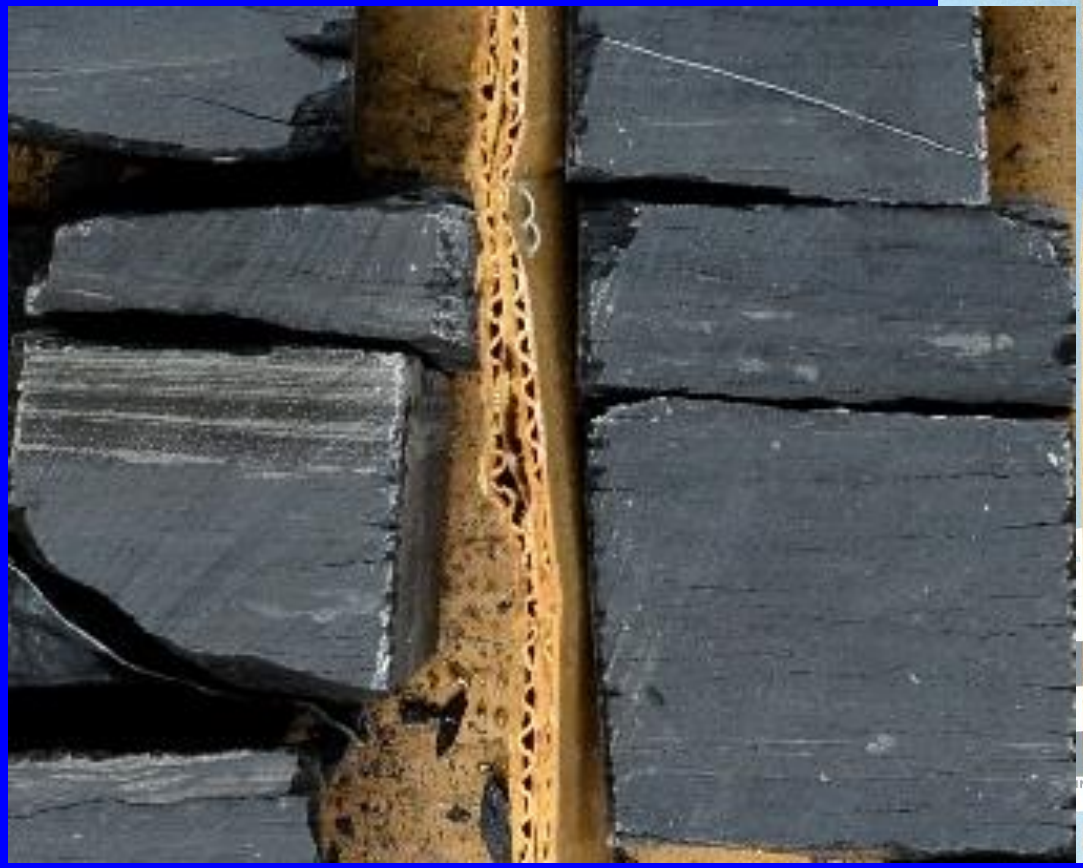


Image courtesy of J. Jenkins, Abarta Energy

Rome Trough Production



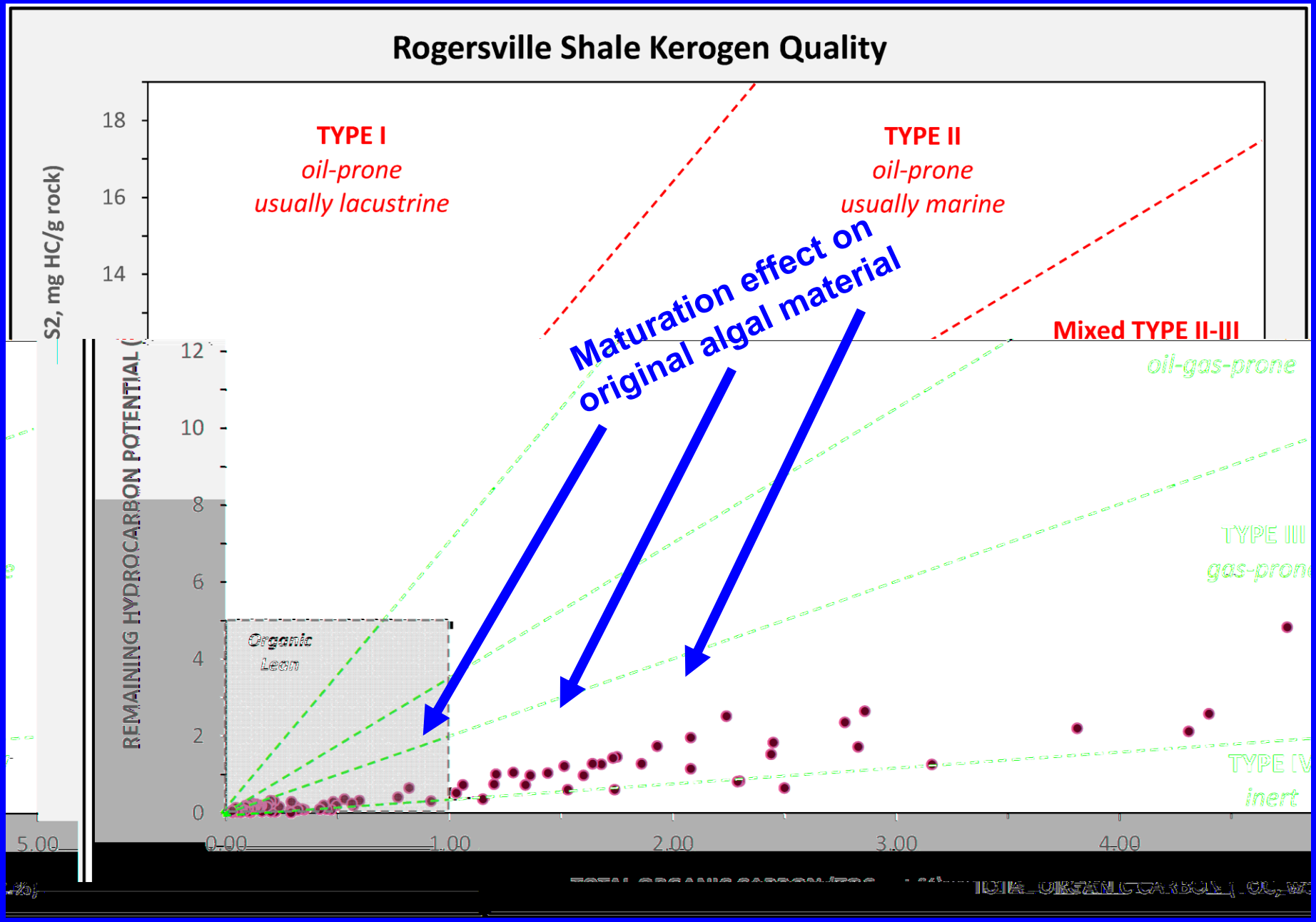
Exxon #1 Smith core: 11,191-11,200’



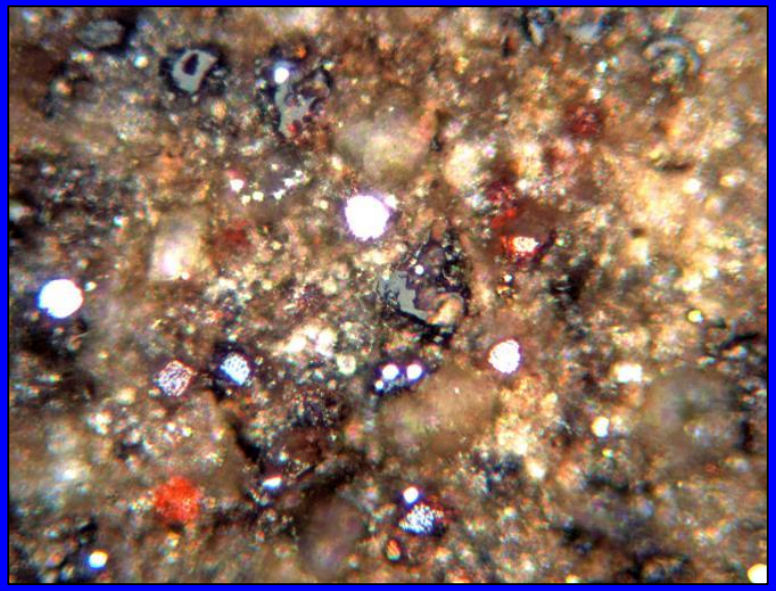
Exxon #1 Smith core: 11,146-11,157’

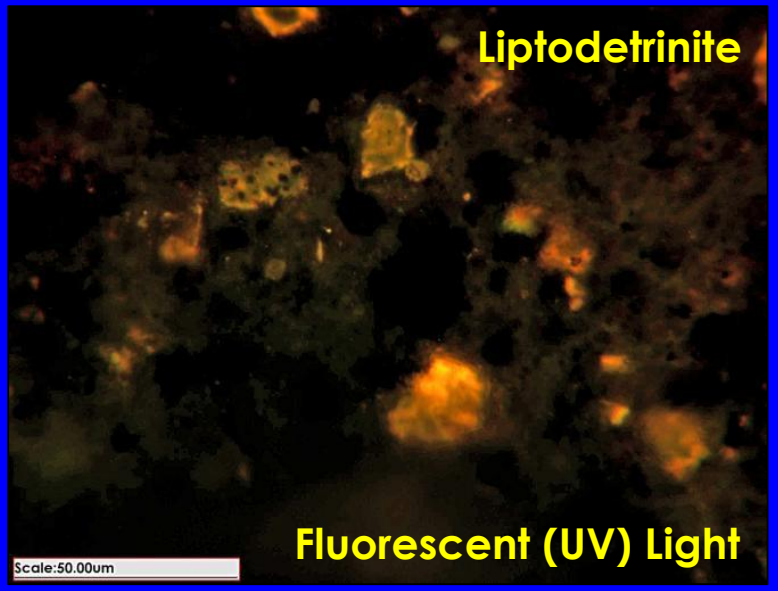
Rogersville Shale Deposition

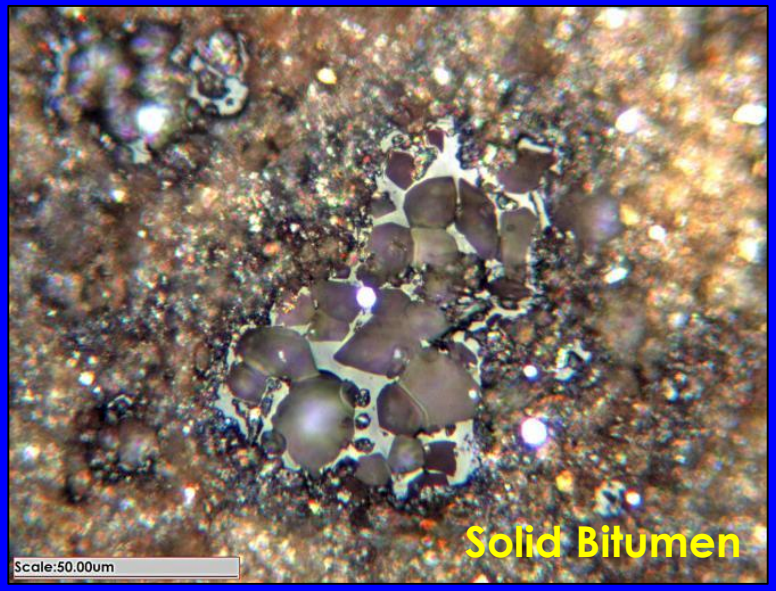
- Shallow marine shale, with minor amounts of limestone and sandstone
- Peritidal bedding textures
- Numerous zones contain bioturbation features

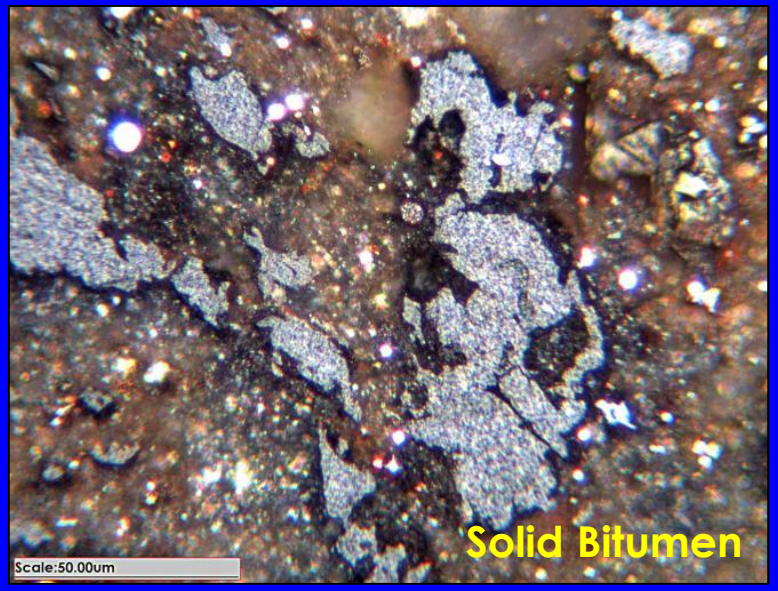

Rogersville Shale Kerogen Quality
TYPE I
oil-prone
usually lacustrine
TYPE II
oil-prone
usually marine
Maturation effect on original algal material
Mixed TYPE II-III
oil-gas-prone
TYPE III
gas-prone
TYPE IV
inert
Organic Lean
REMAINING HYDROCARBON POTENTIAL (
S2, mg HC/g rock)
18
16
14
12
10
8
6
4
2
0
5.00
0.00
1.00
2.00
3.00
4.00

Rogersville Organic Petrography





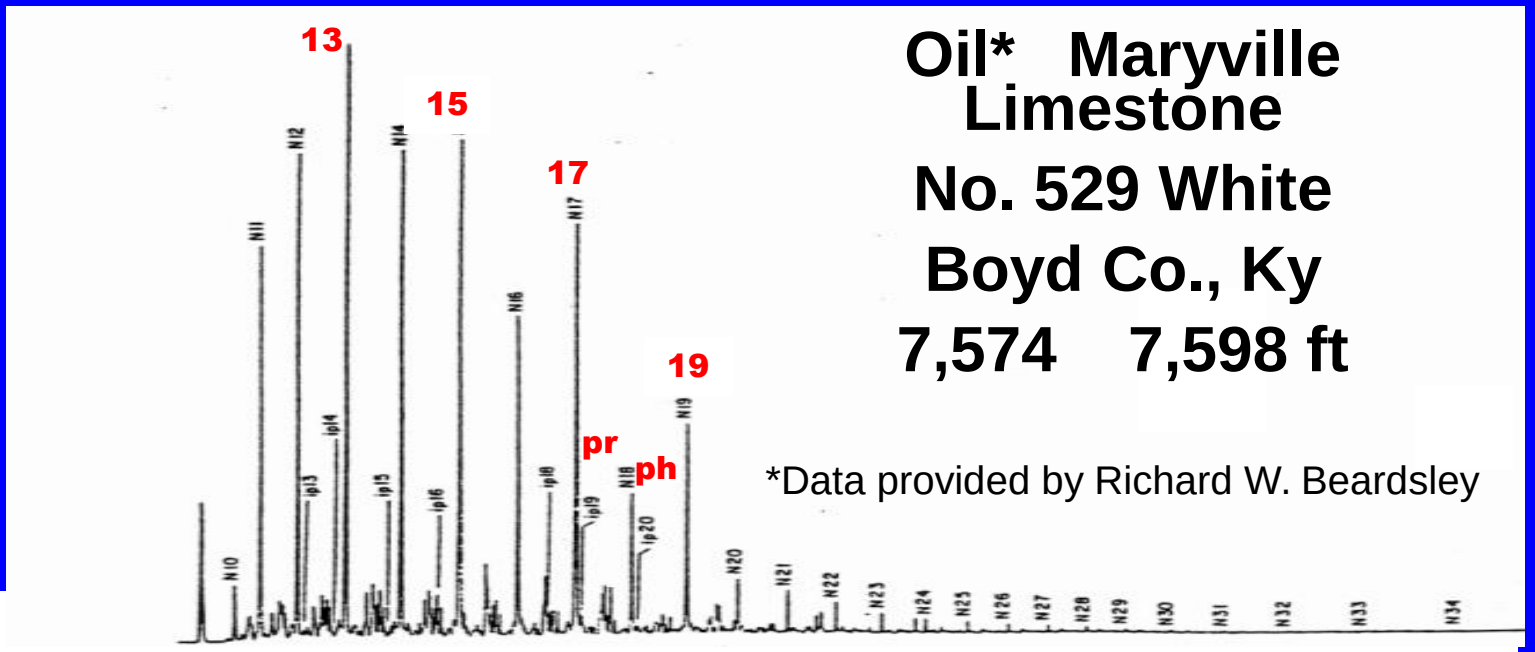




Source Rock Maturity

4709901572 - Exxon #1 Smith, Wayne Co., WV

Bitumen Reflectance				
Core Depth (ft, md)	11167	11178	11191	11197
Average R_o random	1.76	1.80	1.80	1.84
Maximum R_o random	2.11	2.11	2.04	2.10
Minimum R_o random	1.50	1.47	1.53	1.59
Standard deviation	0.14	0.16	0.13	0.13
Observations/sample	50	50	50	50
Calculated R_o equivalent	1.49	1.51	1.51	1.54
(R_o random * 0.618) + 0.4				
(Jacob, 1989)				
Indicated T_{max} from				
calculated R_o equiv.	480	482	482	484



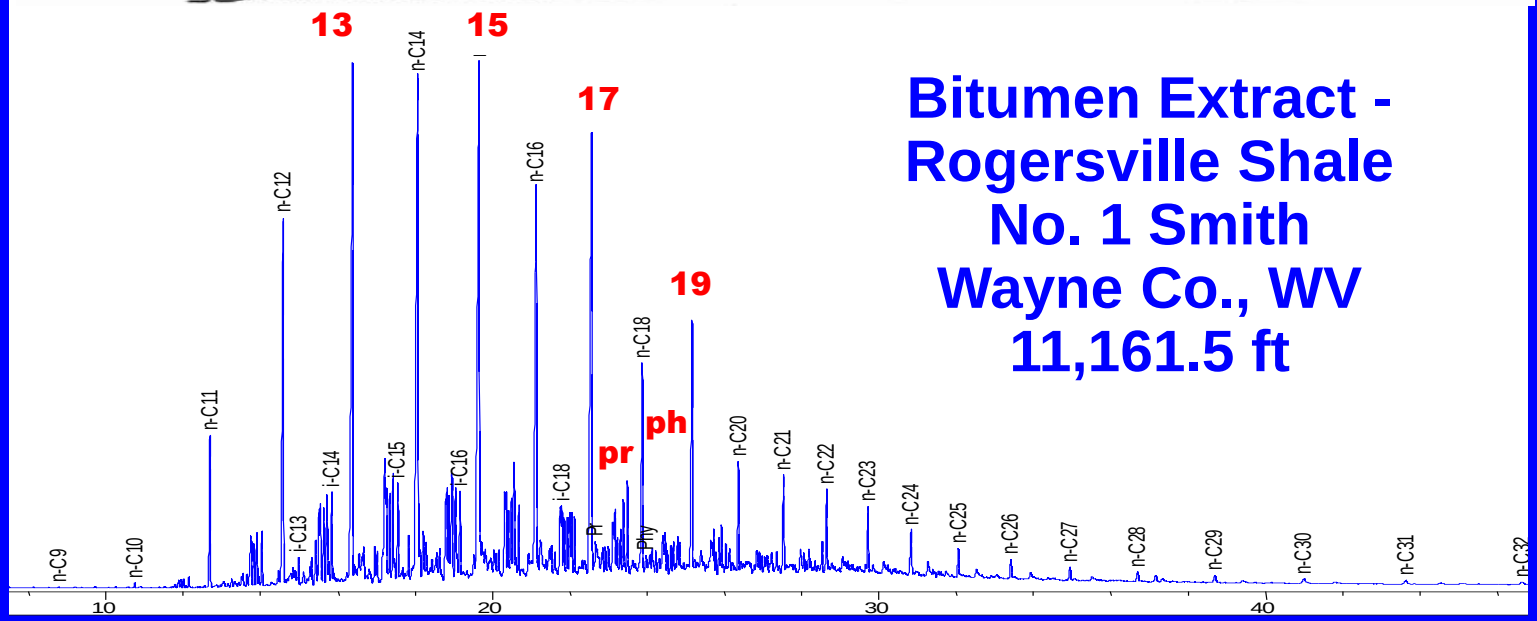
Oil* Maryville Limestone

No. 529 White

Boyd Co., Ky

7,574 7,598 ft

*Data provided by Richard W. Beardsley



Bitumen Extract - Rogersville Shale

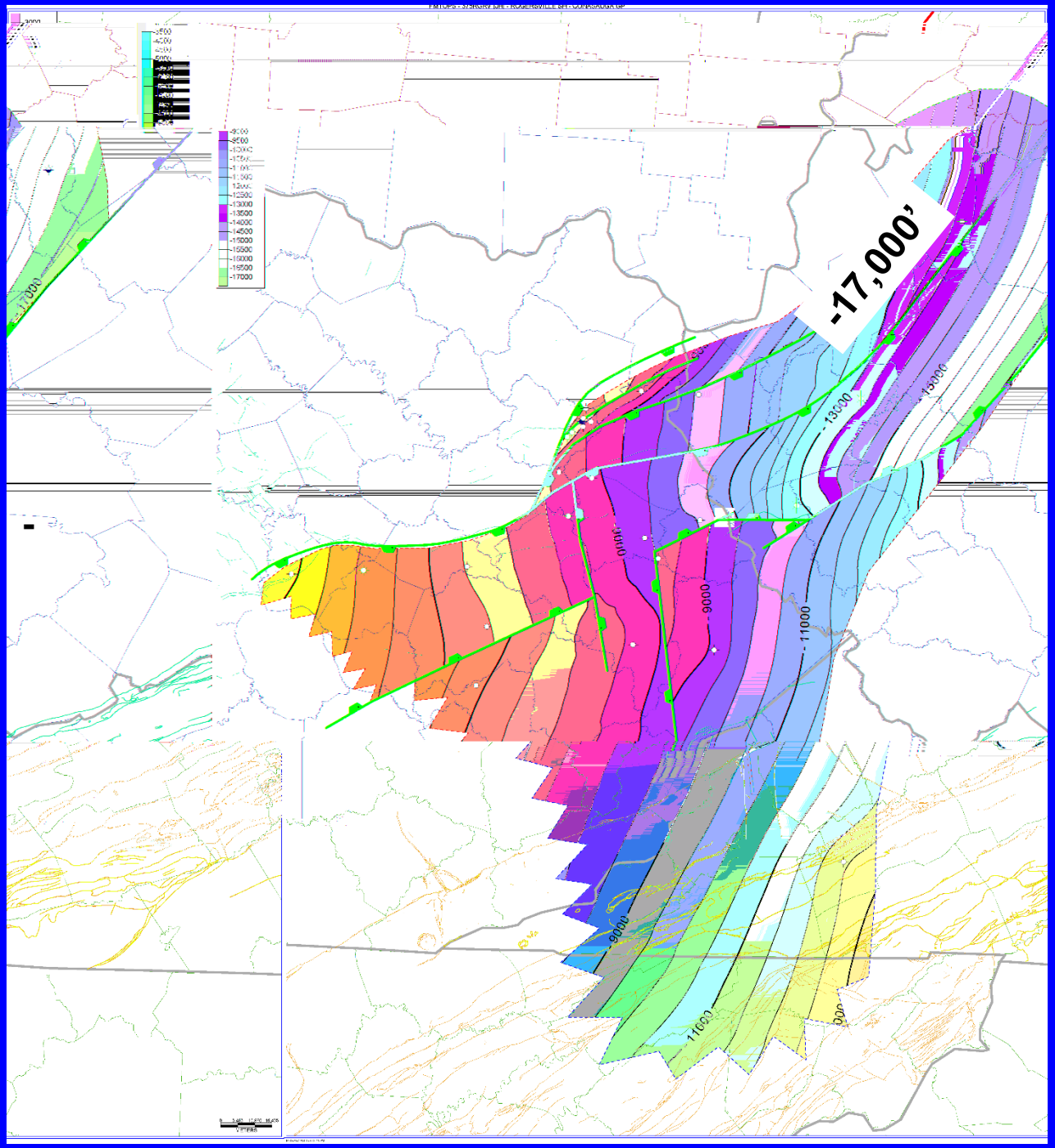
No. 1 Smith

Wayne Co., WV

11,161.5 ft

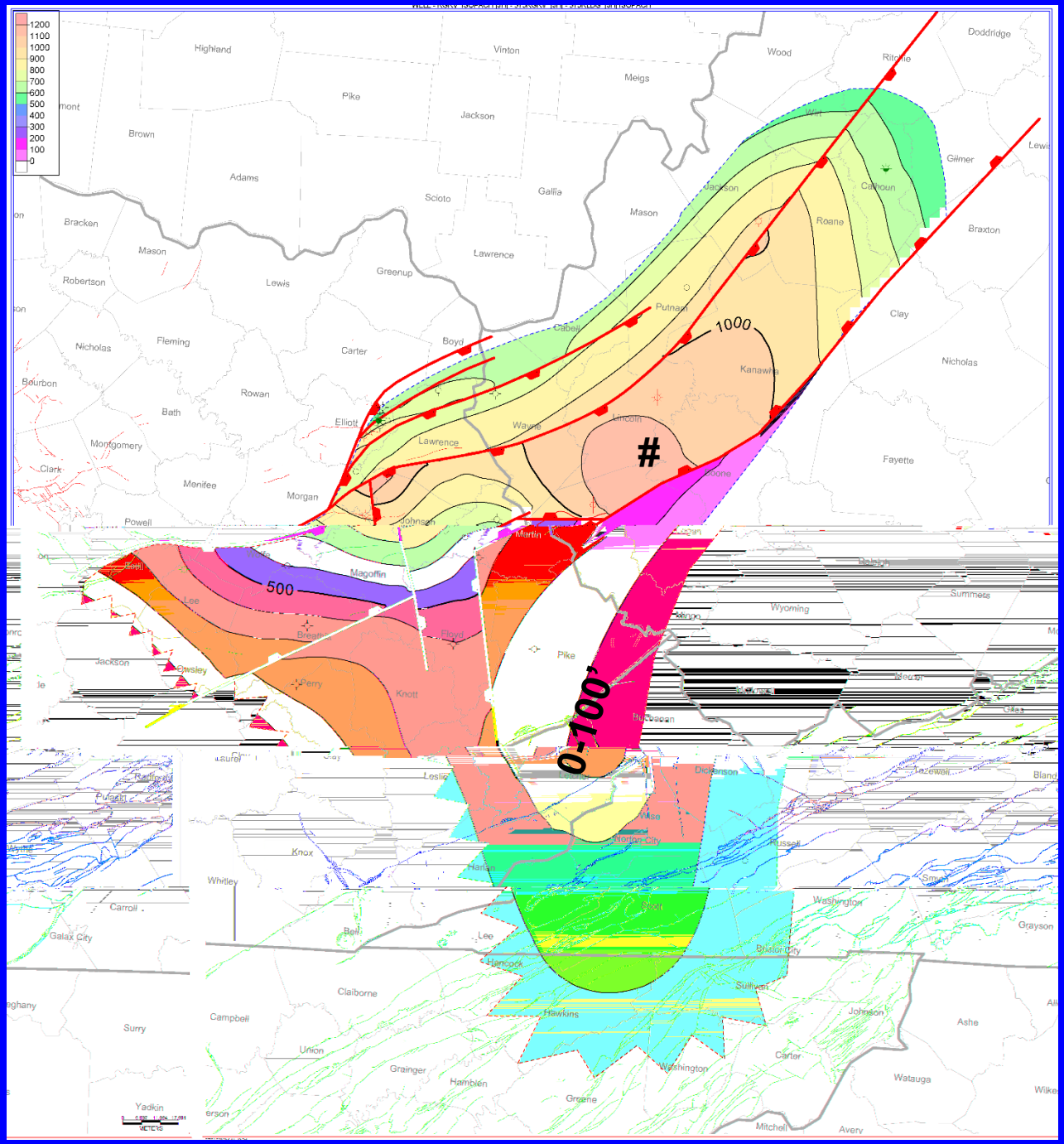
Rogersville Shale Structure Map

4,500 – 17,000 feet below sea level



Rogersville Shale Isopach Map

0 to ~1,125 feet thick



Rogersville Shale Summary

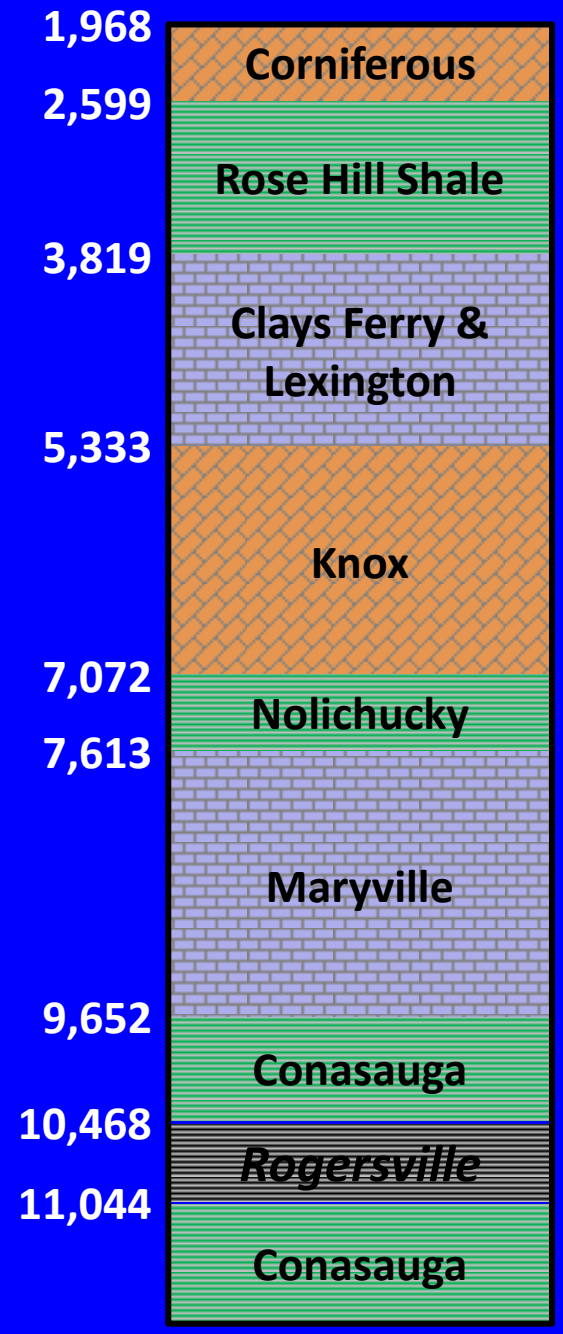
- 5,000 to 18,000 ft deep within Rome Trough
- Up to 1,100 ft thick, but limited to deeper parts of Rome Trough
- Contains up to 4.8% TOC in parts, but not all is organic rich
- Current maturity near wet gas – dry gas transition
- Has generated gas and condensate

Rogersville Shale

Unconventional Shale Exploration Target

Bruin Exploration #1 Young Lawrence County, Kentucky

- Permitted as a stratigraphic test, and drilled to a total depth of 12,169 ft in late 2013.
- Logs, samples from stratigraphic test held confidential for 5 years.
- Re-permitted as oil and gas well in 2014 to complete and test well.
- New horizontal leg permitted 9/04/15.



Bruin #1 Young
Lawrence County

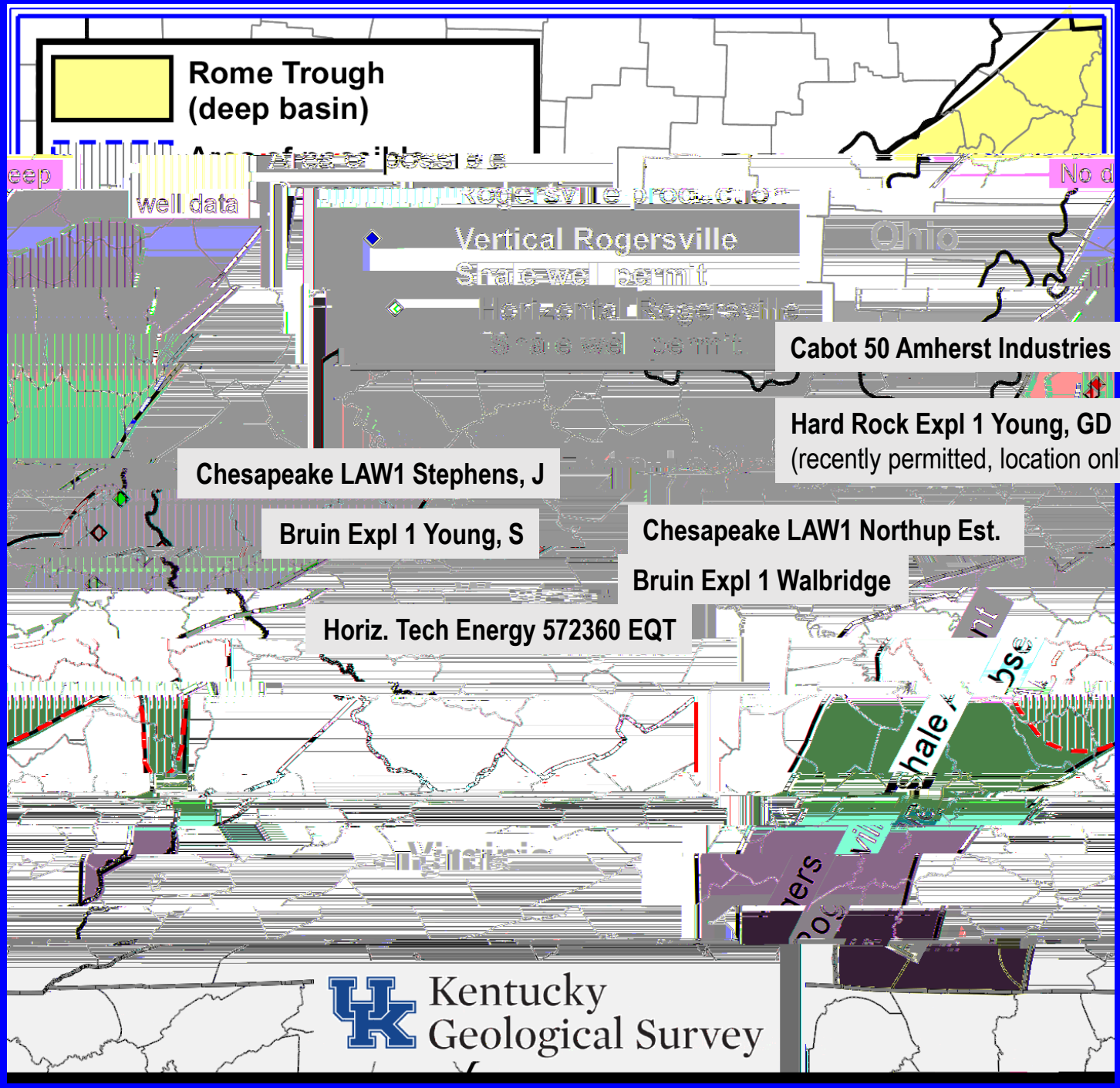
- Slickwater frac (677,000 gal fluid, 600,000 lb sand), 576 ft interval
- Tested 115 MCFPD and 19 BOPD (5/6/2014), 2599 psi SIP
- Shut-in 5/30/2014
- 4,800 ft horizontal lateral permitted

New (2014-

- After rumored success of the Bruin #1 Young well, leasing boom for deep rights in Johnson, Magoffin, and Lawrence Cos., Ky

- More than 4,275 deep leases were sold in 18 months ending June 2015 (Cate, 2015)

- Prices per acre are now $250-300 where $25-50 was common 5 years ago


Rome Trough
(deep basin)
well data
Vertical Rogersville
Horizontal Rogersville
Ohio
Cabot 50 Amherst Industries
Hard Rock Expl 1 Young, GD
(recently permitted, location only)
Chesapeake LAW1 Stephens, J
Bruin Expl 1 Young, S
Chesapeake LAW1 Northup Est.
Bruin Expl 1 Walbridge
Horiz. Tech Energy 572360 EQT
Kentucky
Geological Survey

Current Play Status

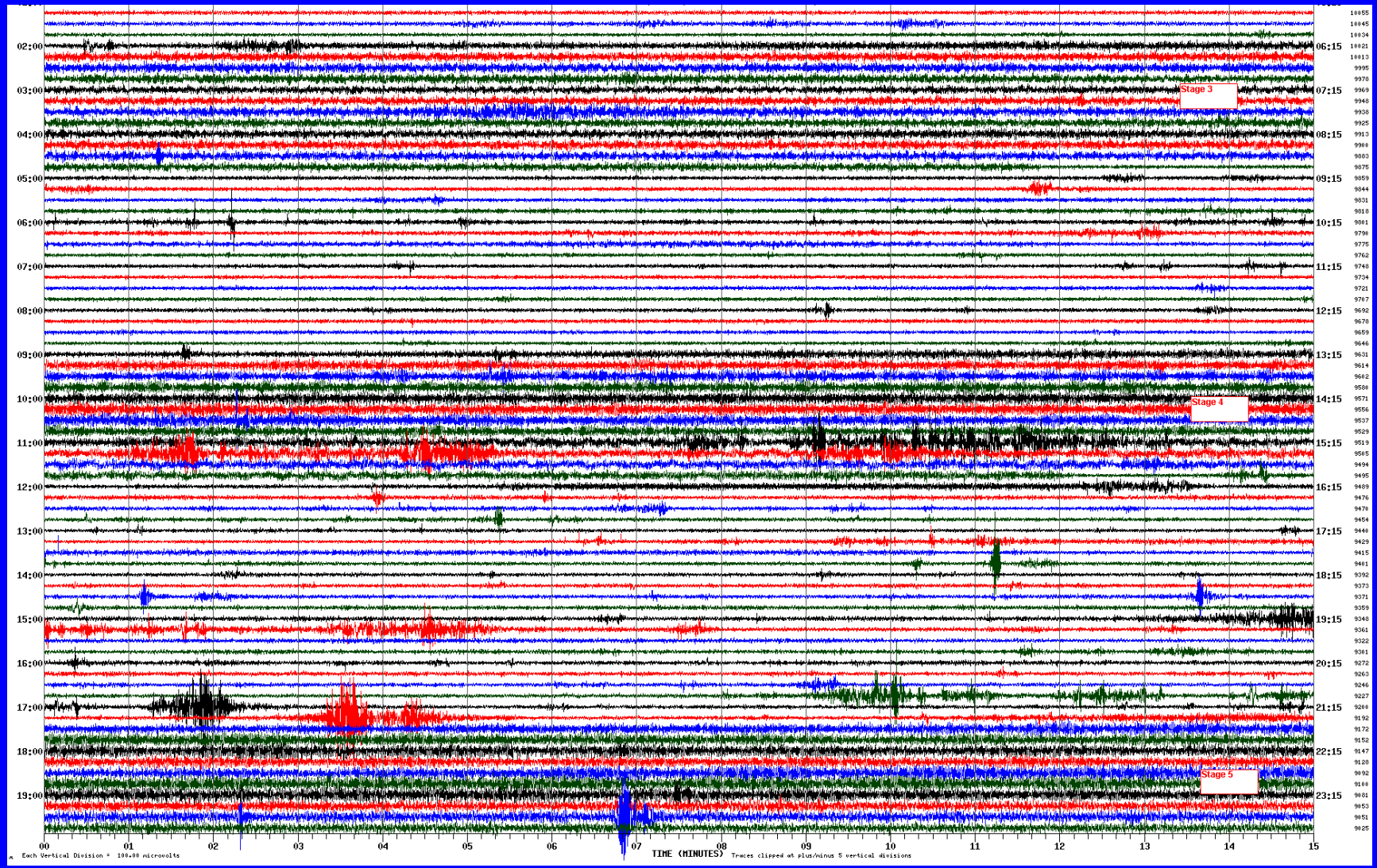
- Five wells drilled to date
  - *Bruin Expl. (Cimarex):* apparent discovery (shut-in) Lawrence Co., Kentucky
  - *Cabot Oil & Gas:* 1 vertical, Putnam Co., West Virginia, producing dry gas, zone unknown
  - *Chesapeake Energy*: 2 verticals (shut-in), Lawrence County, Kentucky
  - *Horiz. Tech. Energy (EQT):* 1 horizontal, (under evaluation?), Johnson Co., KY
- Three horizontal lateral permits
- Most activity on hold due to low prices

KGS Microseismic Research

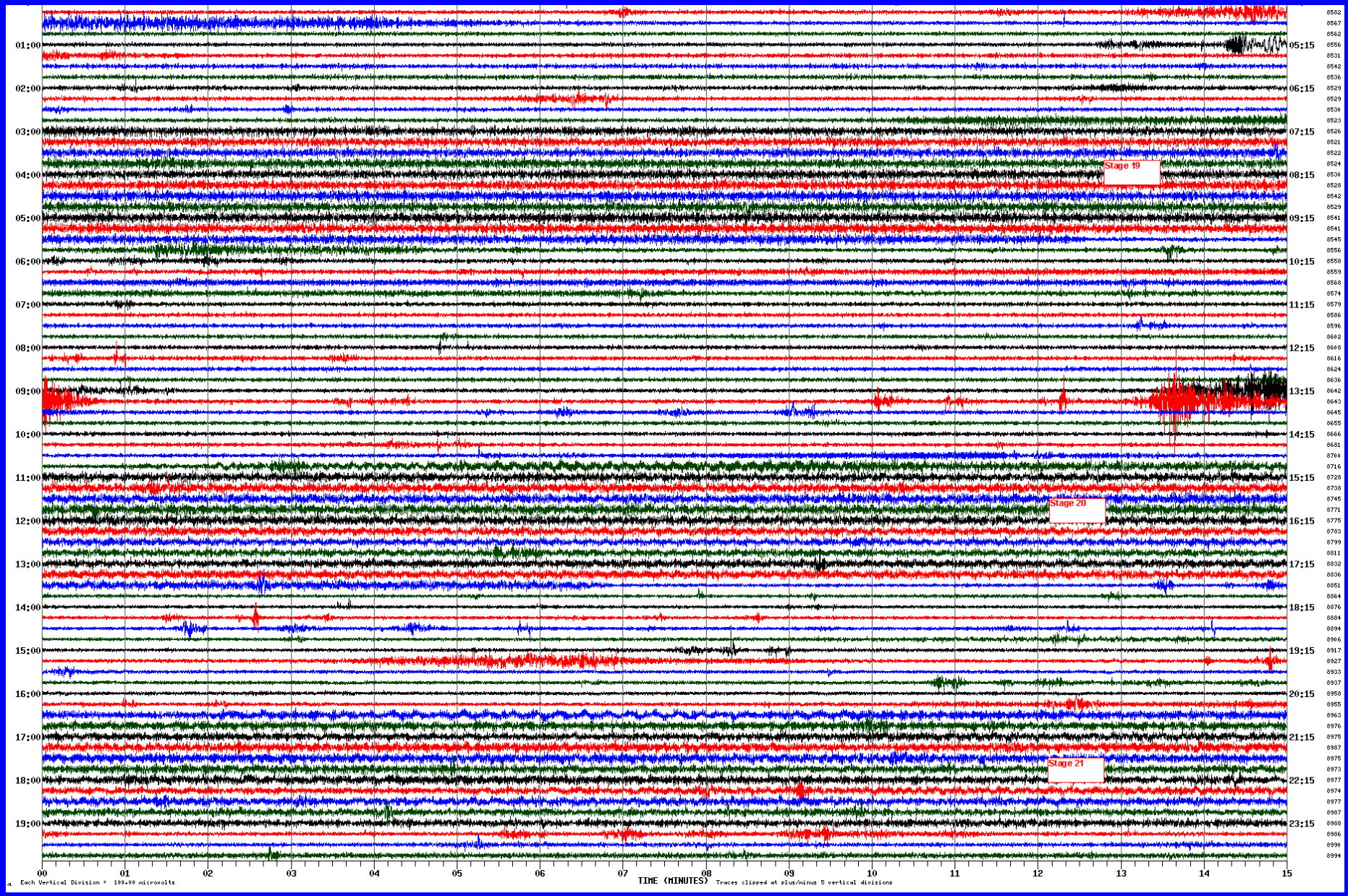
- Two monitoring programs to collect baseline data:
  - Microseismic: 12 stations installed; partnering with Cimarex Energy, Nanometrics
  - Groundwater quality from domestic wells
- Establishing background data prior to development will allow recognition of natural vs. man-made events
- Goal: avoid induced seismicity, fracking concerns seen in other areas

Chesapeake #1 Stephens

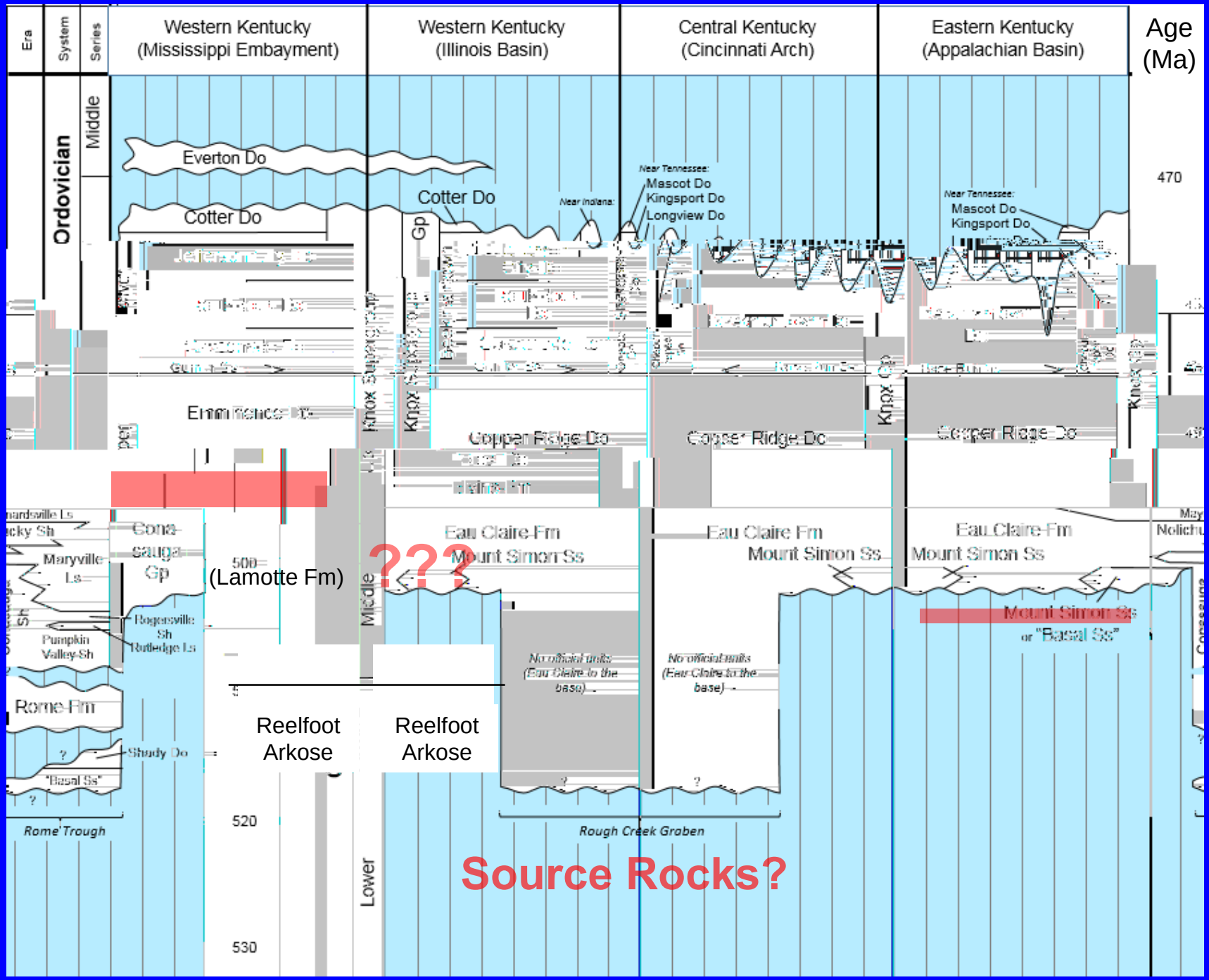
Microseismic response to multi-stage fracking



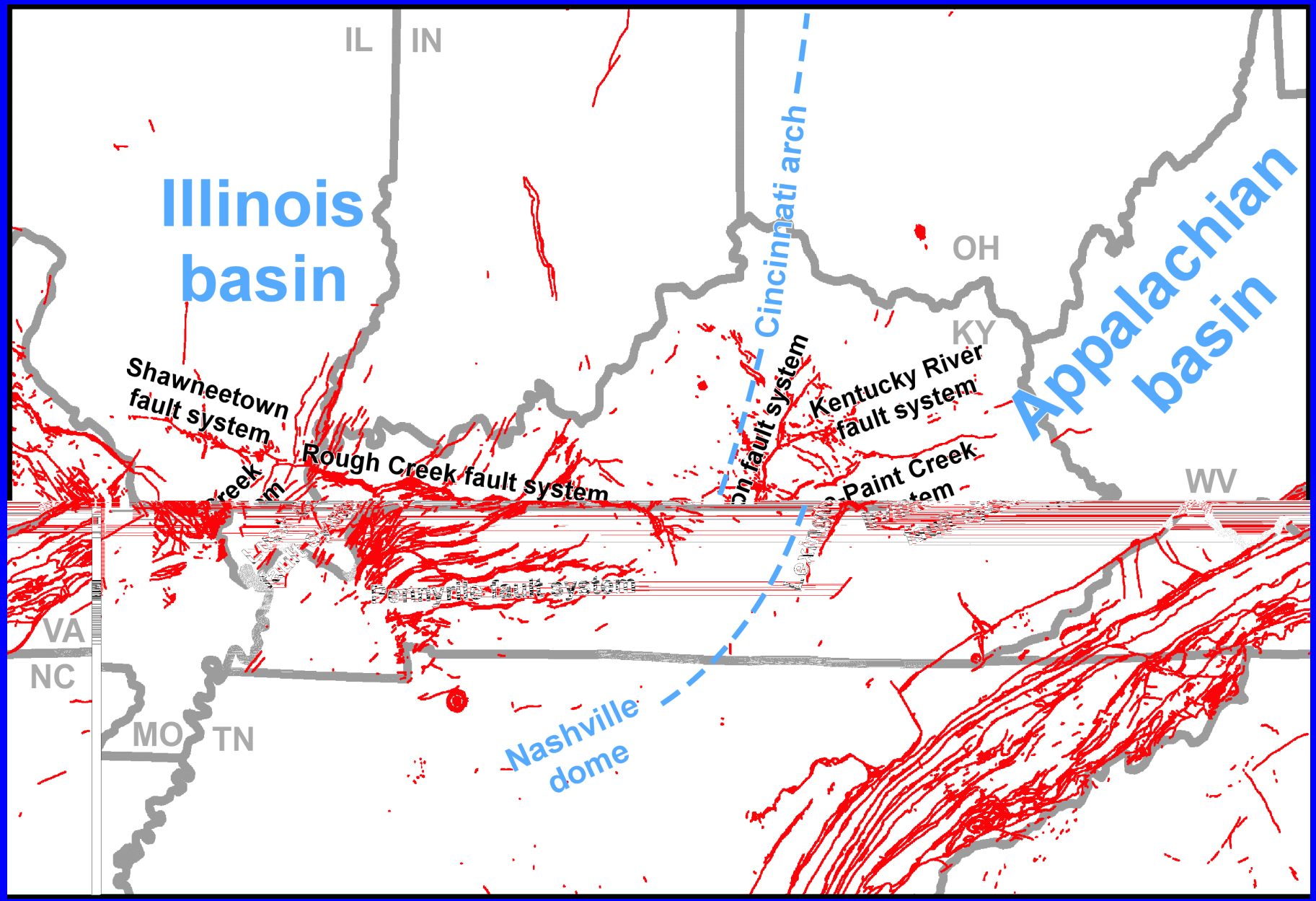
Microseismic Response



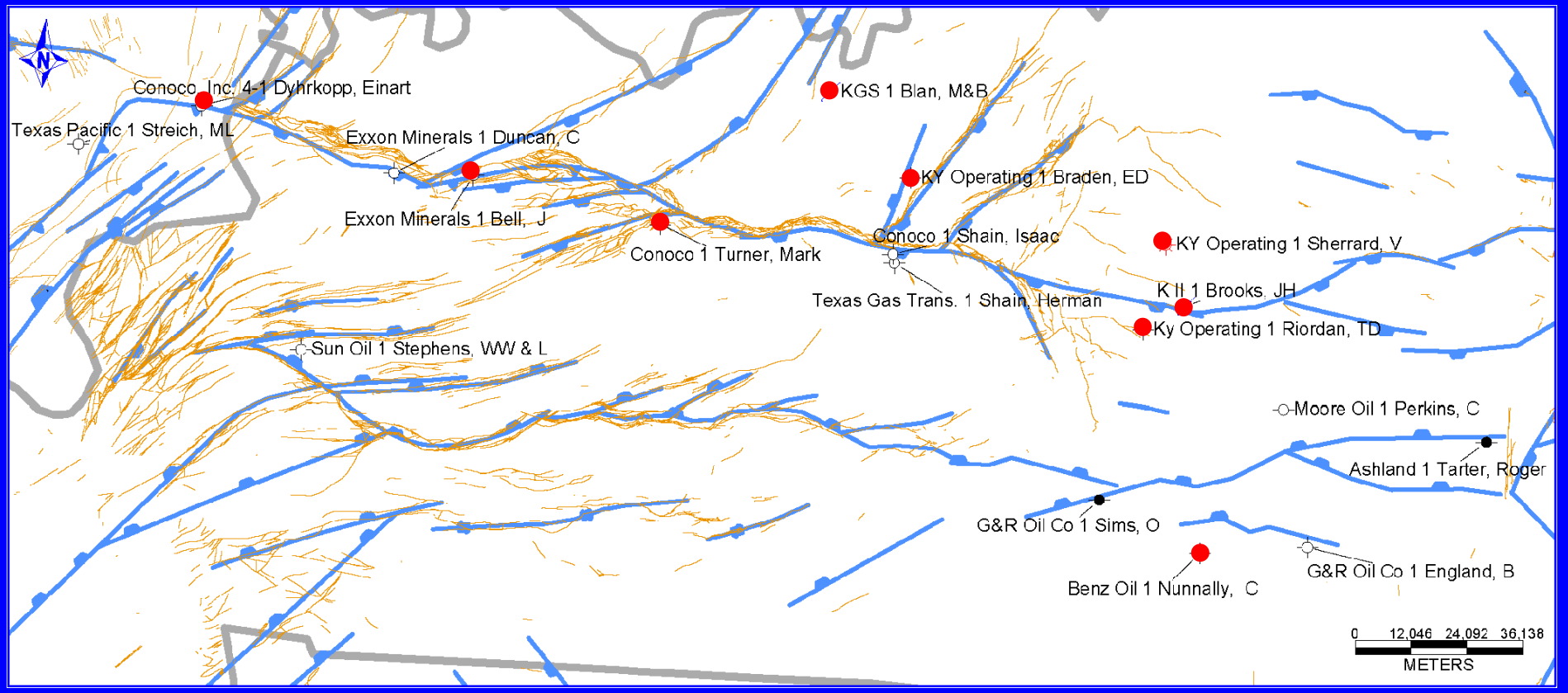
Rough Creek Graben, Cambrian depocenter in the southernmost Illinois Basin


Era
System
Series
Western Kentucky (Mississippi Embayment)
Western Kentucky (Illinois Basin)
Central Kentucky (Cincinnati Arch)
Eastern Kentucky (Appalachian Basin)
Age (Ma)
Ordovician
Middle
Everton Do
Cotter Do
Cotter Do
Gp
Near Indiana:
Near Tennessee:
Mascot Do
Kingsport Do
Longview Do
Near Tennessee:
Mascot Do
Kingsport Do
470
Knox Supergroup
Knox Gp
Knox Gp
Copper Ridge Do
Copper Ridge Do
Copper Ridge Do
Eau Claire Fm
Mount Simon Ss
Eau Claire Fm
Mount Simon Ss
Eau Claire Fm
Mount Simon Ss
Mount Simon Ss or "Basal Ss"
Conasauga Gp
Maryville Ls
Pumpkin Valley Sh
Rogersville Sh
Rutledge Ls
Rome Fm
Shady Do
"Basal Ss"
500
(Lamotte Fm)
???
Middle
No official units (Eau Claire to the base)
No official units (Eau Claire to the base)
Reelfoot Arkose
Reelfoot Arkose
Rome Trough
Rough Creek Graben
520
530
Lower
Source Rocks?

Current Surface Features



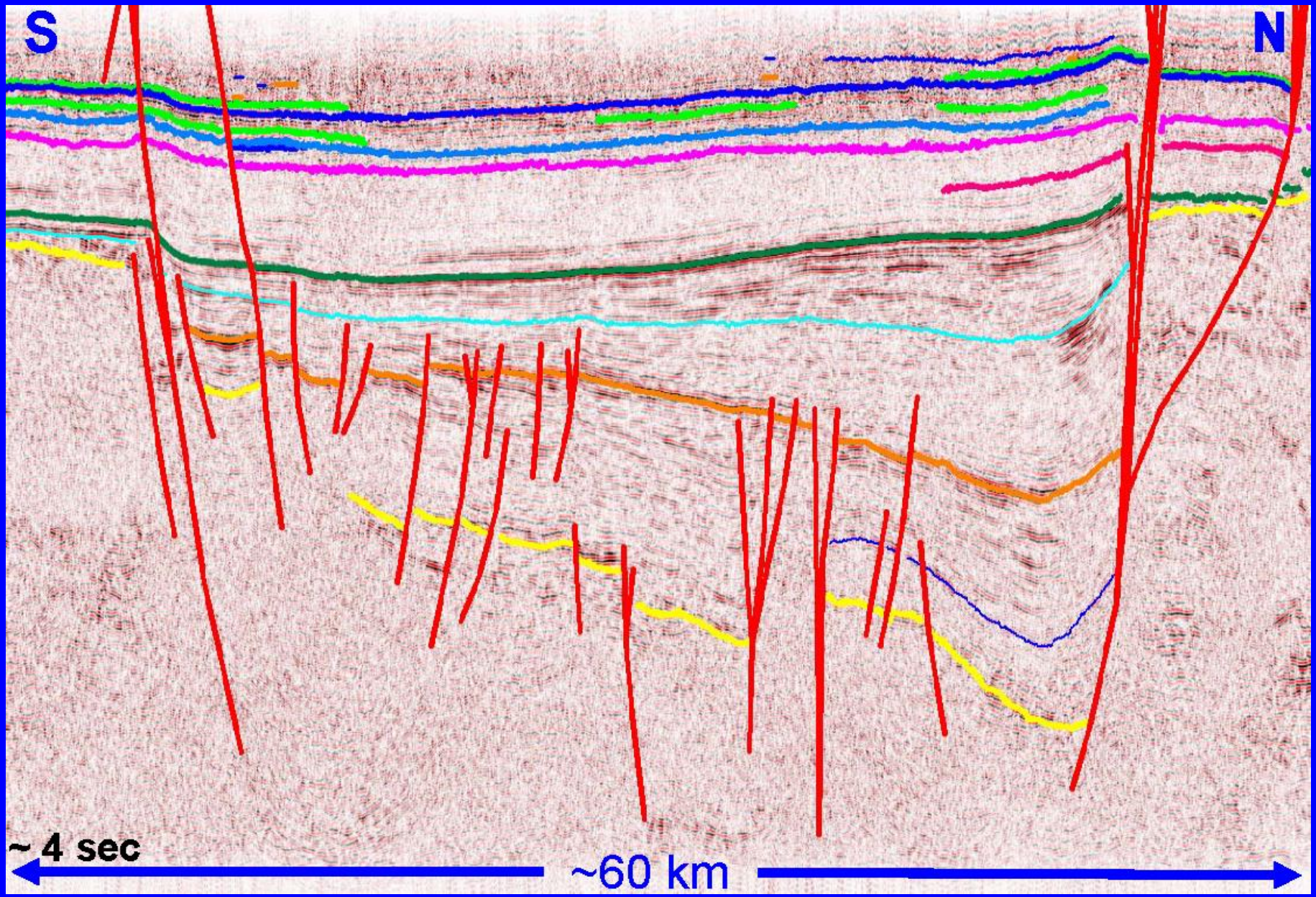
Rough Creek Graben Exploration



Eighteen wells drilled deeper than Knox Group (Arbuckle equiv.) in region.

Nine basement tests (in red), all along (or just outside) graben boundary faults.

Rough Creek Graben seismic profile



Conclusions

- Organic-rich horizons similar to the Rogersville Shale may exist within the Eau Claire Fm of the Rough Creek or Mississippi Valley Grabens (but have not been identified to date).
- Because of complex history of faulting, structure data (seismic, gravity, magnetics) will be a key tool in developing rift-related Cambrian shale plays.


Kentucky
Geological Survey