The Origin and Significance of the Lower Mississippian Sunbury Shale in East-Central United States*

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Abstract

The Sunbury Shale is a relatively thin, Lower Mississippian, organic-rich, black-shale unit that is prominent throughout eastern Ohio, eastern Kentucky and western West Virginia. The Sunbury is the most widespread of the Devonian-Mississippian black shales. Where it occurs in the western Appalachian Basin, it is commonly separated from the black, Upper Devonian Ohio Shale by the gray shales, silts and sandstones of the Bedford-Berea sequence. However, in parts of eastern and central Kentucky, where the Bedford becomes a black shale, the Sunbury merges with black Bedford and Ohio shale equivalents to become the uppermost part of the New Albany and Chattanooga shales. The unit even crosses the Cincinnati Arch into the Illinois Basin and is present in the Michigan Basin, where it attains thicknesses greater than 45 m. To the northeast in northern West Virginia and western Pennsylvania, the Sunbury grades into the much thicker (> 70 m) and more clastic-rich Riddlesburg Shale, which reflects a marginal-marine embayment.

The black-shales of the Devonian-Mississippian sequence all represent subsidence and early deep-water infilling of foreland basins associated with orogeny in the east. Early to Late Devonian black shales all represent deformational loading and foreland-basin infilling associated with the Acadian Orogeny, and these shales occur in basins that migrate southwesterly in time and space. The Sunbury-Riddlesburg, however, is different in that it migrated eastward in time and space, and recent work shows that it represents foreland-basin subsidence accompanying inception of the Early Mississippian Neoacadian Orogeny in New England. The Neoacadian Orogeny represents the initial collision of the exotic Carolina terrane at New England and the terrane's subsequent southwestward transpressional convergence with the eastern margin of Laurussia (North America). In

response, the initial Sunbury-Riddlesburg Basin formed just cratonward of the orogen in western Pennsylvania and northern West Virginia and subsequently expanded southwestwardly along with dextral transpression in the orogen. While the Sunbury and its equivalents represent a deeper, sediment-starved, foreland-basin infilling, the overlying Price-Pocono-Borden-Grainger clastic units represent relaxational, post-orogenic, deltaic complexes that developed from erosion of Neoacadian Mountains formed in the orogen.

Economically, it is thought that the Sunbury may have sourced conventional reservoirs in the underlying Bedford-Berea sequence as well as in the overlying Lower Mississippian clastic units. However, in places throughout the western Appalachian Basin where it has sufficient thickness and TOC greater than 20%, the unit should probably be examined as a future unconventional resource.

The Origin and Significance of the Sunbury Shale in East-Central United States

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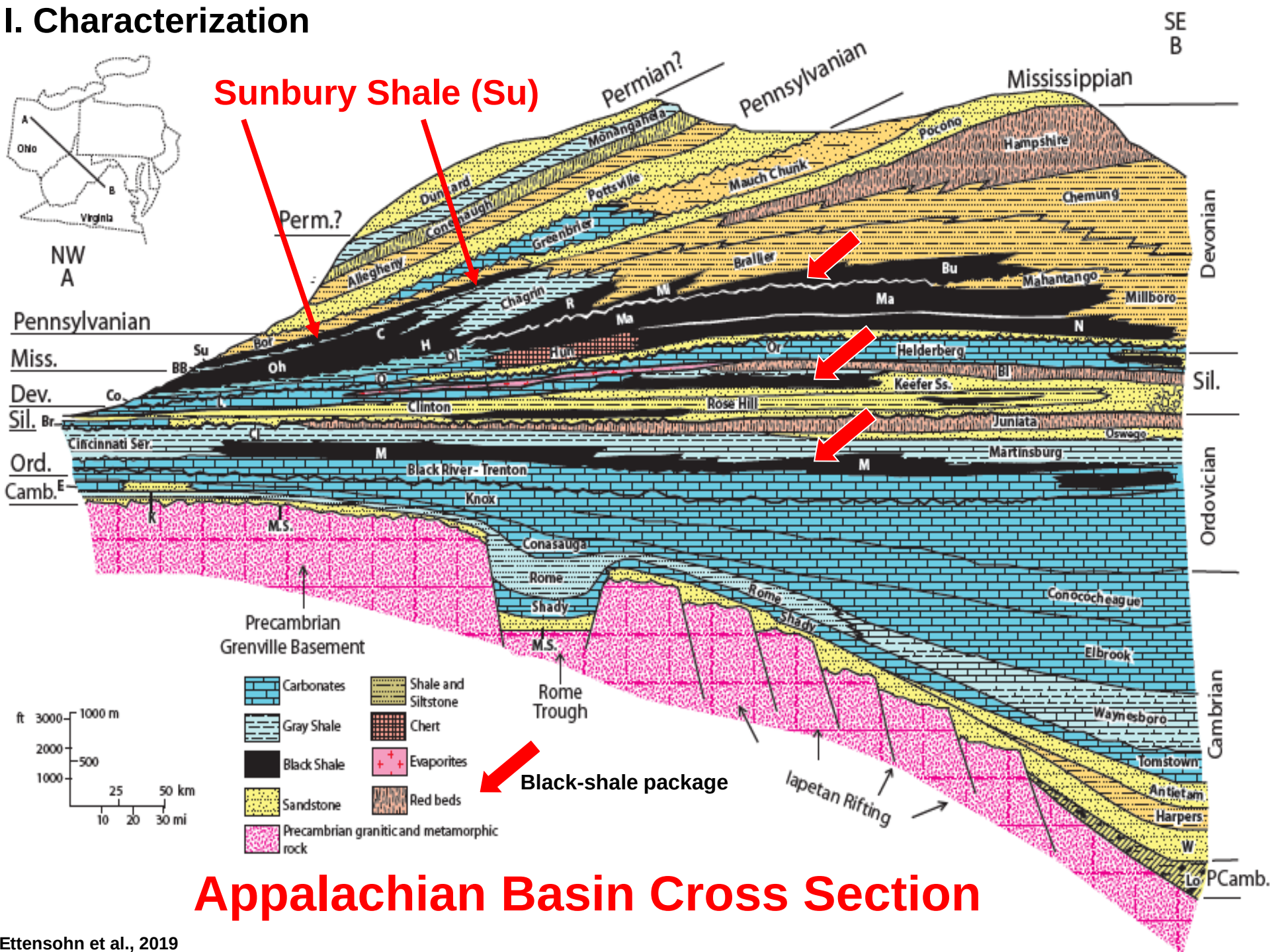
Lower Borden Fm. and Sunbury Sh., eastern KY

Talk Outline

I. Characterization
II. Riddlesburg equivalent
III. The Neoacadian Orogeny and the Sunbury Shale
IV. Summary

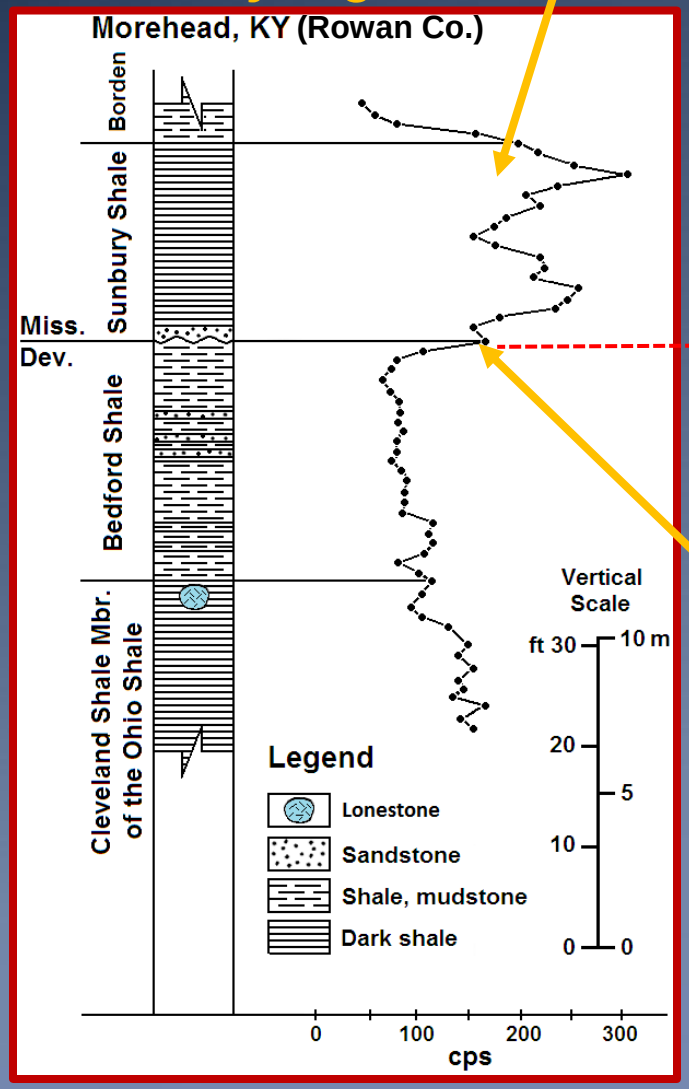
I. Characterization

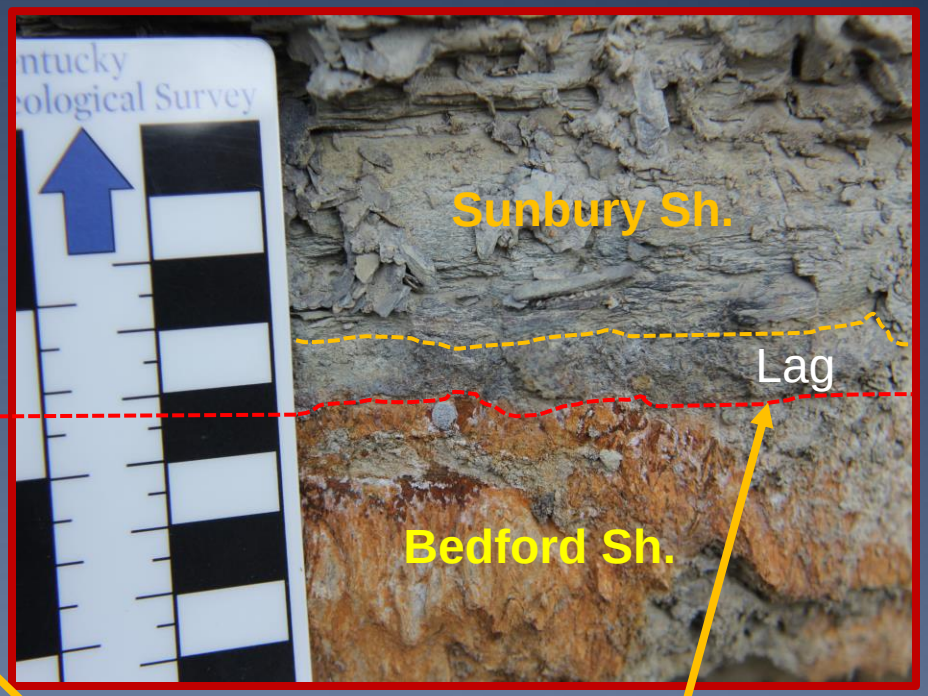


Appalachian Basin Cross Section

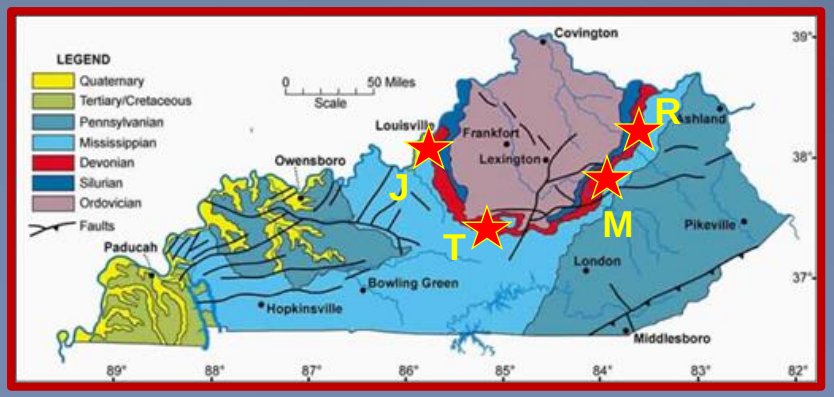
Ettensohn et al., 2019

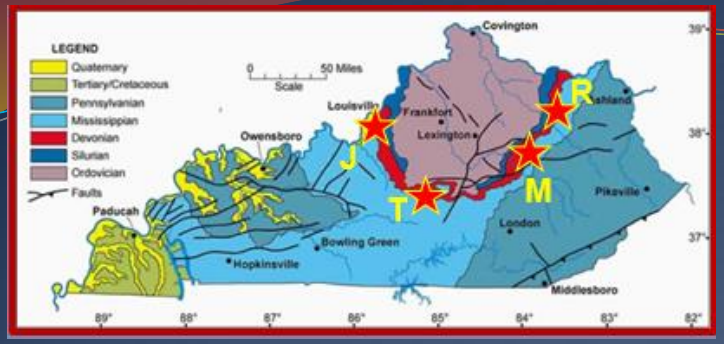
Characteristic Gamma-Ray Signature



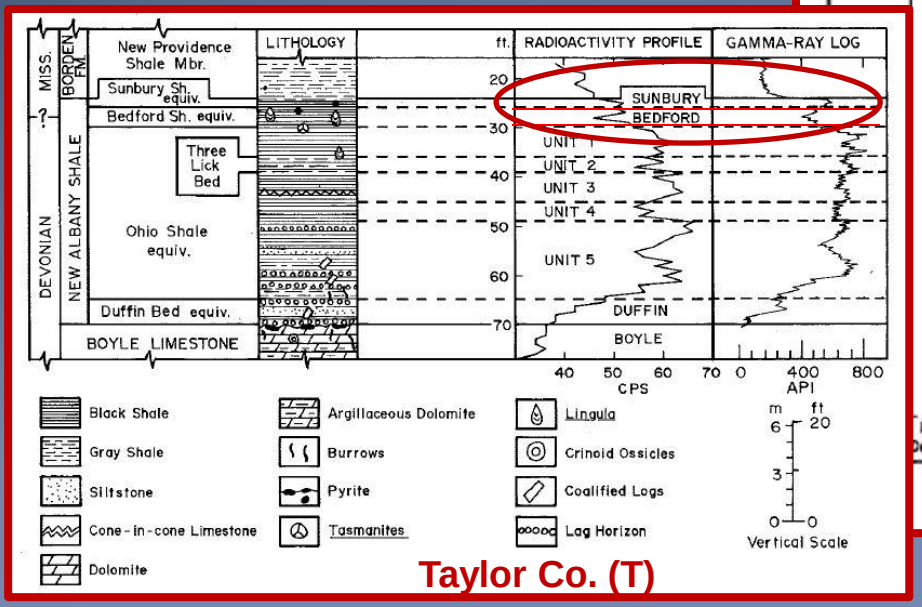


Underlying Unconformity

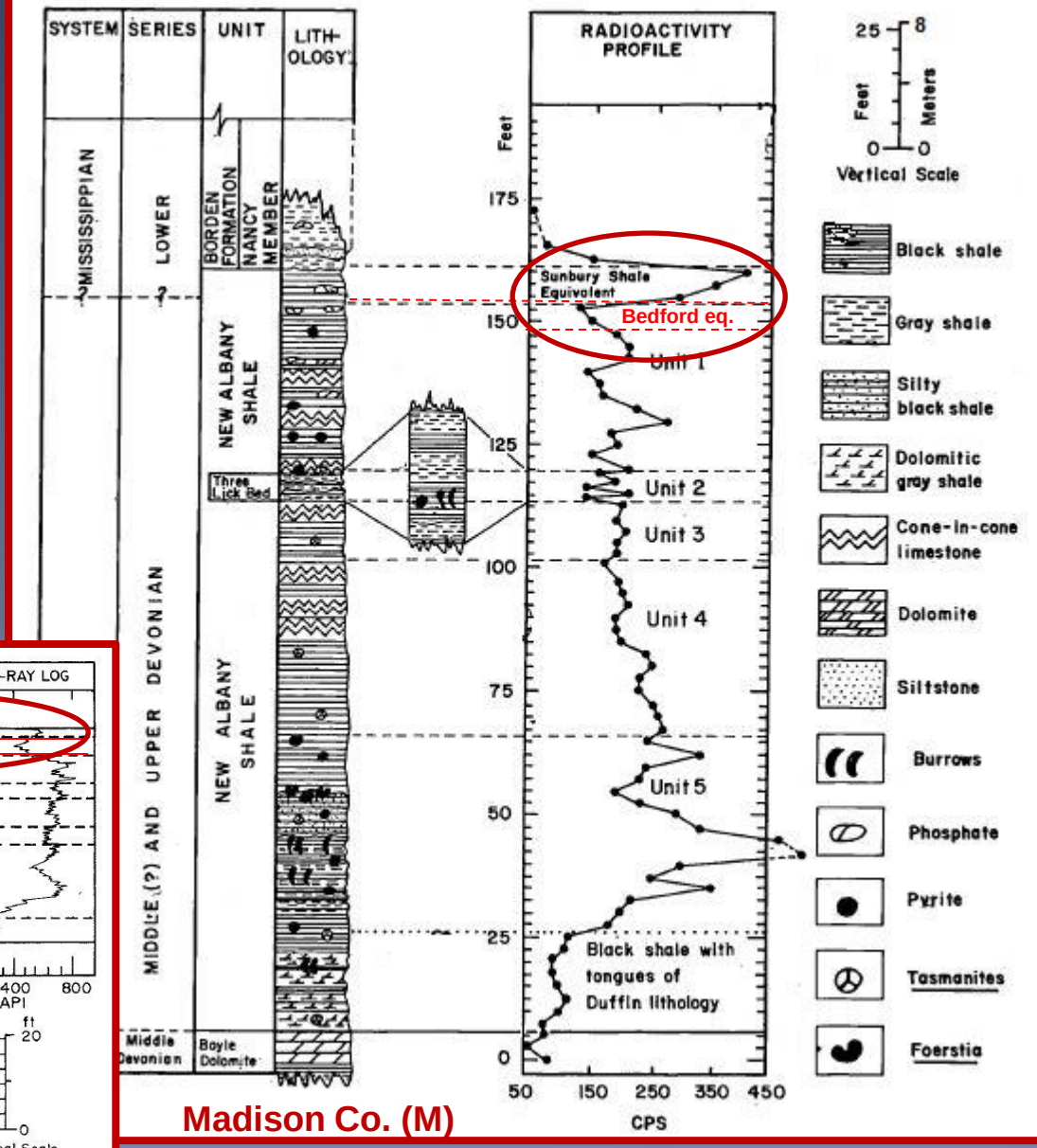




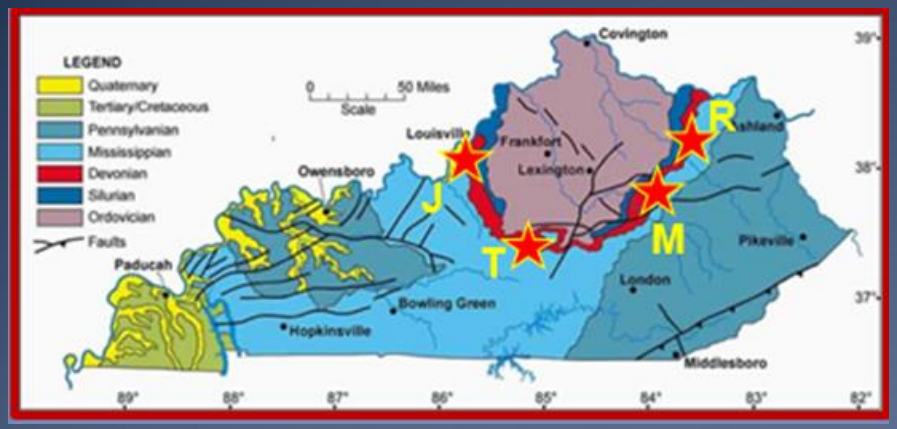
In the New Albany and Chattanooga Shales in east-central Kentucky, the Sunbury merges with underlying black shales where the Bedford equivalent becomes black.



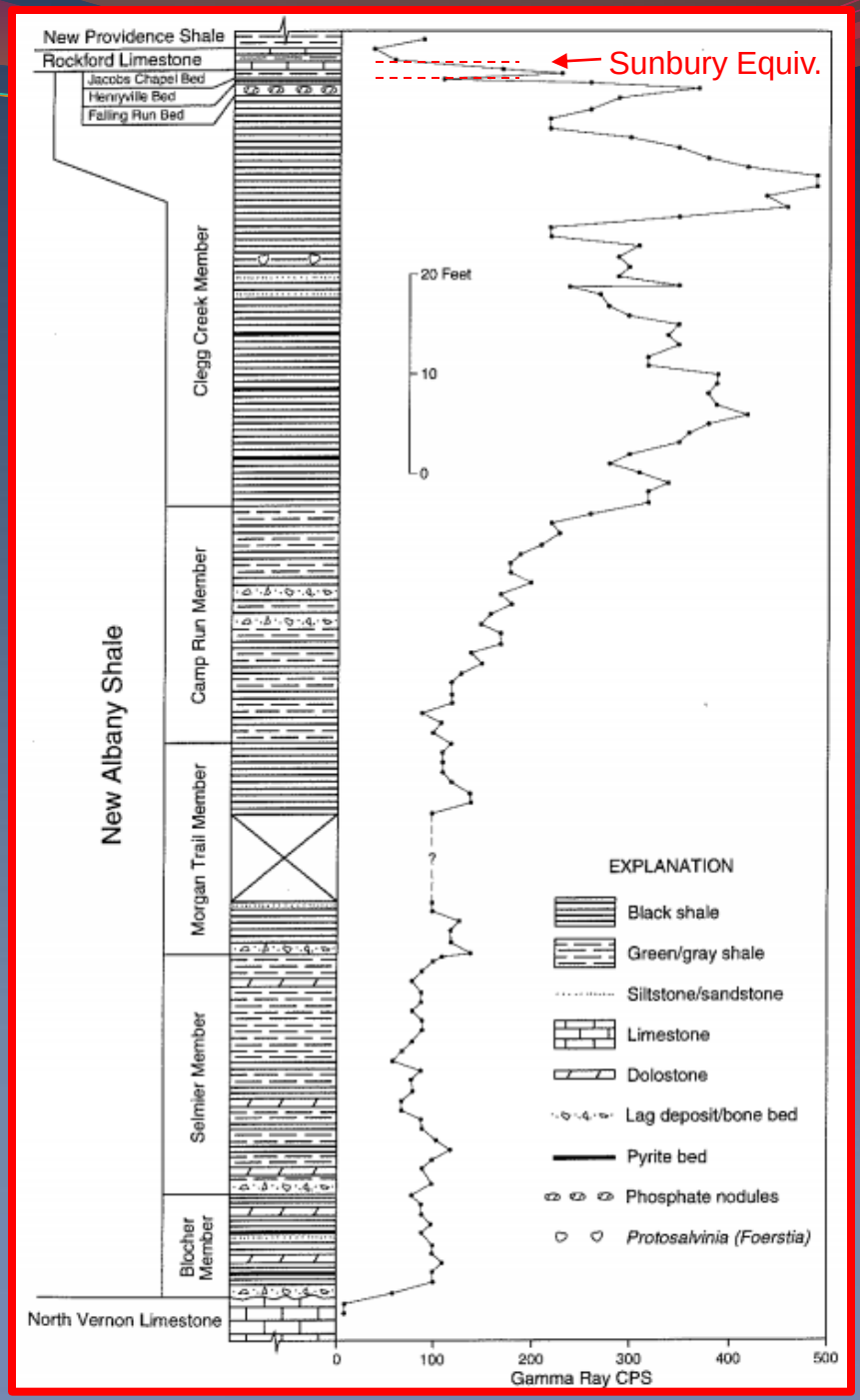
Taylor Co. (T)



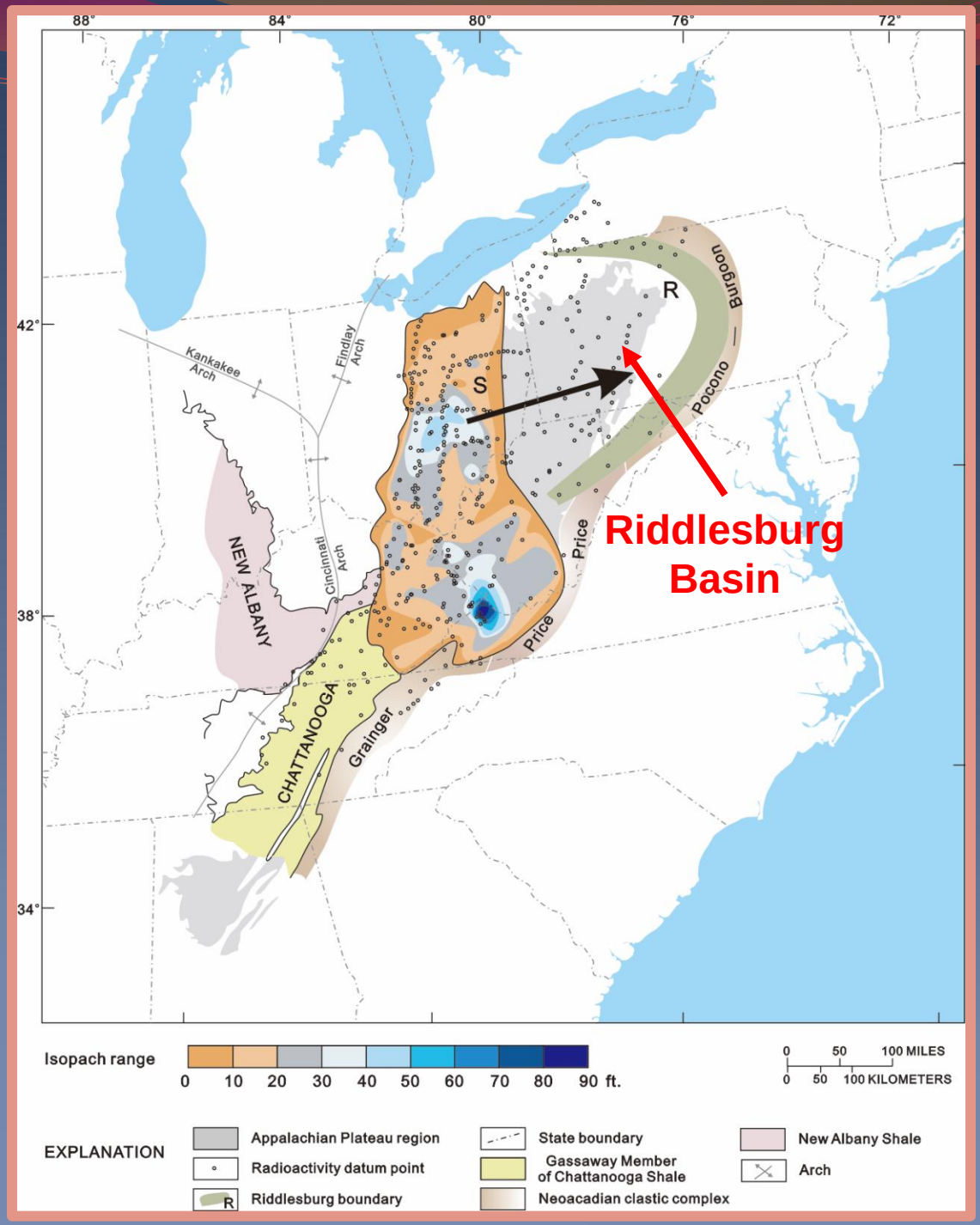
Madison Co. (M)



Sunbury equivalent in the New Albany Shale at Louisville, KY, in Jefferson Co. (J)



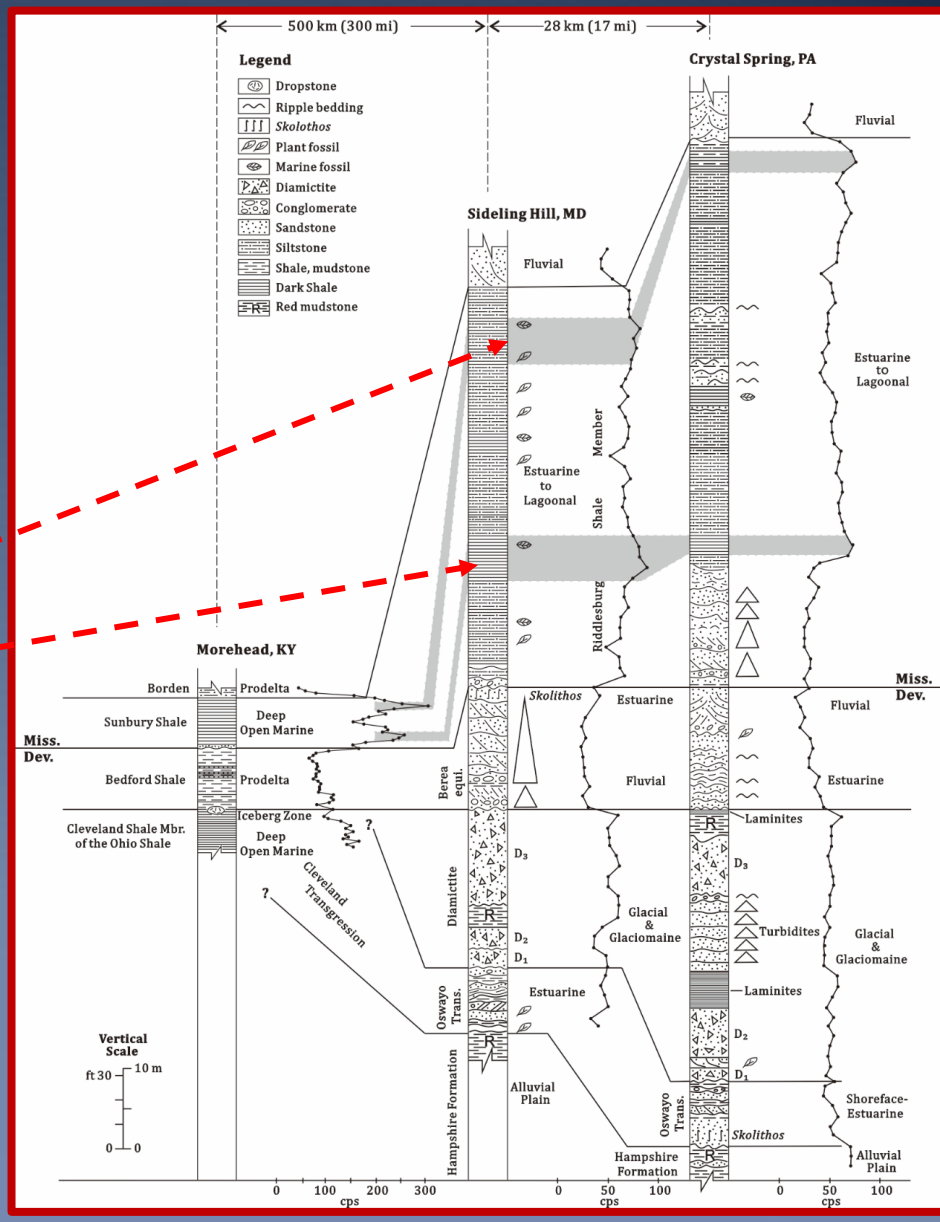
Distribution and Thickness of the Sunbury and its Equivalents in the East-Central U.S.



II. Riddlesburg Equivalent

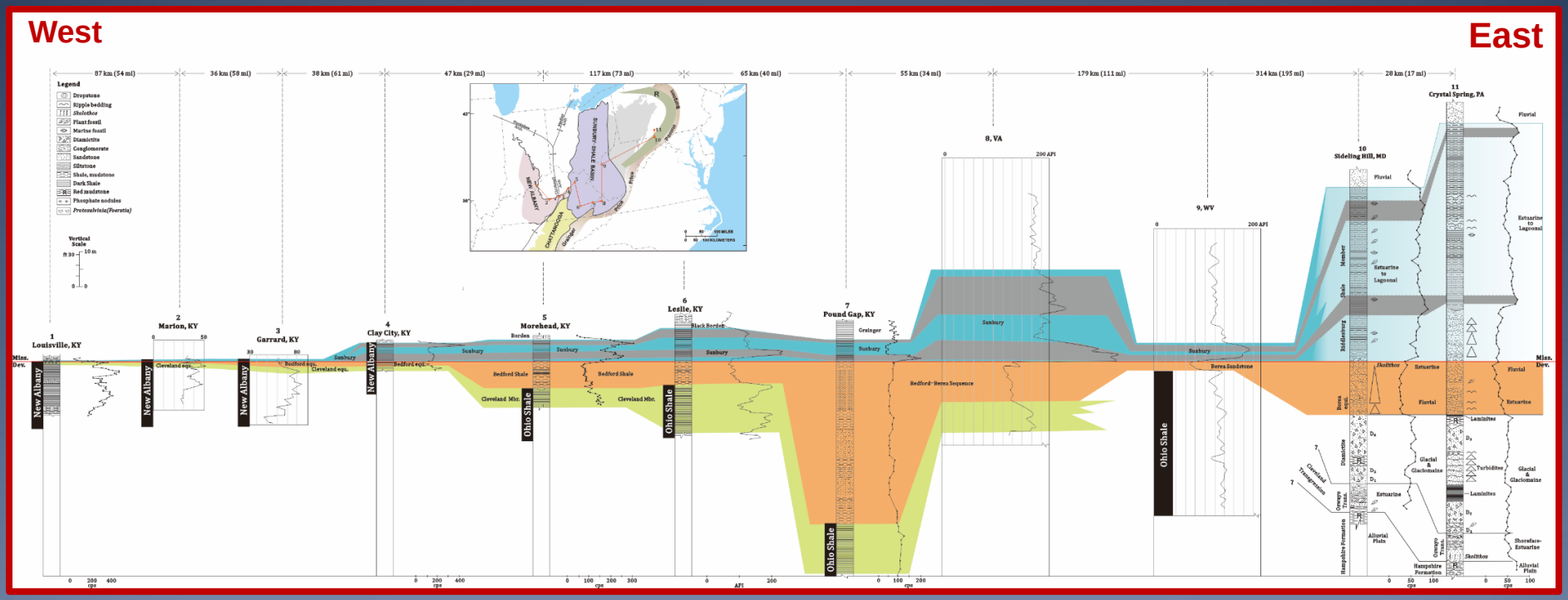
Riddlesburg Mbr. equivalent of the Sunbury Shale at Sideling Hill, MD

Correlations between the Sunbury and Riddlesburg



Sunbury and equivalents: Cross-section from central PA to west-central KY

Uppermost part, New Albany Sh. ← **Sunbury Shale** → **Riddlesburg**



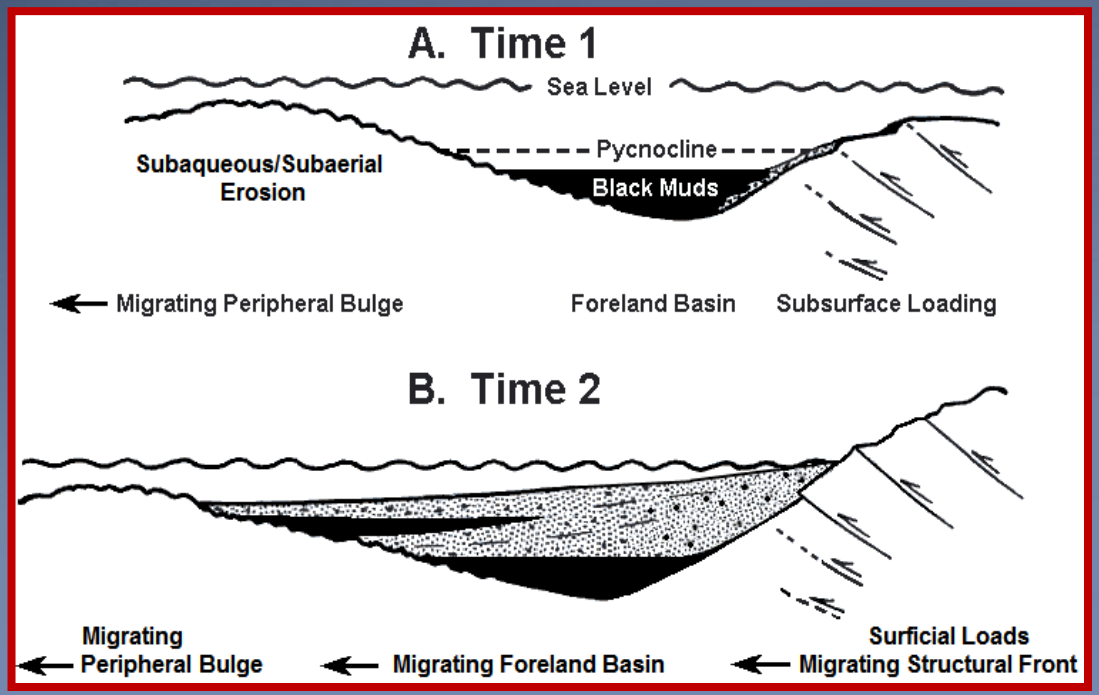
Thickest Sunbury, SW Virginia

III. The Neoacadian Orogeny and the Sunbury Shale

Sunbury is part of the Devonian-Mississippian black-shale sequence.

The black shales represent early flexural subsidence in response to deformational loading in the Acadian and Neoacadian orogenies.

The black-shale basins migrate in space and time as they track the progress of orogeny.



Time 1

a.) Subsurface or subaqueous loading

b.) Rapid subsidence, underfilled, sediment-starved basin

c.) No major clastic sources

d.) Organic matter from water column and suspended clays and silts are major sediments

e.) O_2-deficient conditions preserve organic matter

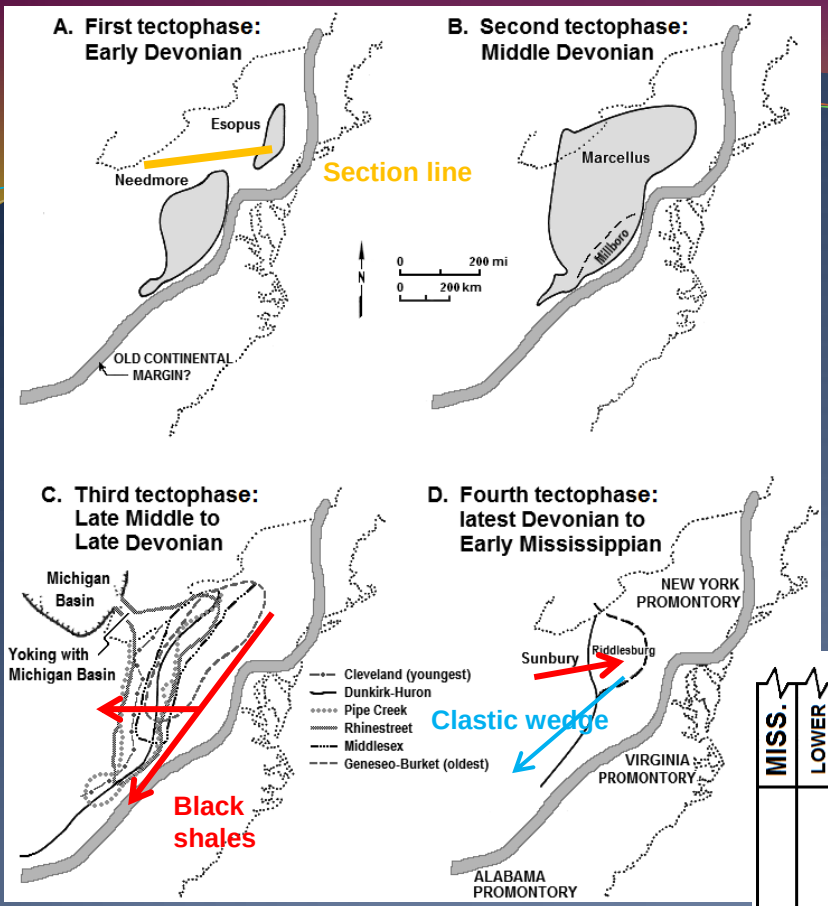
Time 2

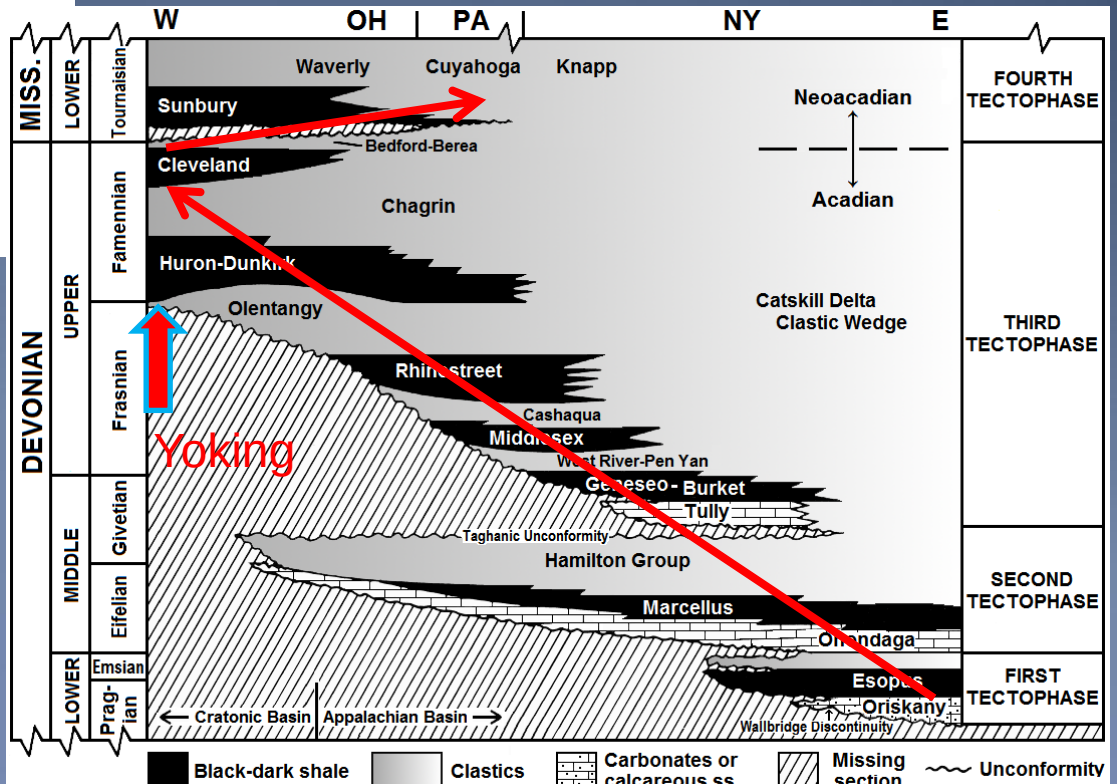
a.) Surficial load developed

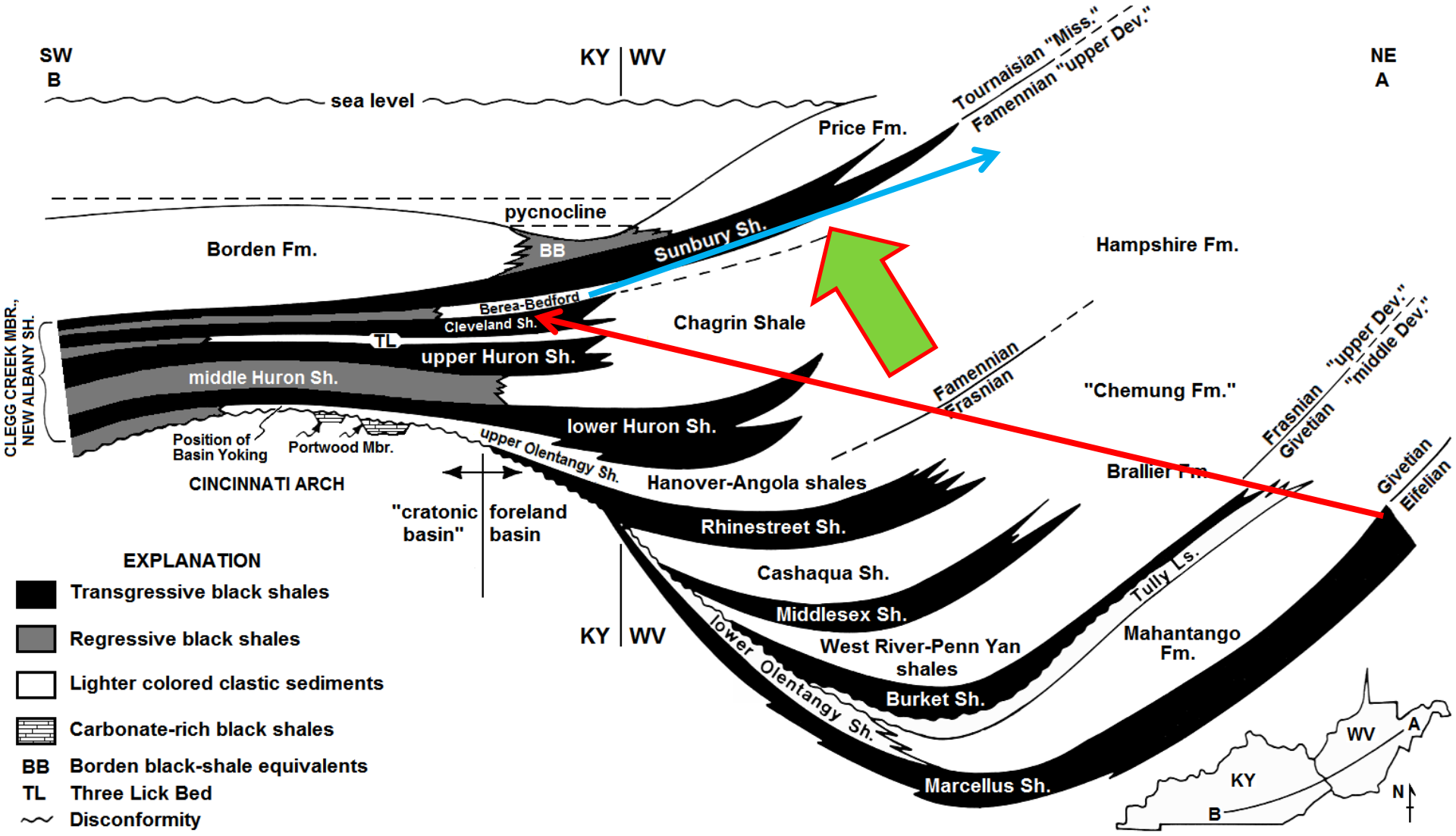
b. Drainage nets developed

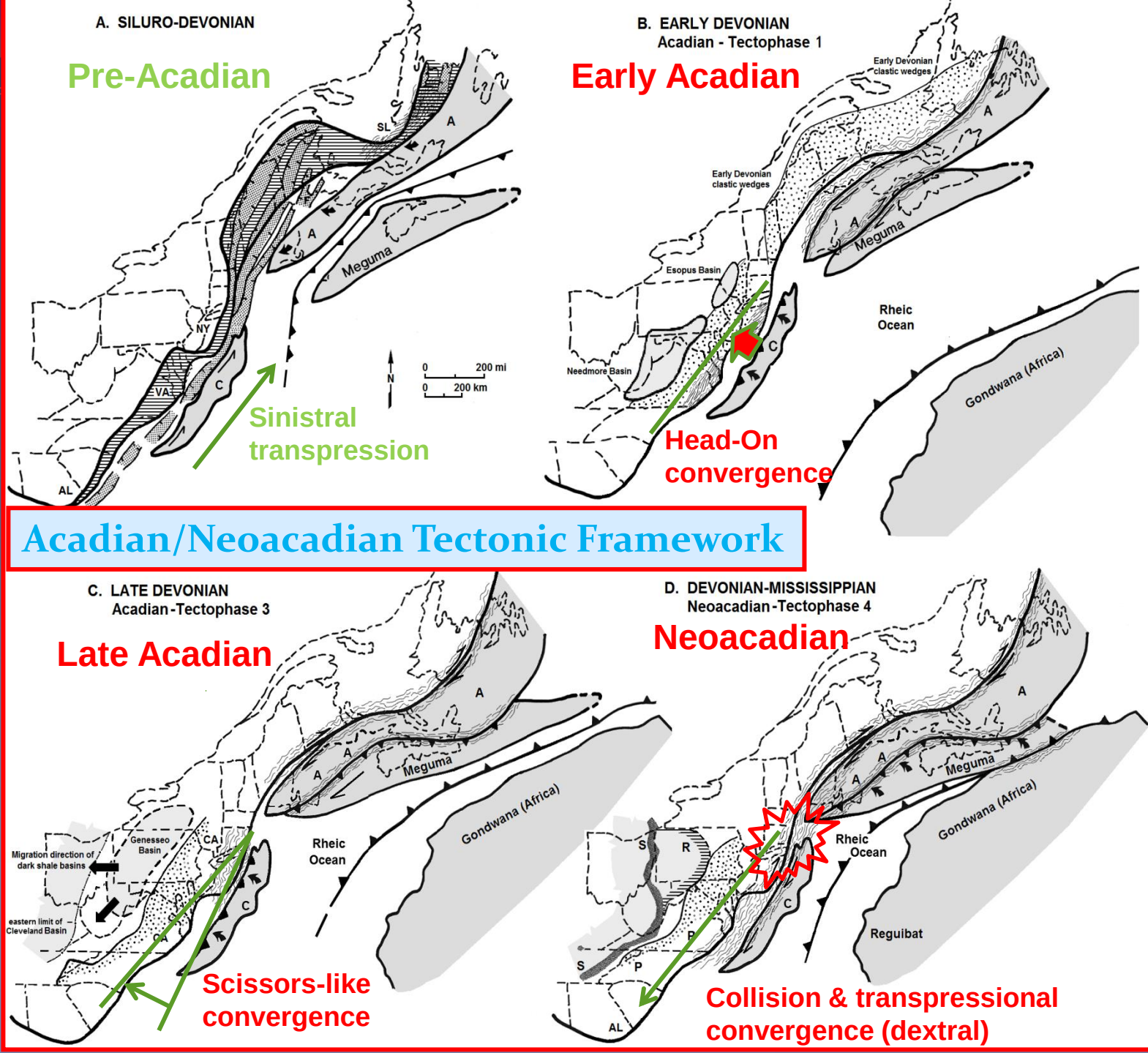
c.) Coarse-grained clastic influx into basin

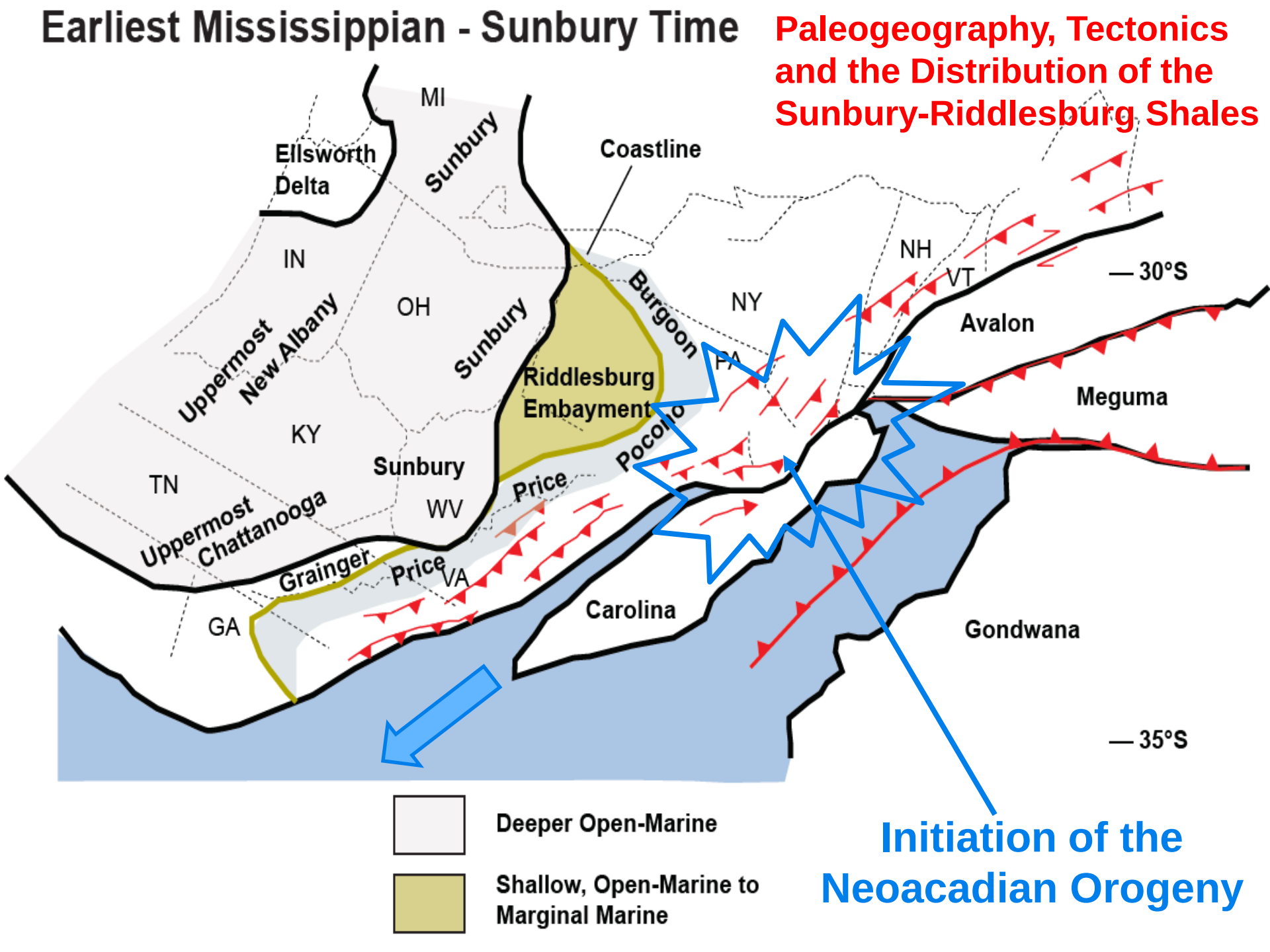
Acadian/Neoacadian (Devonian-Mississippian) stratigraphic sequence in the Appalachian foreland basin






SW
B
KY | WV
NE
A
sea level
Tournaisian "Miss."
Famennian "upper Dev."
Price Fm.
pycnocline
Borden Fm.
BB
Sunbury Sh.
Hampshire Fm.
Berea-Bedford
Cleveland Sh.
TL
upper Huron Sh.
middle Huron Sh.
lower Huron Sh.
CLEGG CREEK MBR.,
NEW ALBANY SH.
Chagrin Shale
Famennian
Frasnian
"Chemung Fm."
Frasnian
Givetian
"upper Dev."
"middle Dev."
Position of
Basin Yoking
Portwood Mbr.
upper Olentangy Sh.
Hanover-Angola shales
Brallier Fm.
Givetian
Eifelian
CINCINNATI ARCH
"cratonic basin"
foreland basin
Rhinestreet Sh.
Cashaqua Sh.
Middlesex Sh.
Tully Ls.
KY | WV
lower Olentangy Sh.
West River-Penn Yan shales
Mahantango Fm.
Burket Sh.
Marcellus Sh.
EXPLANATION
Transgressive black shales
Regressive black shales
Lighter colored clastic sediments
Carbonate-rich black shales
BB Borden black-shale equivalents
TL Three Lick Bed
Disconformity
WV
A
KY
B
N


A. SILURO-DEVONIAN
Pre-Acadian
SL
A
A
Meguma
NY
VA
C
AL
N
0 200 mi
0 200 km
Sinistral transpression
B. EARLY DEVONIAN
Acadian - Tectophase 1
Early Acadian
Early Devonian clastic wedges
Early Devonian clastic wedges
A
A
Meguma
Esopus Basin
Needmore Basin
C
Rheic Ocean
Gondwana (Africa)
Head-On convergence
Acadian/Neoacadian Tectonic Framework
C. LATE DEVONIAN
Acadian-Tectophase 3
Late Acadian
A
A
A
Meguma
Migration direction of dark shale basins
Genesseo Basin
CA
eastern limit of Cleveland Basin
C
Rheic Ocean
Gondwana (Africa)
Scissors-like convergence
D. DEVONIAN-MISSISSIPPIAN
Neoacadian-Tectophase 4
Neoacadian
A
A
A
Meguma
S
R
C
P
S
P
Rheic Ocean
Gondwana (Africa)
Reguibat
AL
Collision & transpressional convergence (dextral)


Earliest Mississippian - Sunbury Time
Paleogeography, Tectonics and the Distribution of the Sunbury-Riddlesburg Shales
MI
Ellsworth Delta
Sunbury
Coastline
IN
OH
Uppermost New Albany
Sunbury
Burgoon
NY
NH
VT
— 30°S
Avalon
PA
Riddlesburg Embayment
Meguma
KY
Sunbury
Pocono
TN
Uppermost Chattanooga
WV
Price
Grainger
Price
VA
Carolina
Gondwana
GA
— 35°S
Deeper Open-Marine
Shallow, Open-Marine to Marginal Marine
Initiation of the Neoacadian Orogeny

IV. Summary

- Sunbury black shales represent deeper-water, foreland-basin deposition during the Early Mississippian Neoacadian Orogeny.
- The shales are up to 90-ft thick in a north-south belt through eastern Ohio, western West Virginia and southwestern Virginia, which approximates the most actively subsiding parts of the Neoacadian foreland basin.
- Sunbury equivalents to the south and west are extremely thin and condensed, representing starved-basin sedimentation beyond the foreland-basin sink.
- To the northeast, the Sunbury grades into the clastic-rich and marginal-marine Riddlesburg Shale, which filled a subsiding embayment behind the new York promontory, the initial locus of Neoacadian convergence.
- The Sunbury Shale and its overlying clastic wedge (Borden-Grainger-Price-Pocono) represent the initial collision of Carolina at the New York Promontory and its subsequent southwestward transpressional collision with the southeastern margin of Laurussia.
- With TOC values up to 20%, the Sunbury might be a viable unconventional resource, but probably only in an area near the junction of Kentucky, West Virginia and Virginia, where thicknesses are sufficient.