Early Post-Depositional Bedding-Plane-Parallel Melanges Created by Shear and Liquefaction: A Common but Largely Misinterpreted Organic-Rich Mudrock Facies

Paul E. Olsen
Sean T. Kinney

September 26, 2016

How they were first found

Summary of conclusions

Examples

Summary of key observations and patterns

Possible processes

Conclusions

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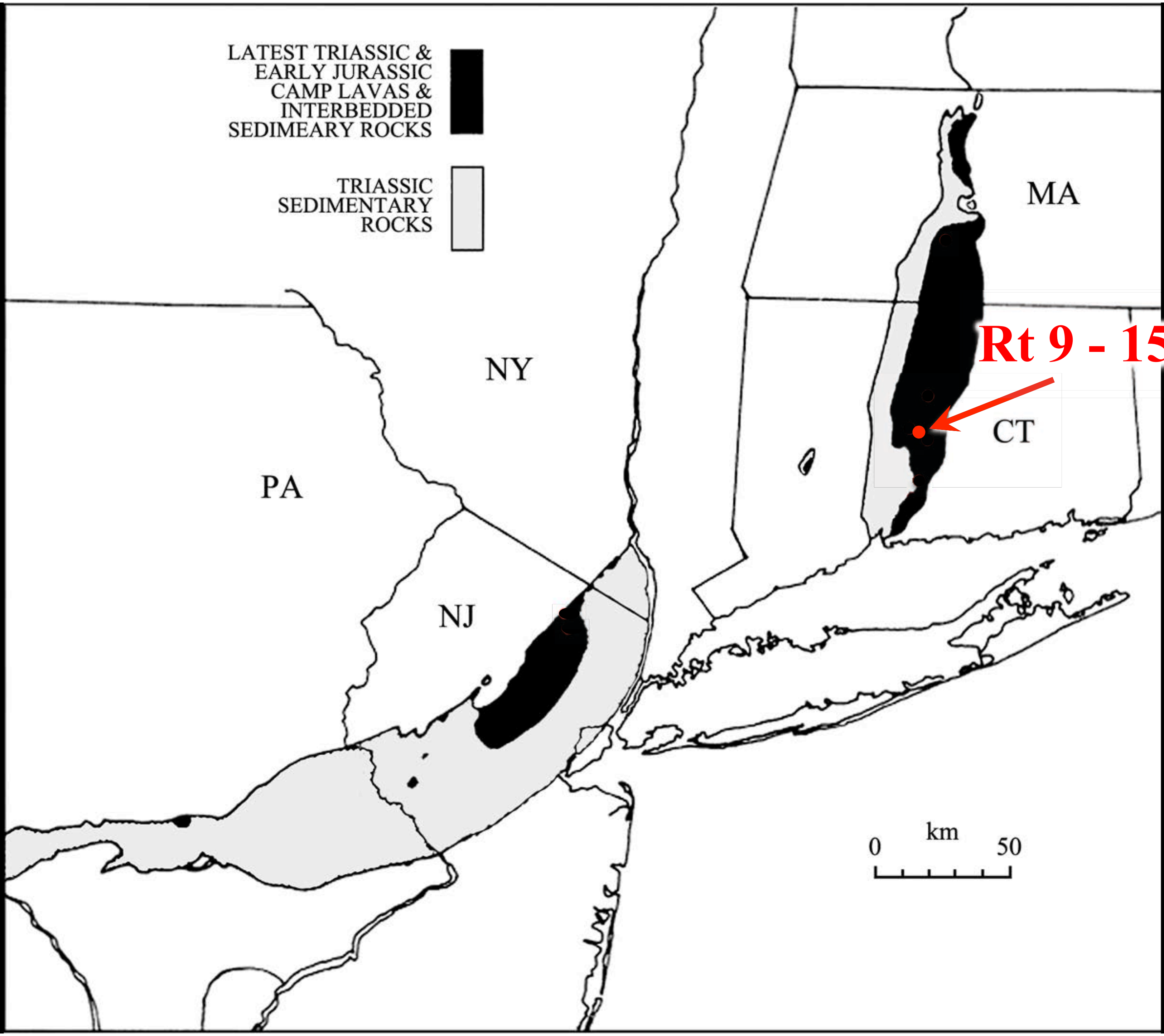

LATEST TRIASSIC & EARLY JURASSIC CAMP LAVAS & INTERBEDDED SEDIMEARY ROCKS
TRIASSIC SEDIMENTARY ROCKS
MA
NY
PA
NJ
CT
Rt 9 - 15
0
km
50

Hartford Basin

Early Jurassic, East Berlin Formation

Semionotus sp.

N.G. McDonald collection

Westfield Bed, East Berlin, CT


1 cm

Olsen et al., 1989

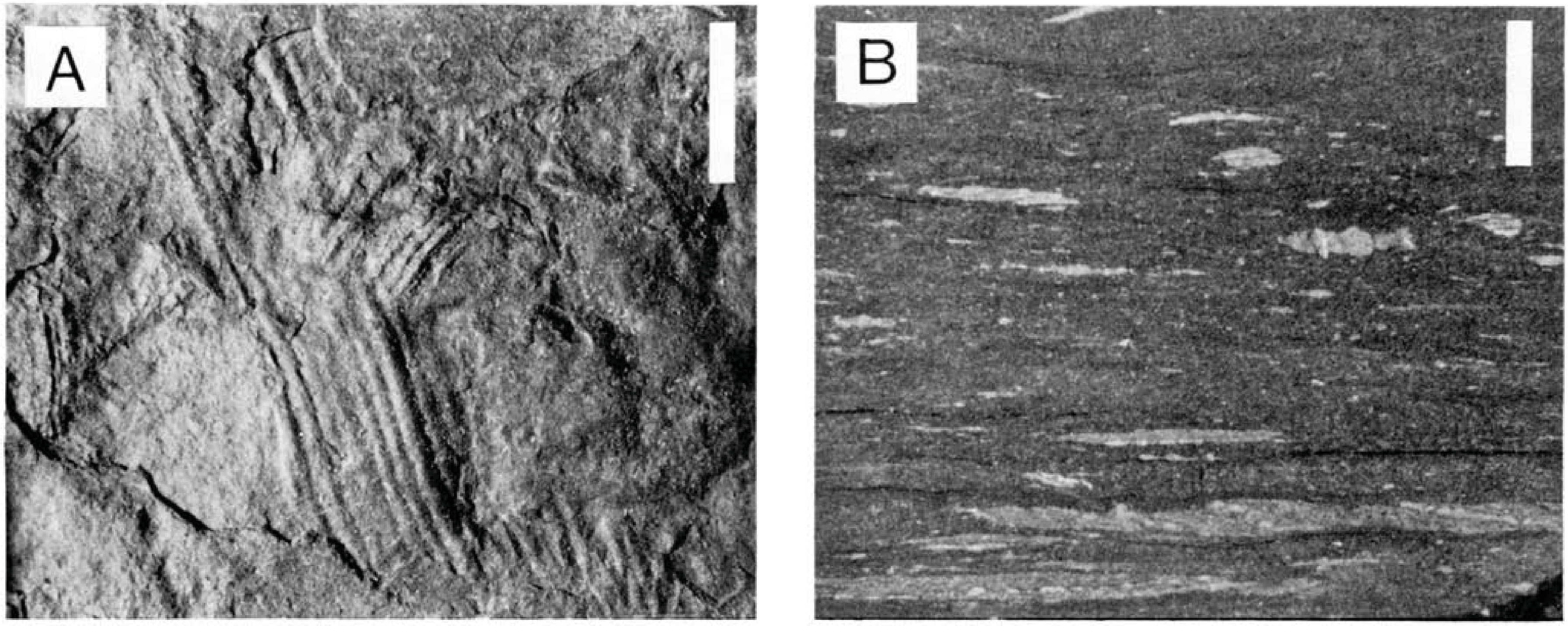

Figure 7.6: "Dead horses" from laminated siltstones at Stop 7.2: A) plan view (scale bar is 2 cm); B) cross-section in which the carbonate-rich "dead horses" show up as the lighter patches with oblique lamination (scale bar is 1 cm). Photo by P.E. Olsen.

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Organic-rich massive mudstone matrix suggests partial liquefaction accompanied by bedding-parallel shear that produced largely rhombic clasts of more competent lithogies from the base and roof exhibiting both brittle and ductile features.

Process occurred early in compaction and presumably early in the sediment history.

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4) Triassic Lockatong Formation

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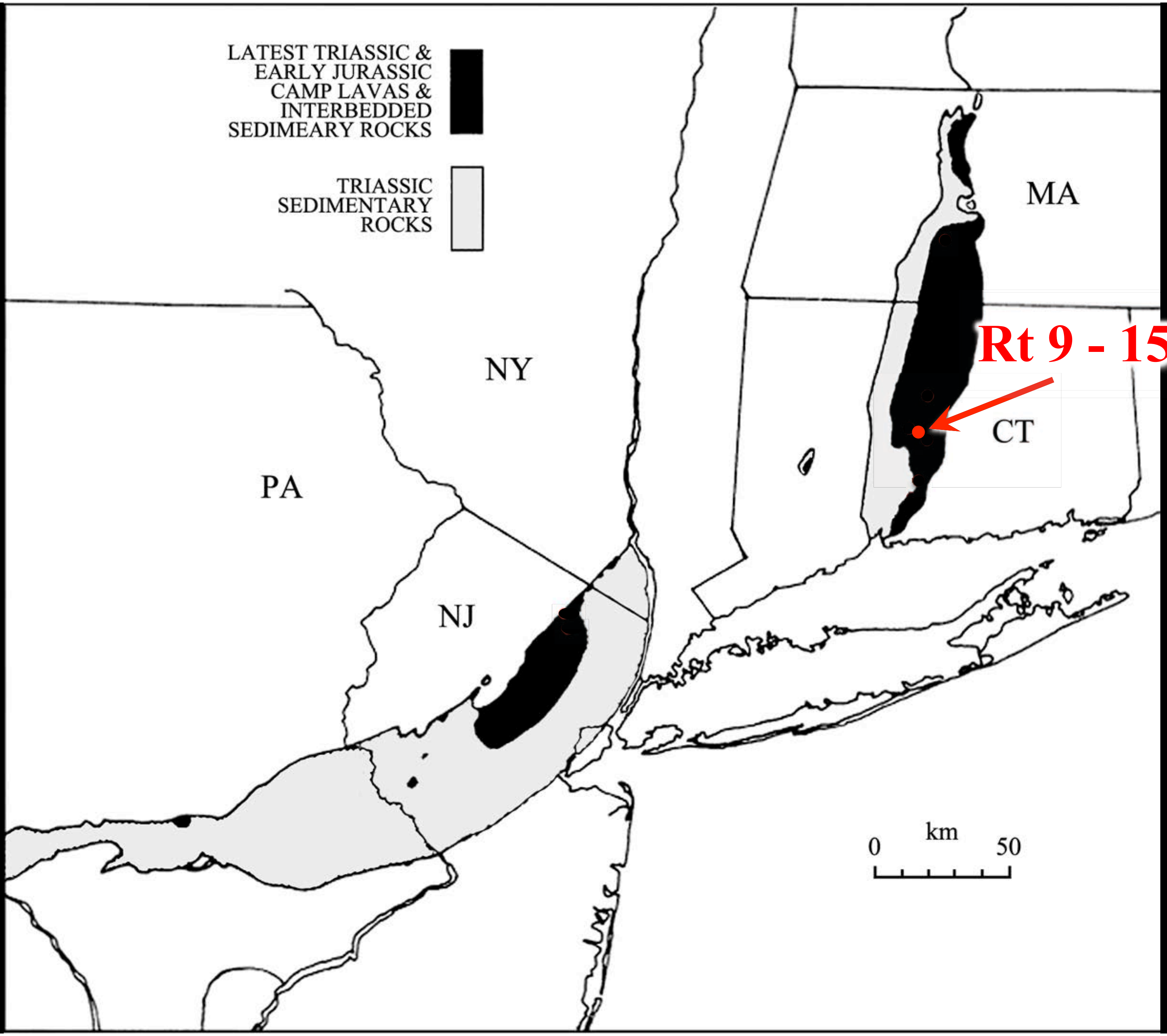
LATEST TRIASSIC &
EARLY JURASSIC
CAMP LAVAS &
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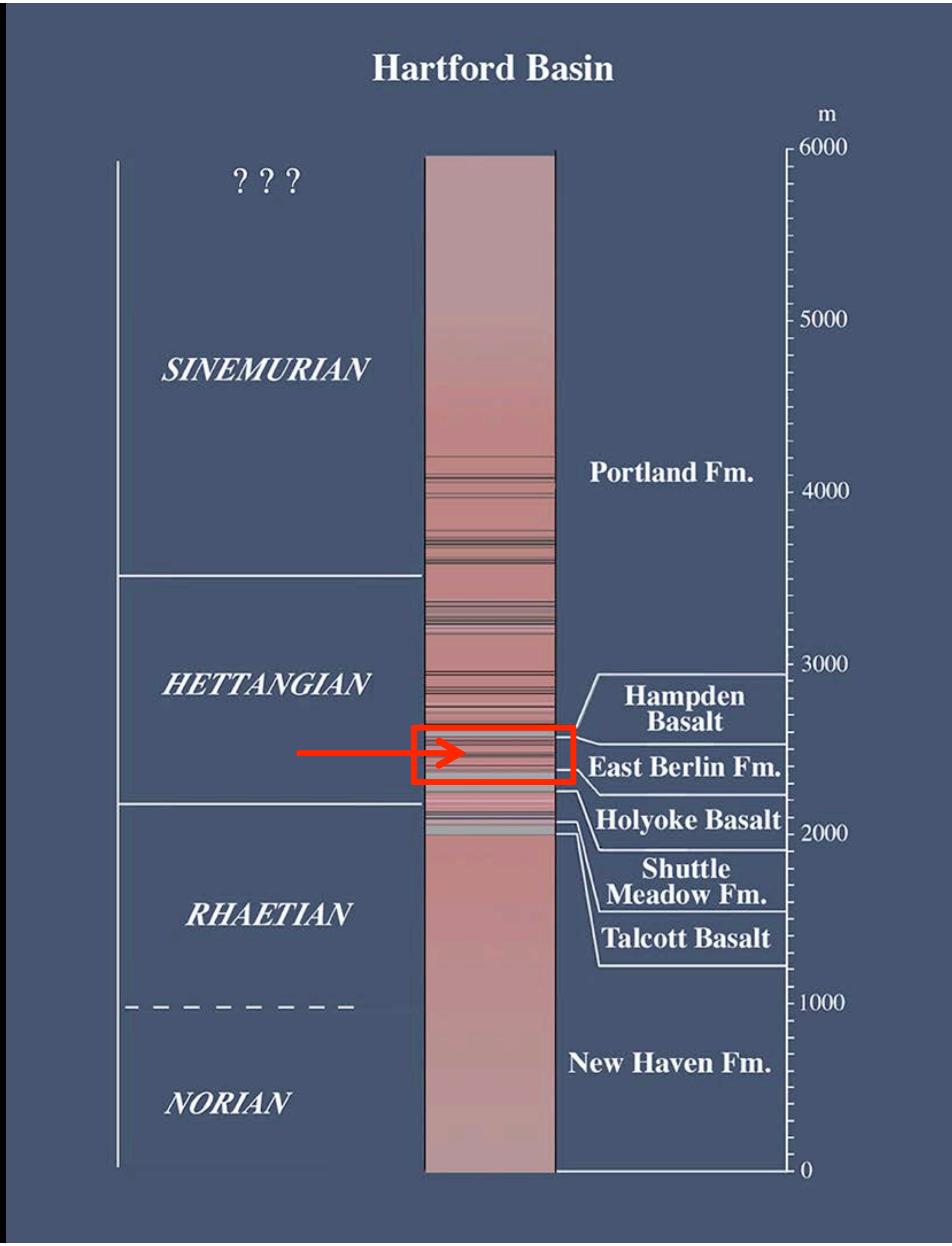
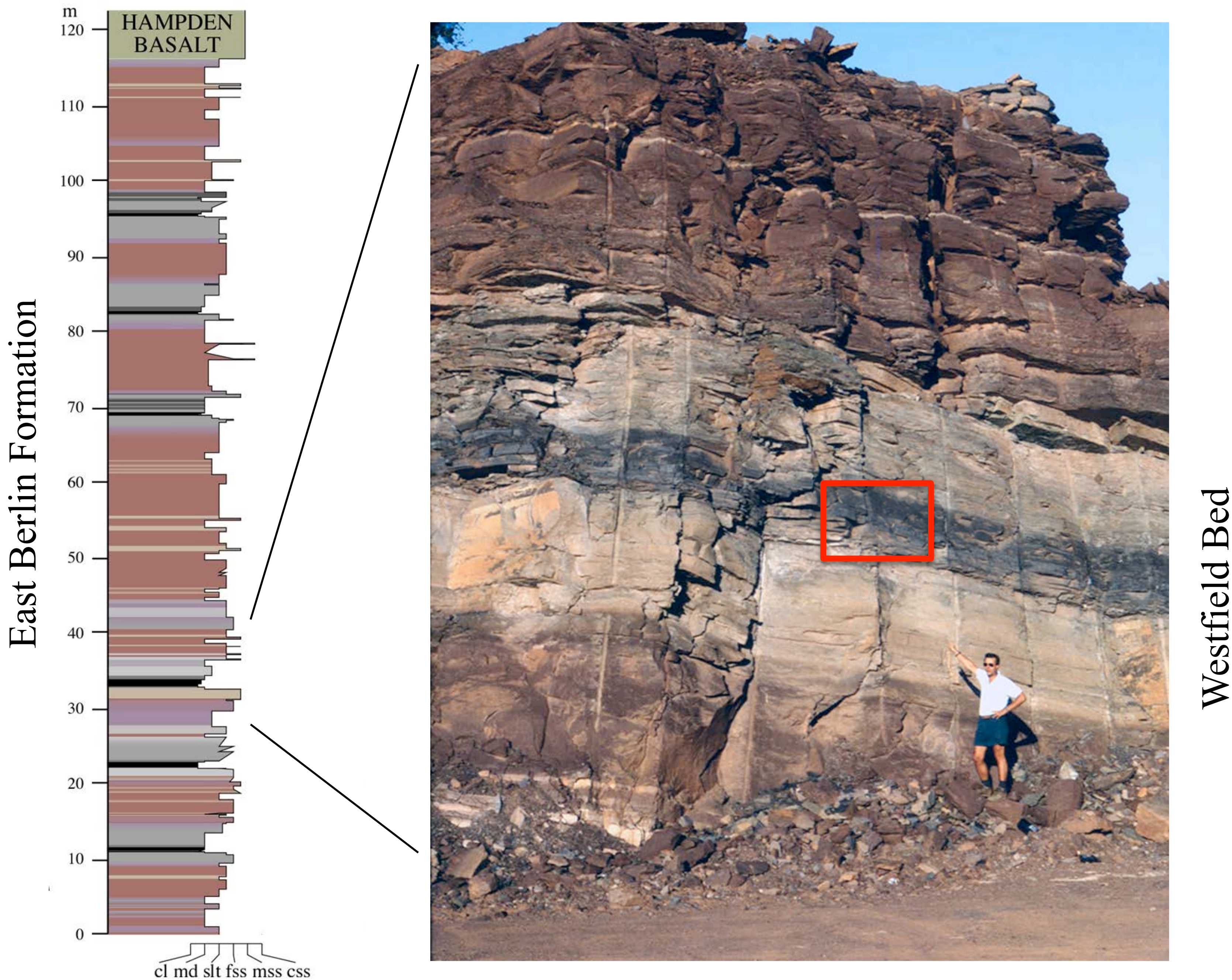
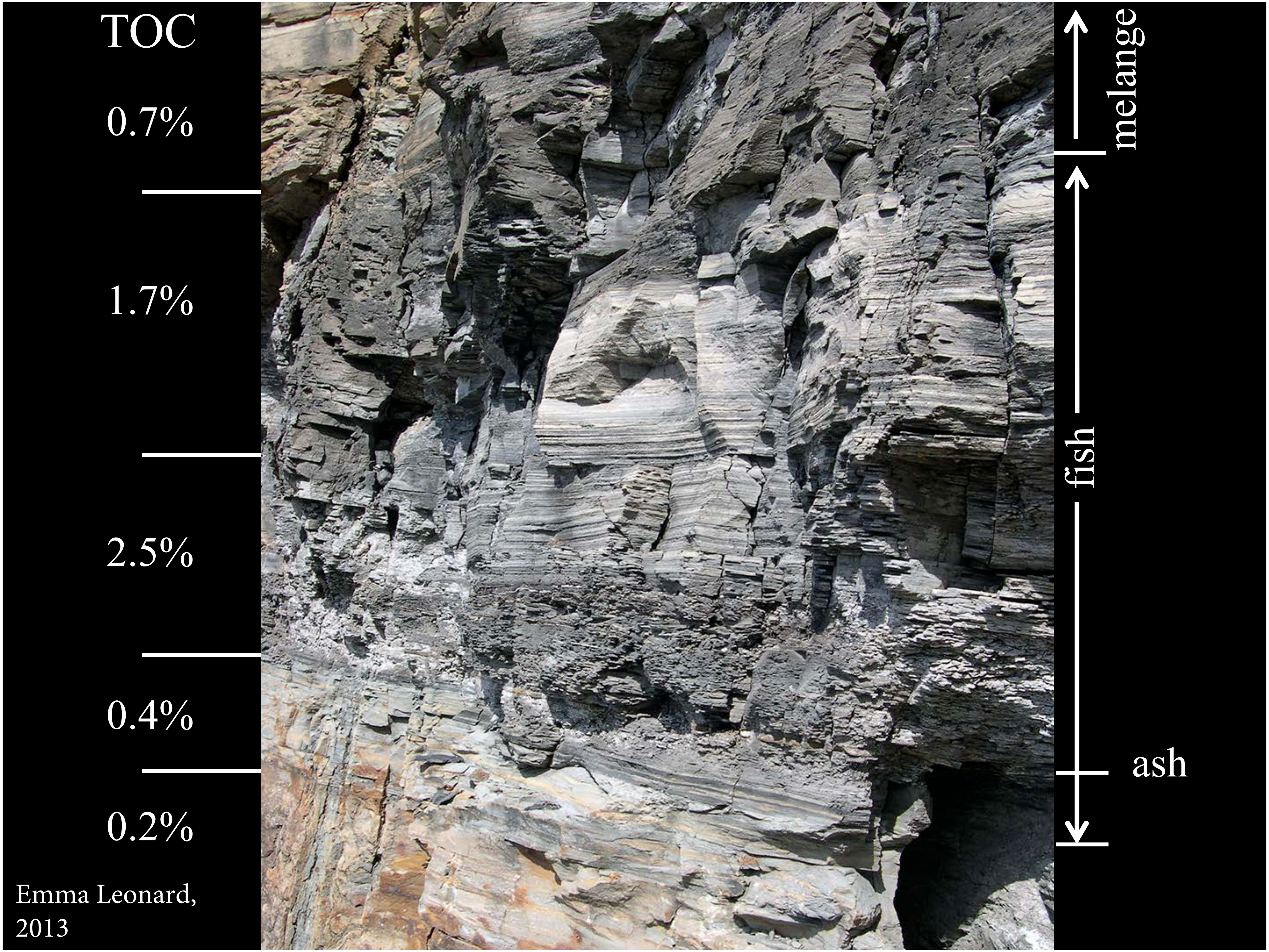
50



Hartford Basin
m
6000
5000
4000
3000
2000
1000
0
? ? ?
SINEMURIAN
HETTANGIAN
RHAETIAN
NORIAN
Portland Fm.
Hampden Basalt
East Berlin Fm.
Holyoke Basalt
Shuttle Meadow Fm.
Talcott Basalt
New Haven Fm.


East Berlin Formation
m
120
110
100
90
80
70
60
50
40
30
20
10
0
HAMPDEN
BASALT
cl md slt fss mss css
Westfield Bed



TOC
0.7%
1.7%
2.5%
0.4%
0.2%
Emma Leonard,
2013
melange
fish
ash

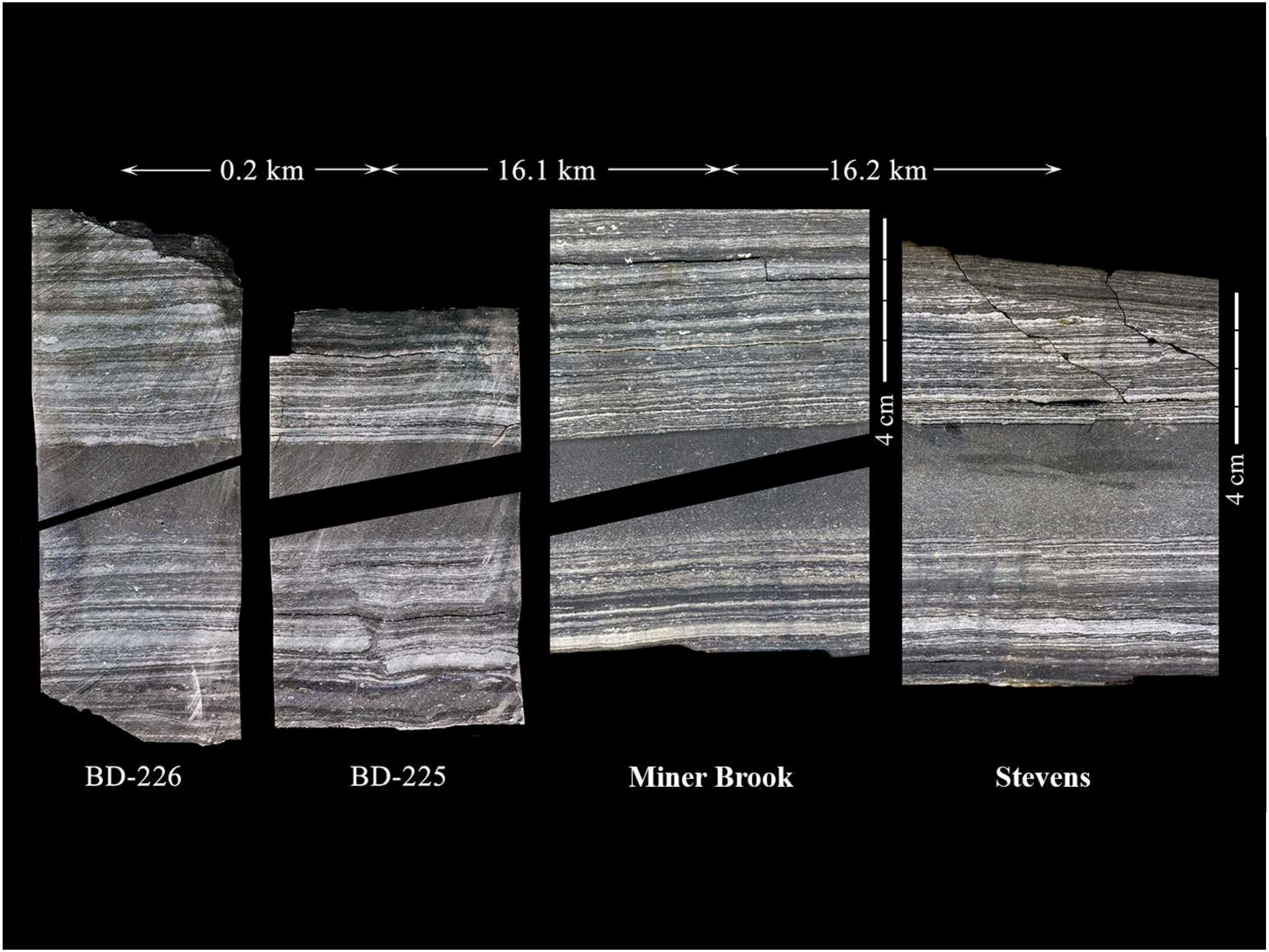
Redfieldius sp.

Westfield Bed, East Berlin, CT

N.G. McDonald collection

Rt 9, East Berlin Formation

Pompton Tuff, Westfield Fish Bed

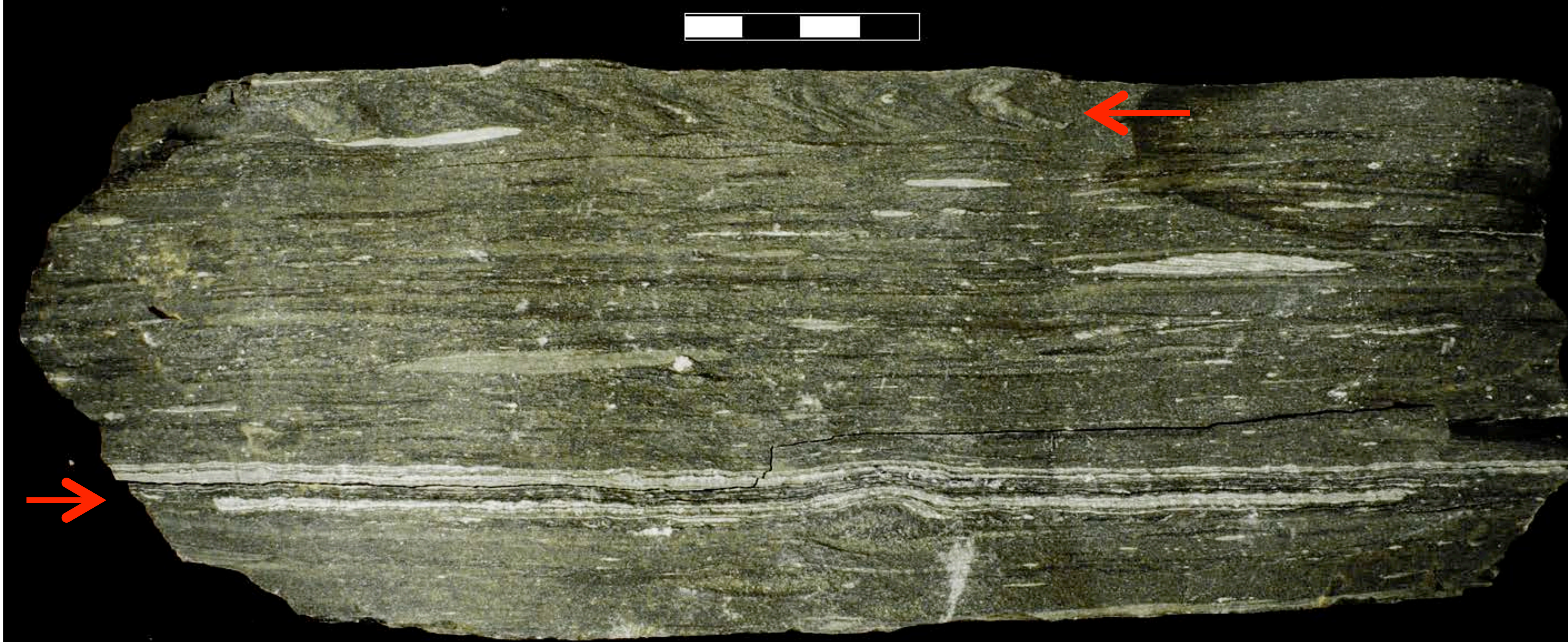


0.2 km
16.1 km
16.2 km
4 cm
4 cm
BD-226
BD-225
Miner Brook
Stevens


STANLEY

East Berlin Fm., East Berlin, CT

Slab cut perpendicular to bedding



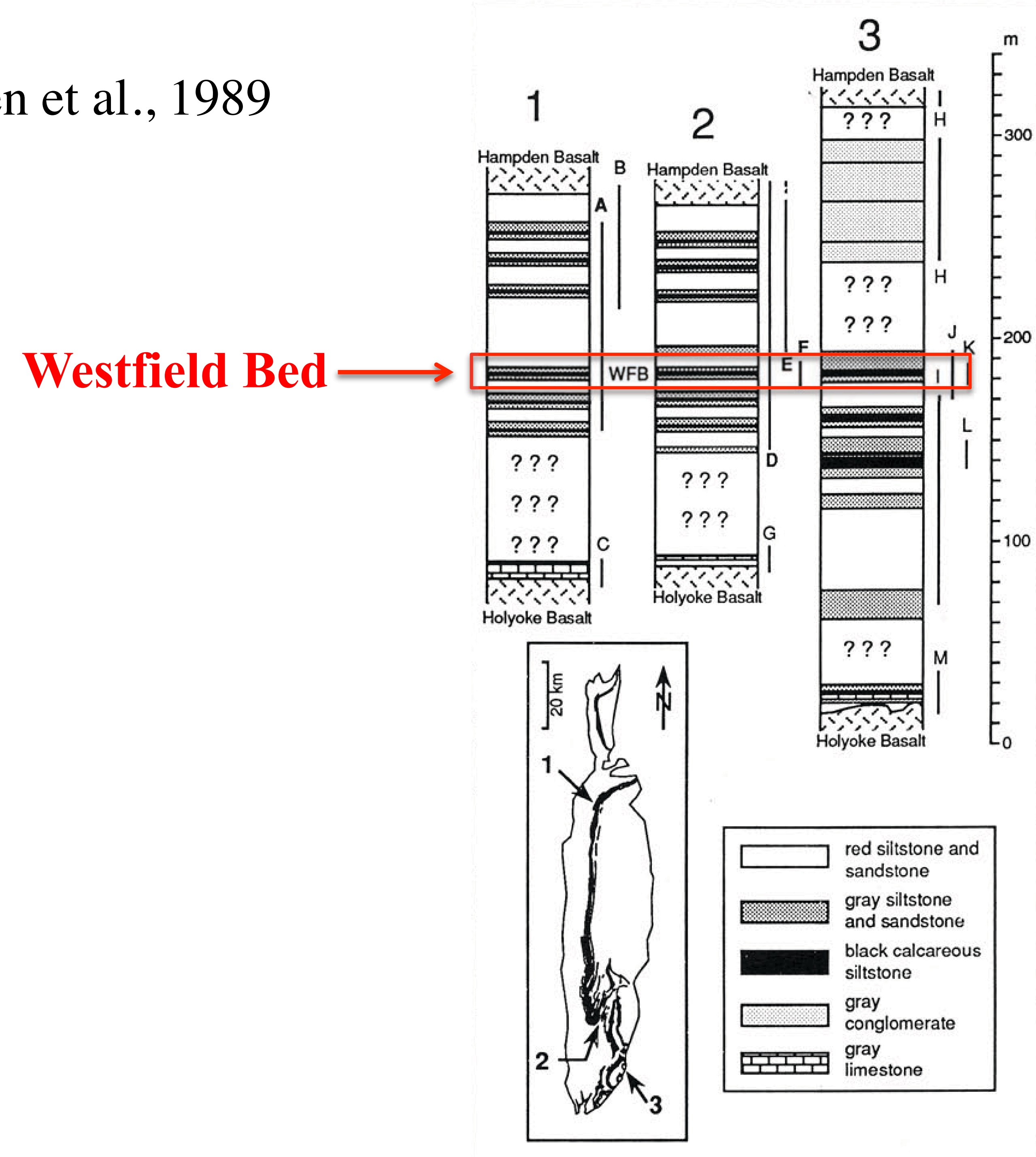
East Berlin Fm., East Berlin, CT

Large clasts

East Berlin Fm., East Berlin, CT


outcrop uppermost cycle
East Berlin Fm., East Berlin, CT

Olsen et al., 1989



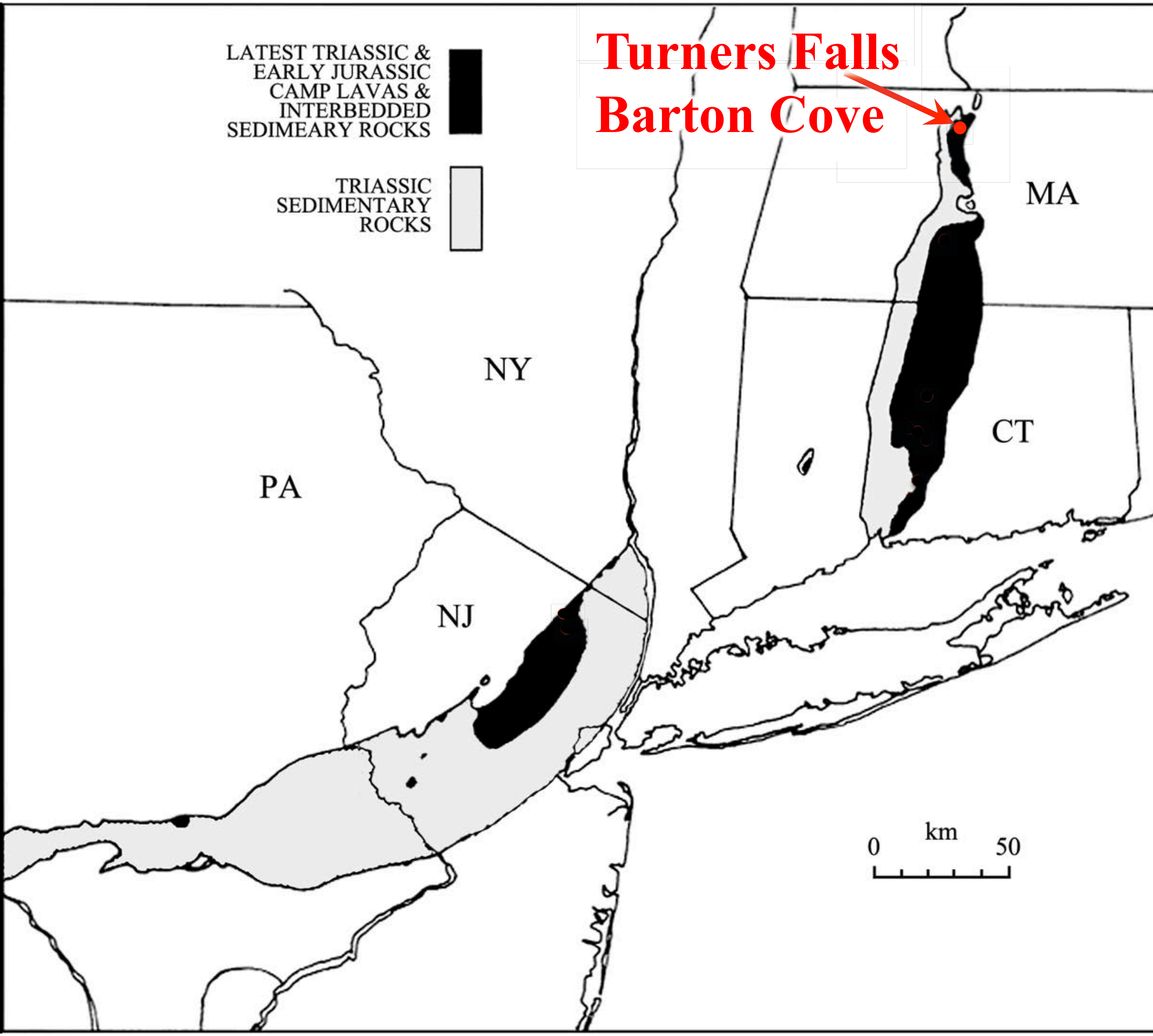
Recumbent Fold

Westfield Bed, East Berlin Fm., North Branford, CT

Semionotus sp.

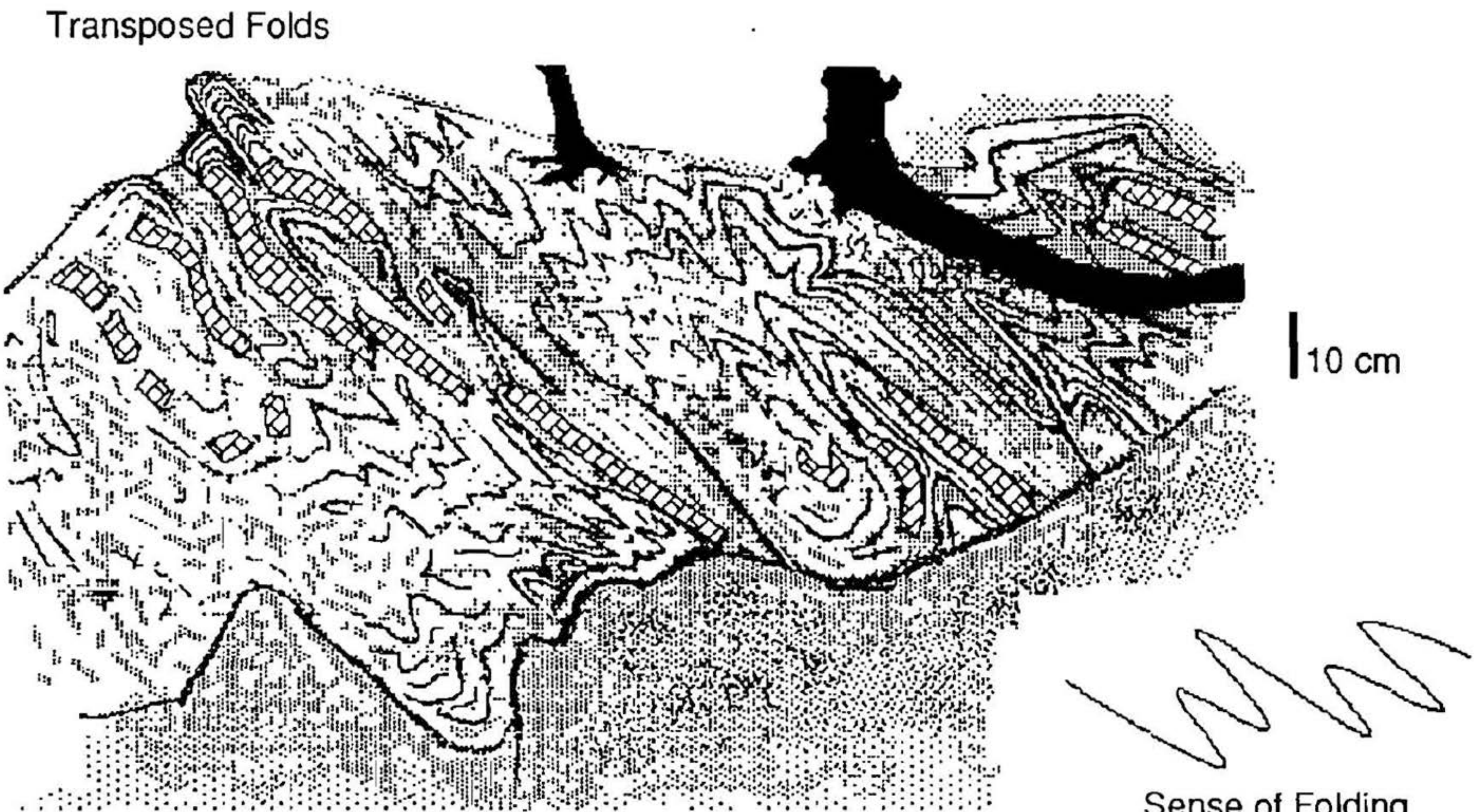
Westfield Bed, North Branford, CT

N.G. McDonald collection


Turners Falls
Barton Cove
LATEST TRIASSIC & EARLY JURASSIC CAMP LAVAS & INTERBEDDED SEDIMEARY ROCKS
TRIASSIC SEDIMENTARY ROCKS
MA
NY
CT
PA
NJ
0
km
50

Transposed folds, Turners Falls Fish Bed, Turners Falls, MA

Fold Breccia
Barton Cove, Gill, MA



Olsen et al., 1992

Examples

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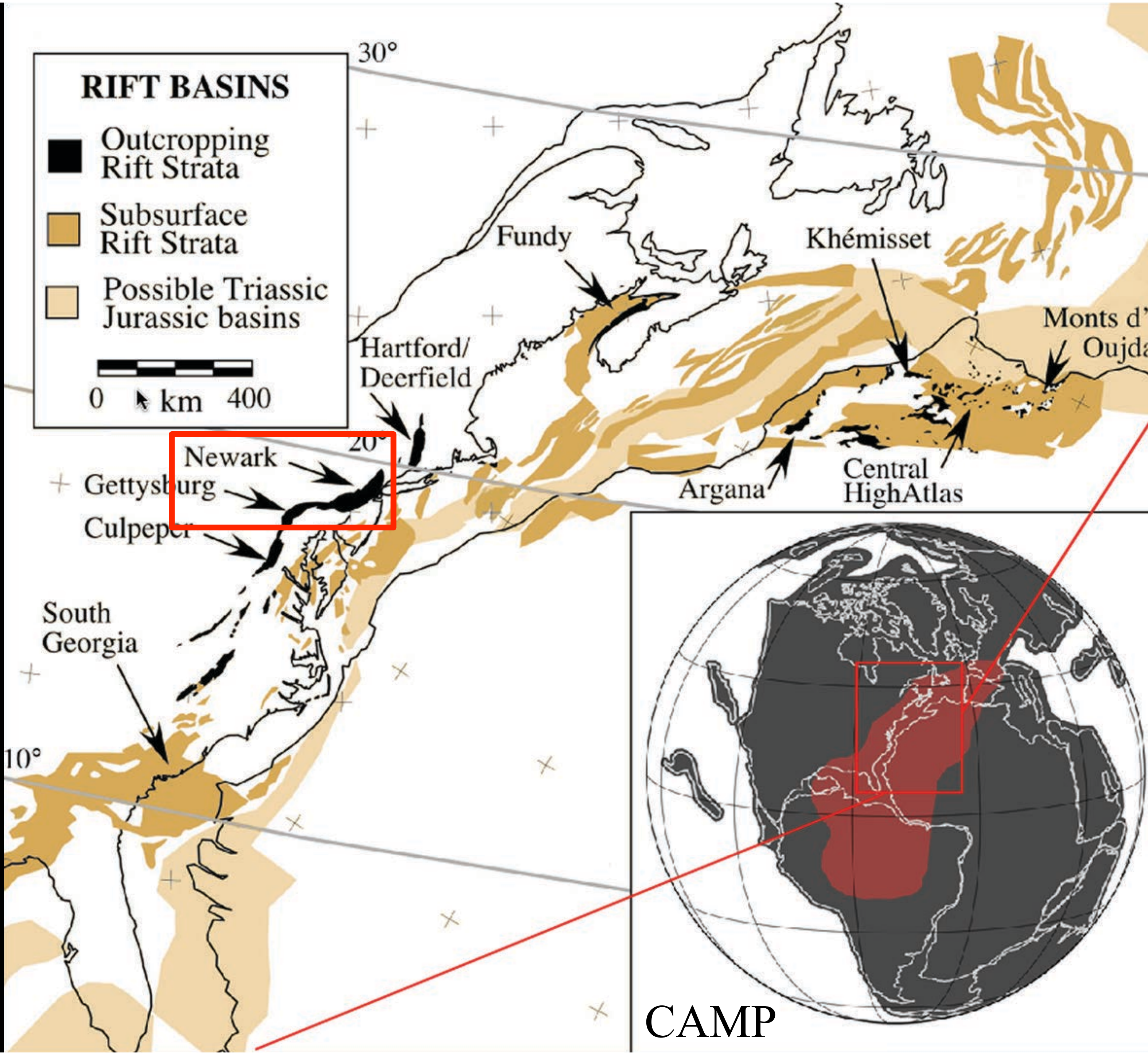
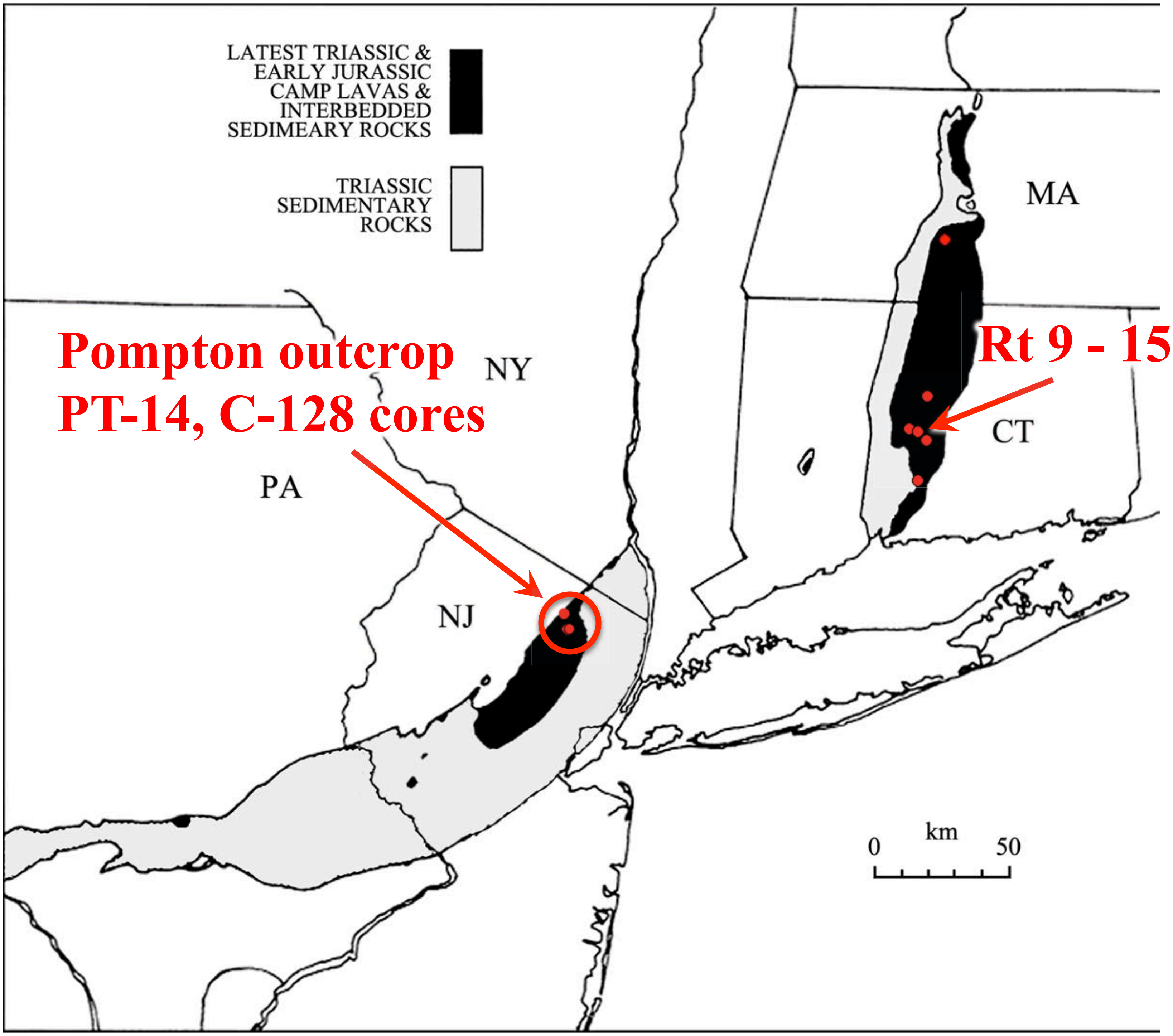
3) Triassic Feltville Formation

4) Triassic Lockatong Formation

5) Eocene Green River Formation

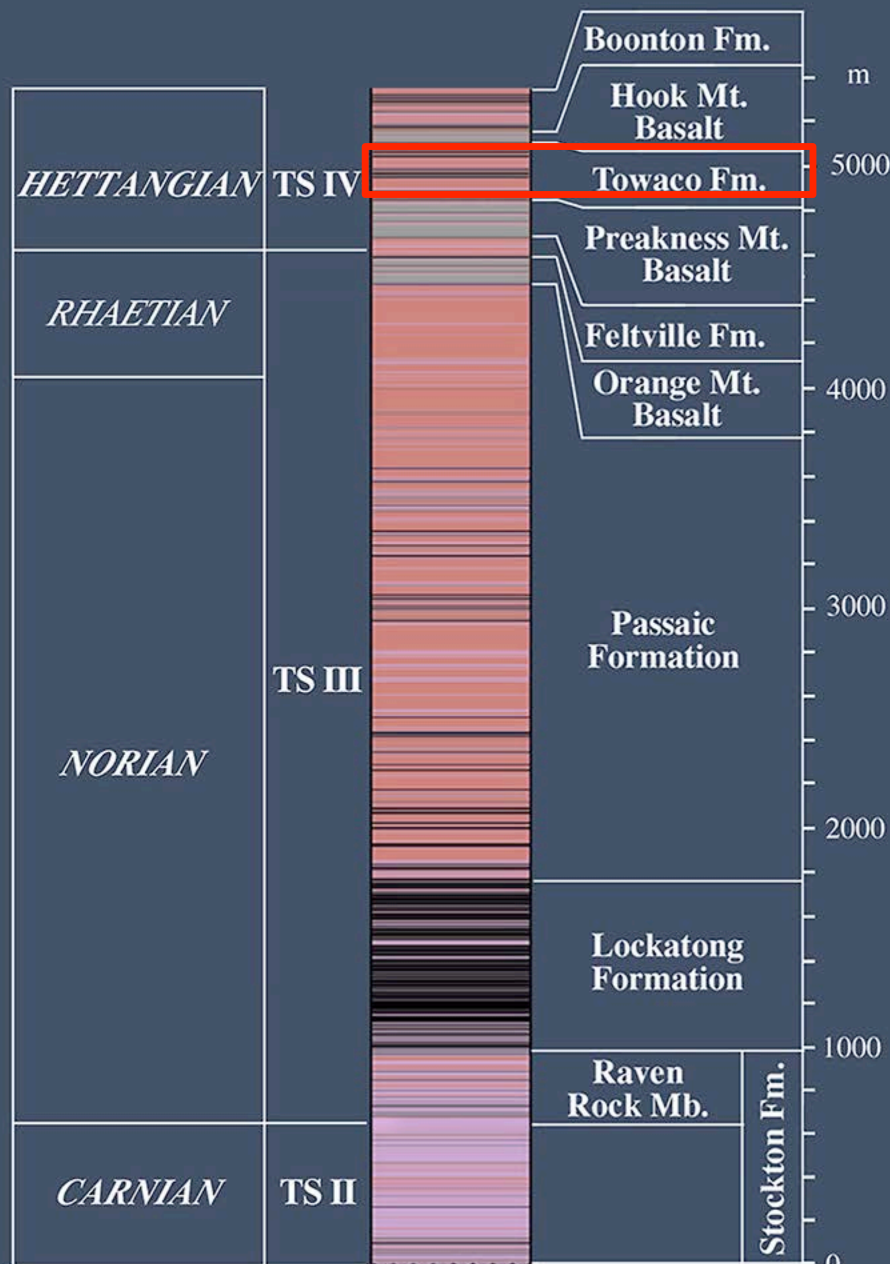


RIFT BASINS
Outcropping Rift Strata
Subsurface Rift Strata
Possible Triassic Jurassic basins
0 km 400
30°
20°
10°
Fundy
Hartford/ Deerfield
Newark
Gettysburg
Culpeper
South Georgia
Khémisset
Monts d' Oujda
Argana
Central HighAtlas
CAMP

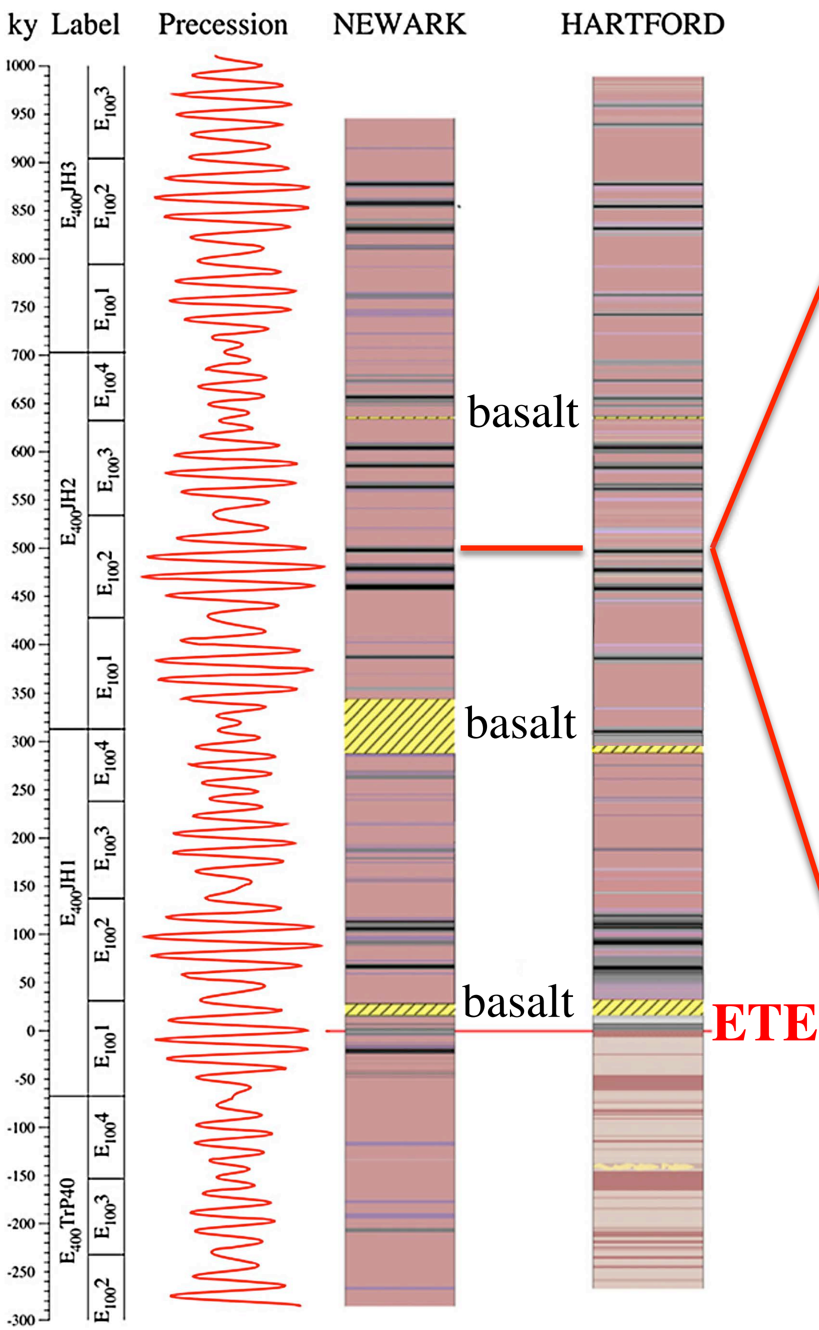


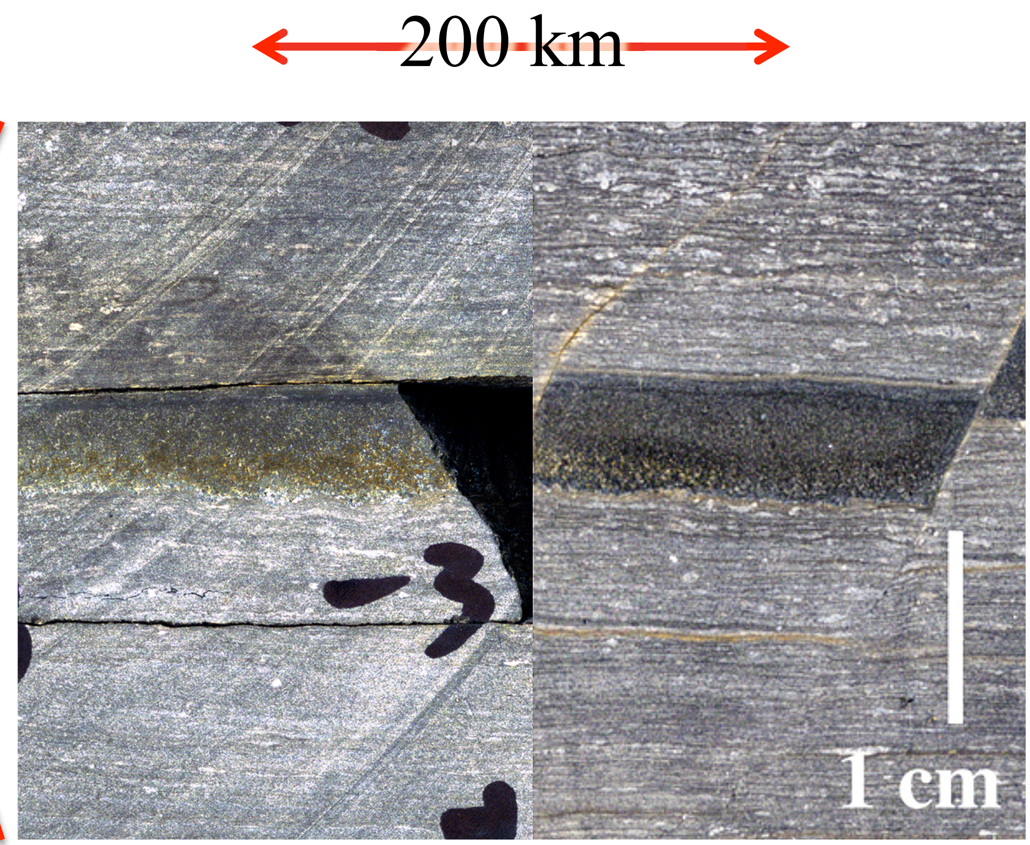
LATEST TRIASSIC & EARLY JURASSIC CAMP LAVAS & INTERBEDDED SEDIMEARY ROCKS
TRIASSIC SEDIMENTARY ROCKS
MA
NY
PA
NJ
CT
Pompton outcrop
PT-14, C-128 cores
Rt 9 - 15
0
km
50

Newark Basin



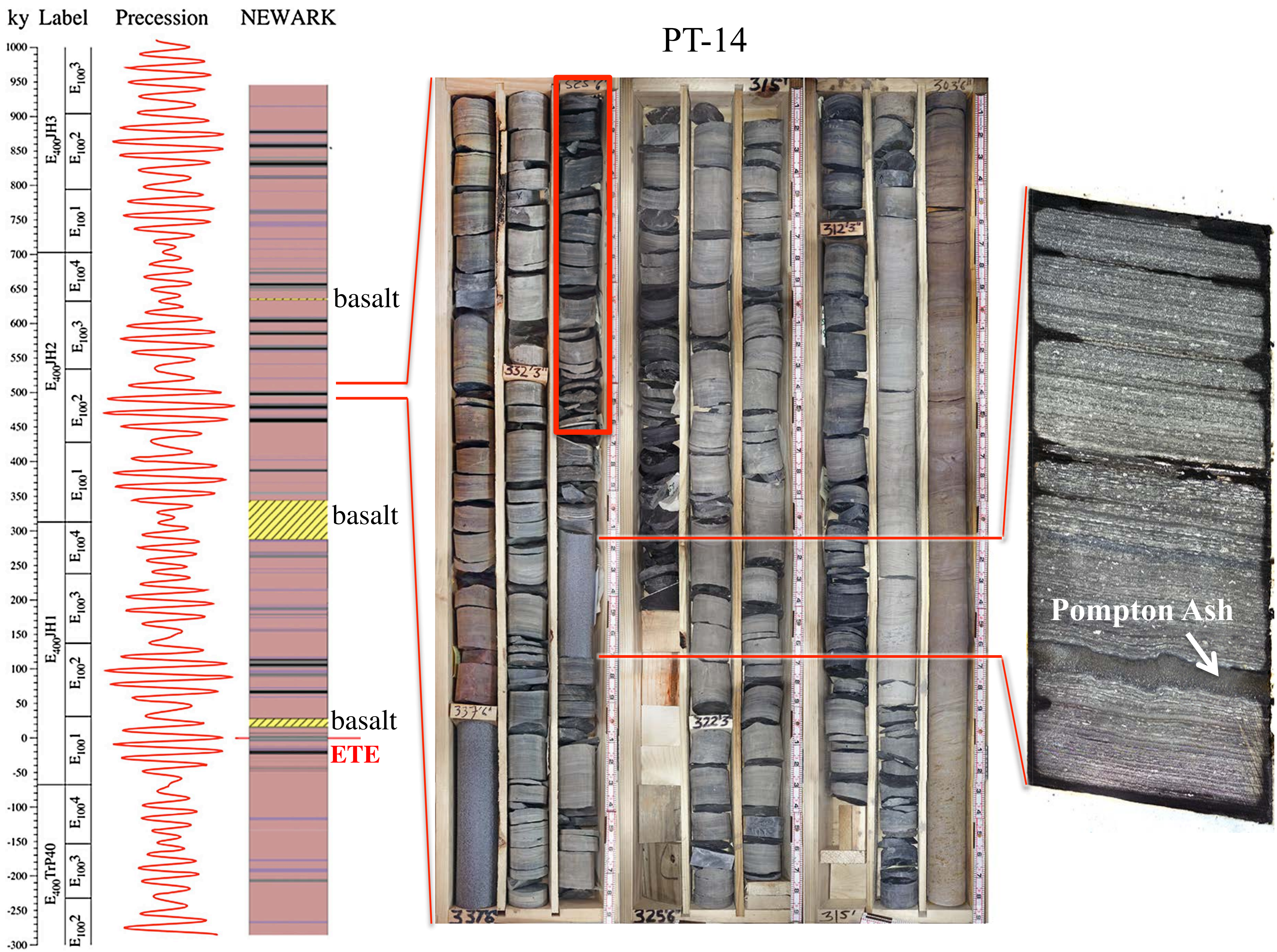
20°-21° N: Newark and Hartford Basins, Eastern US





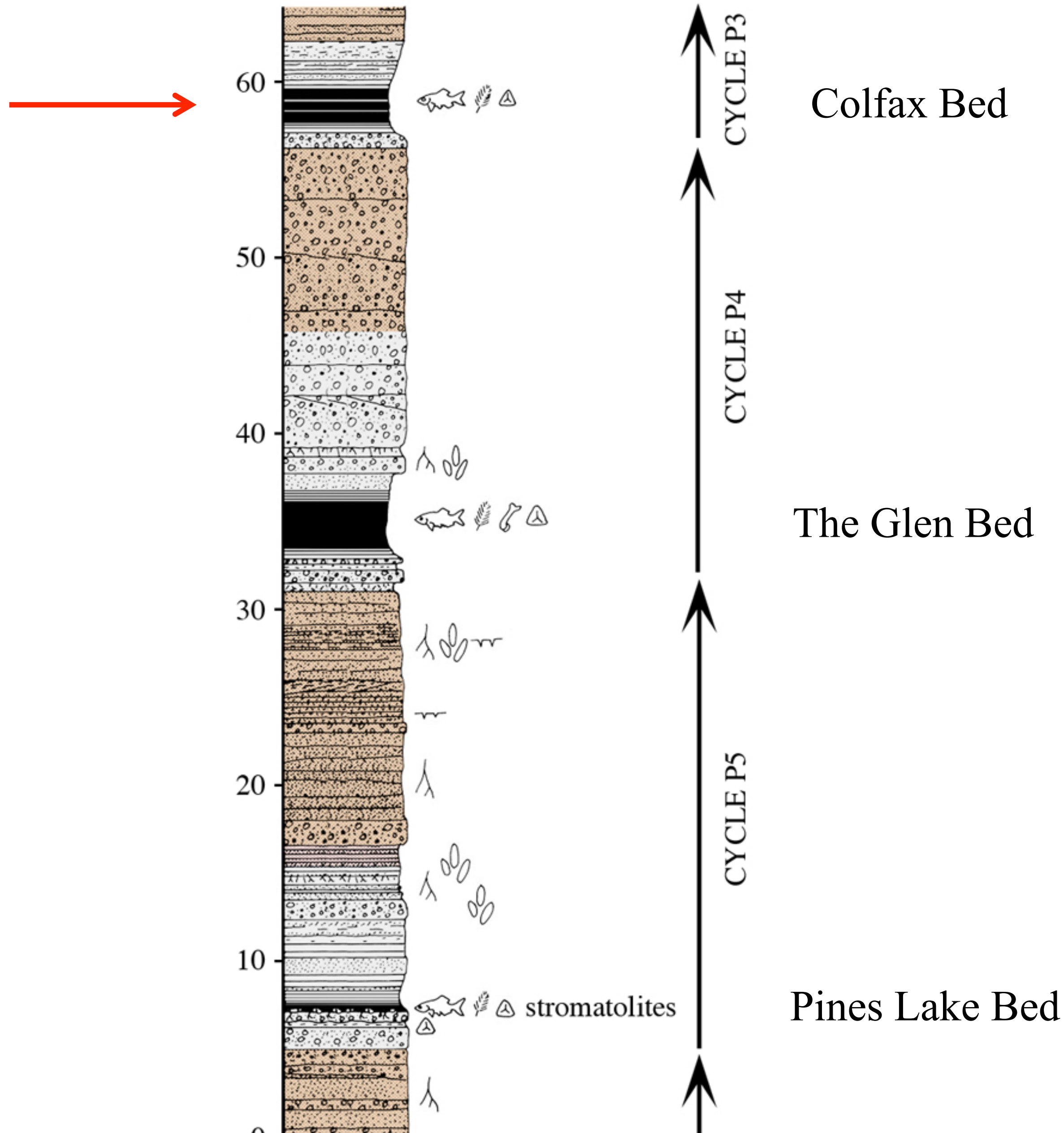
Towaco Fm. C-128 Core
Newark Basin

East Berlin Fm., Stevens
Hartford Basin



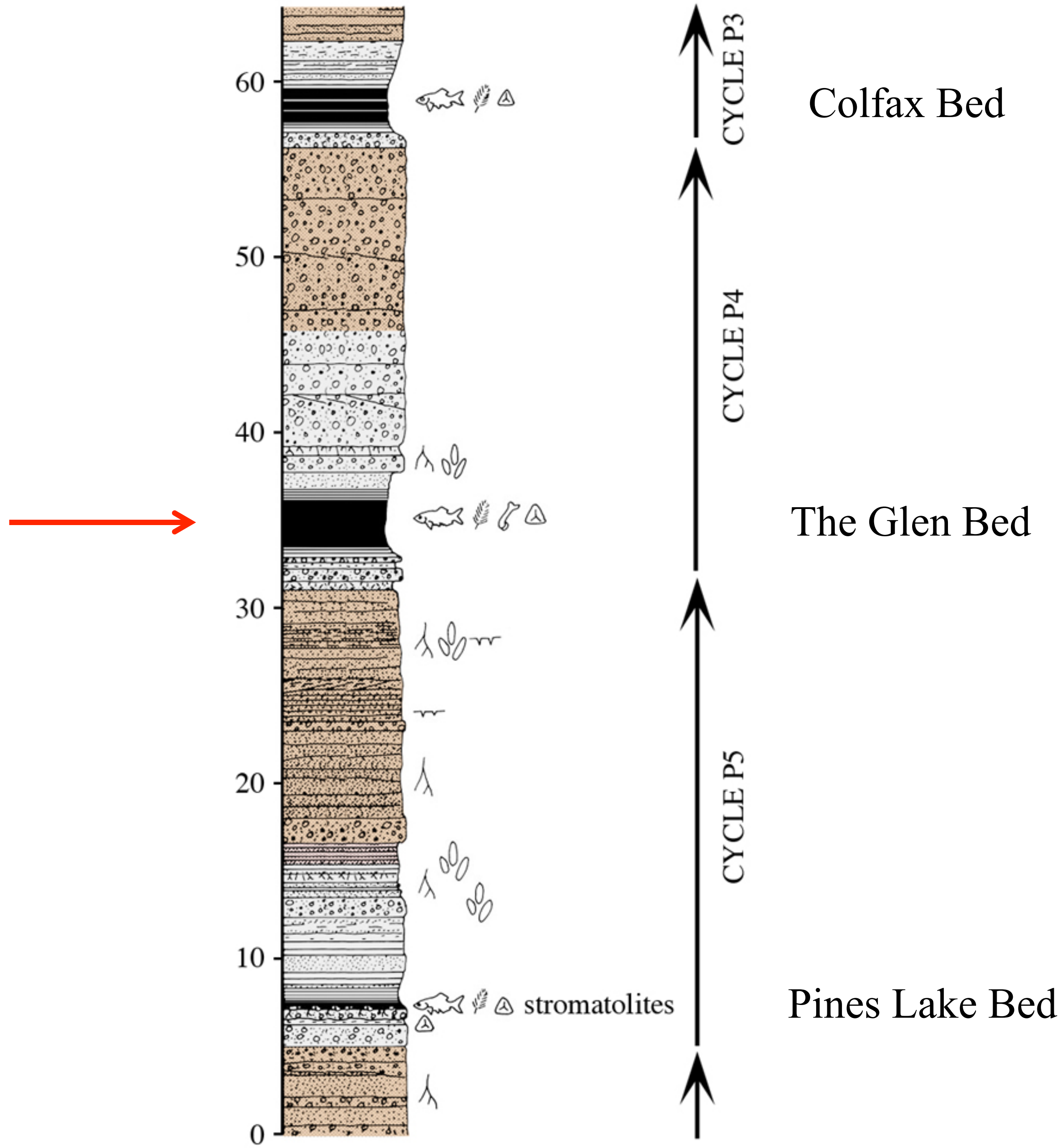
ky
Label
Precession
NEWARK
PT-14
1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
E400JH3
E400JH2
E400JH1
E400TrP40
basalt
basalt
basalt
ETE
Pompton Ash

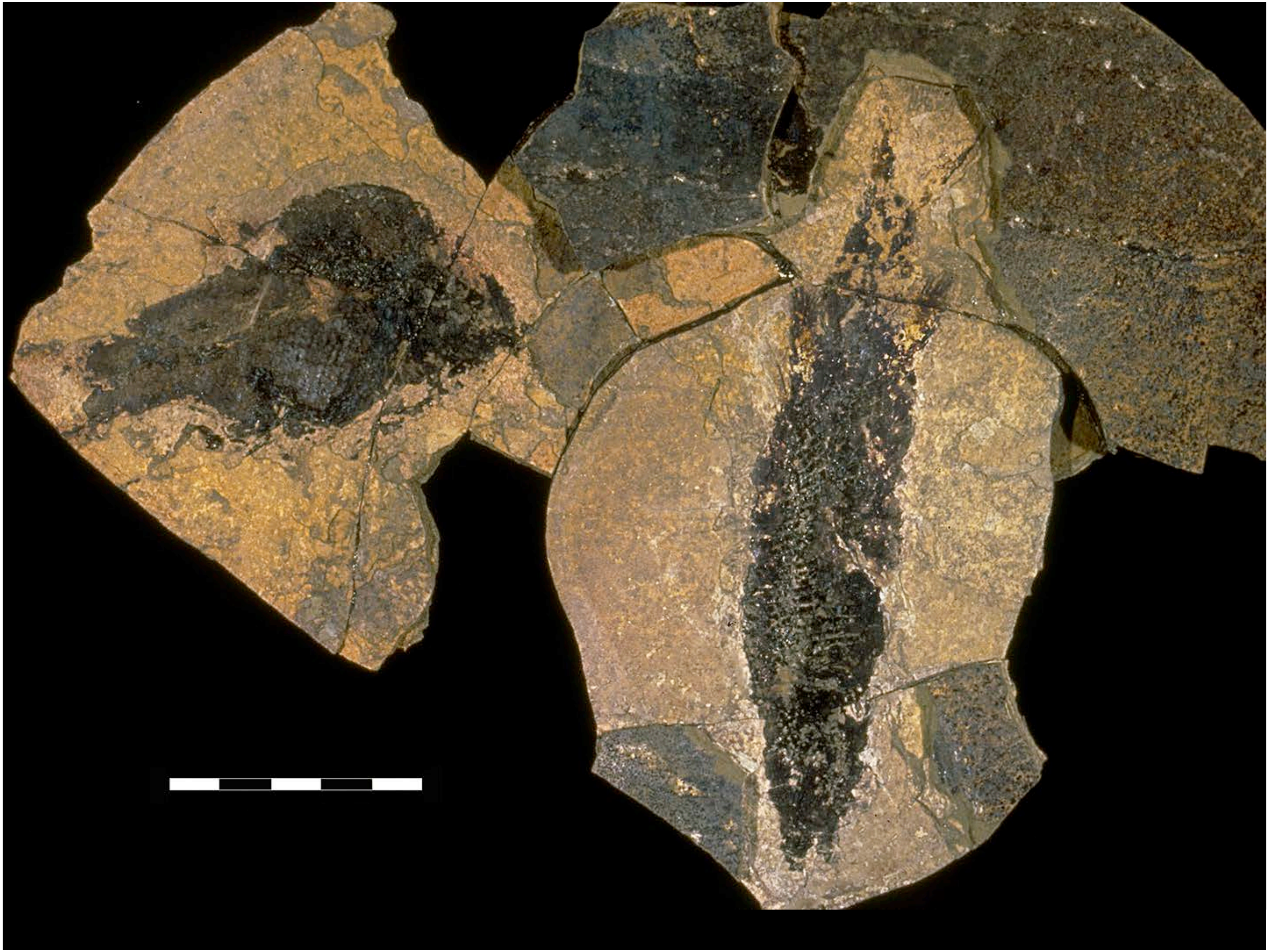
Section at Pompton, Middle Towaco Formation




Pompton Tuff at Pompton, NJ

Section at Pompton, Middle Towaco Formation





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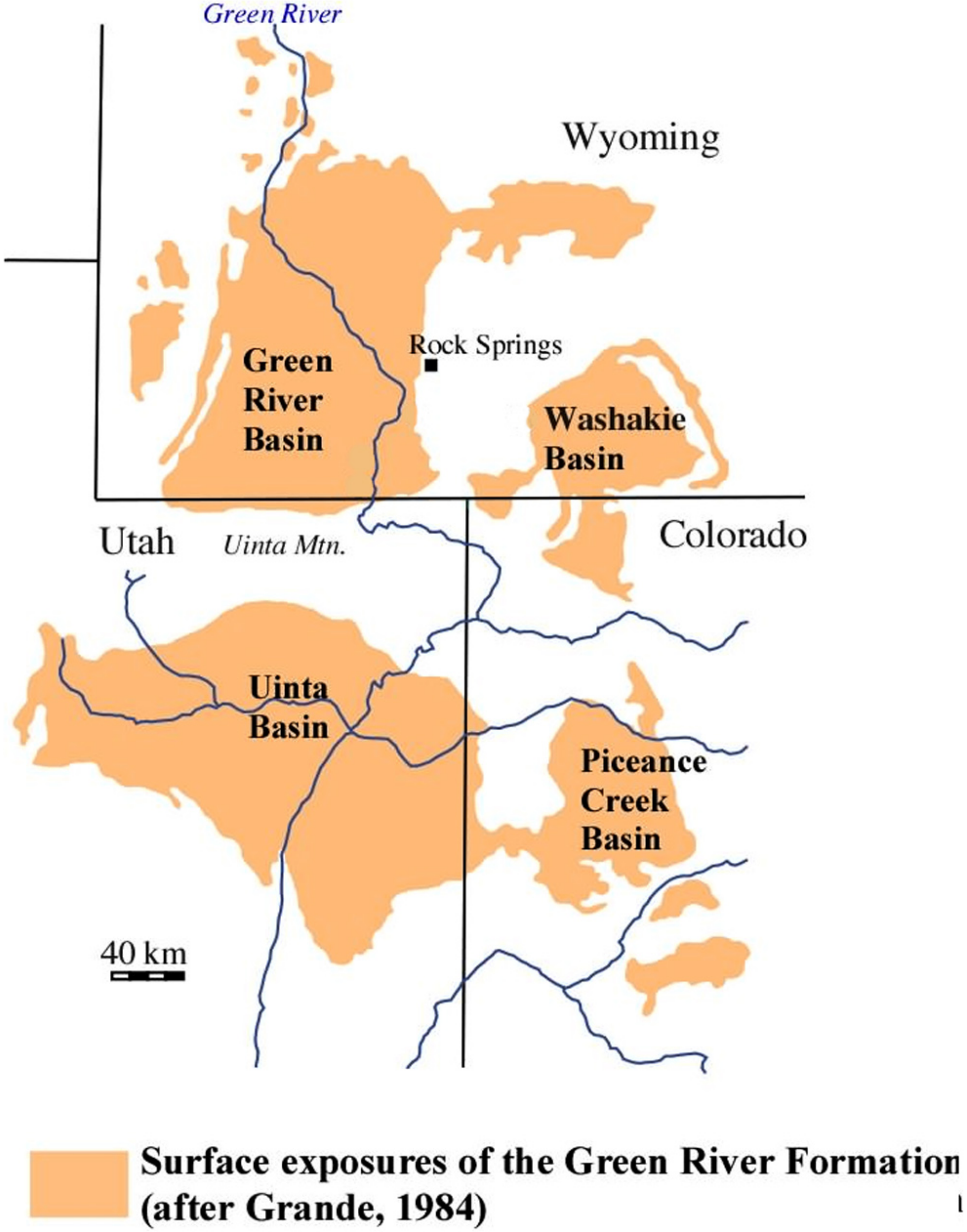
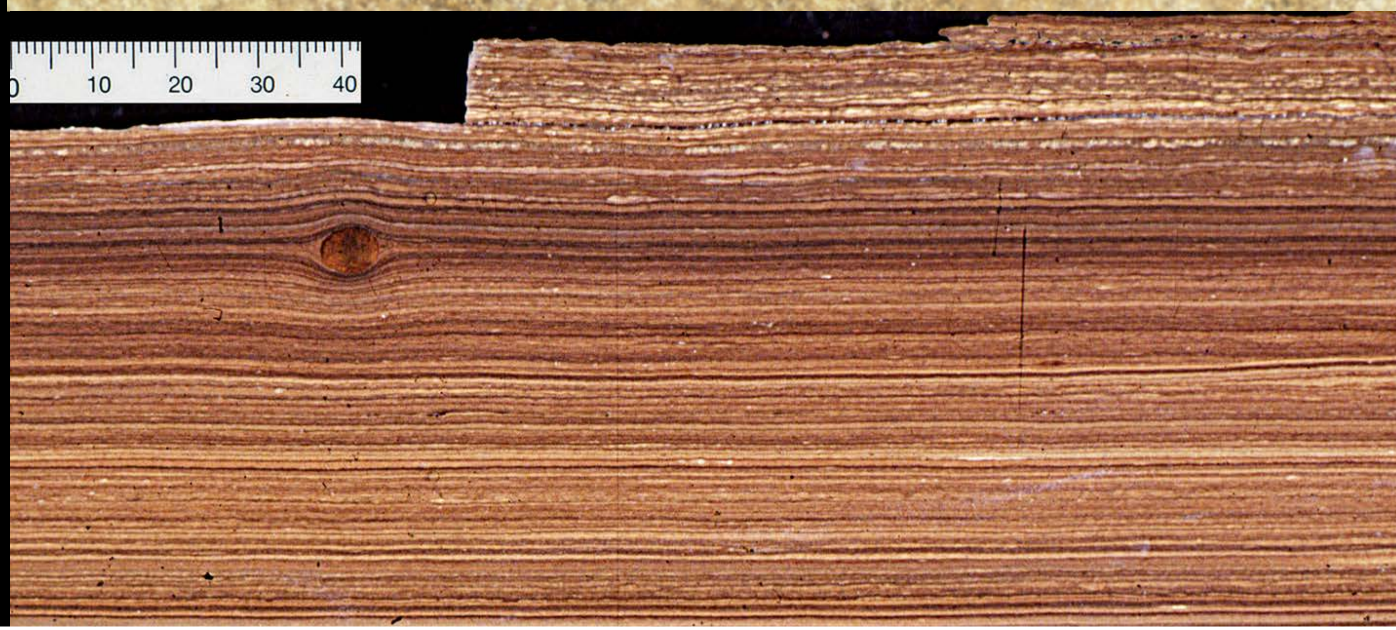
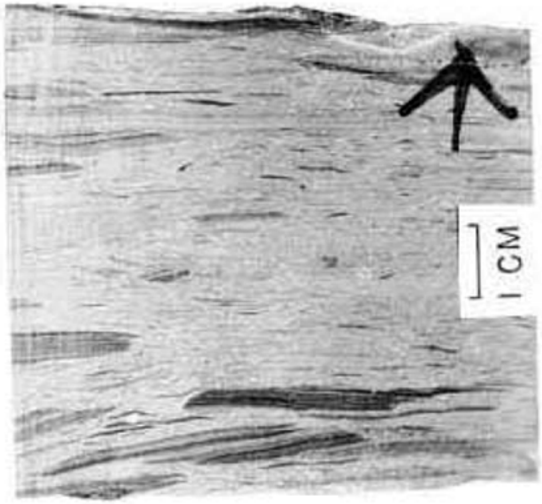
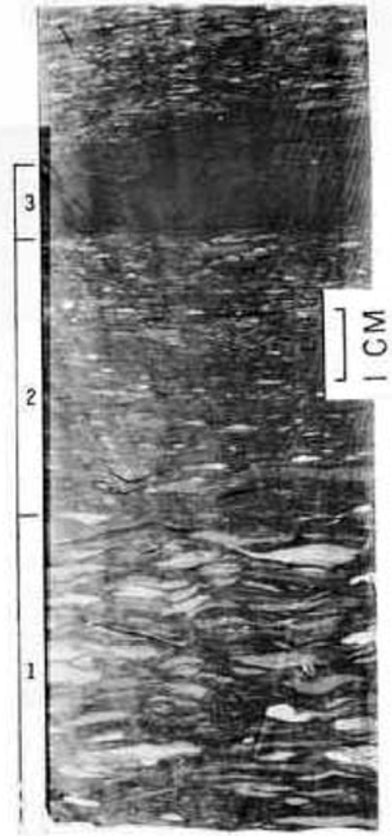
Eocene Green River Formation




0 10 20 30 40

USGS





from Dyni, 1981

Johnson et al., 2014

Mahogany zone, Parachute Creek Mb., Green River Fm.

Johnson et al., 2014
Mahogany zone, Parachute Creek Mb., Green River Fm.

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Matrix generally without clear bedding

Clasts can match lithologies below and ABOVE melange

Clasts or often but not always rhombic

Clasts can be folded or with laminae at high angles to bedding

Clasts with near vertical laminae show effects of strong compaction AFTER rotation

Clasts may be in boudins or adjacent “fitted” pieces.

There may be roof pendants or basal “flames”

There is no sign of a depositional or erosional upper contact

Can be discordant to bedding

Can have high angle boundaries with bedding

Melange present usually in higher organic, fine grained units

In same beds in siltier facies towards the border faults (in the same cycle) melange is replaced by folded and thrust faulted beds border faults

Intermediate condition may be brecciated folds

Clasts in melange in higher organic, fine grained units resemble adjacent lithologies and NOT marginal siltier facies and often represent adjacent stratigraphy where melange is locally less vertically extensive.

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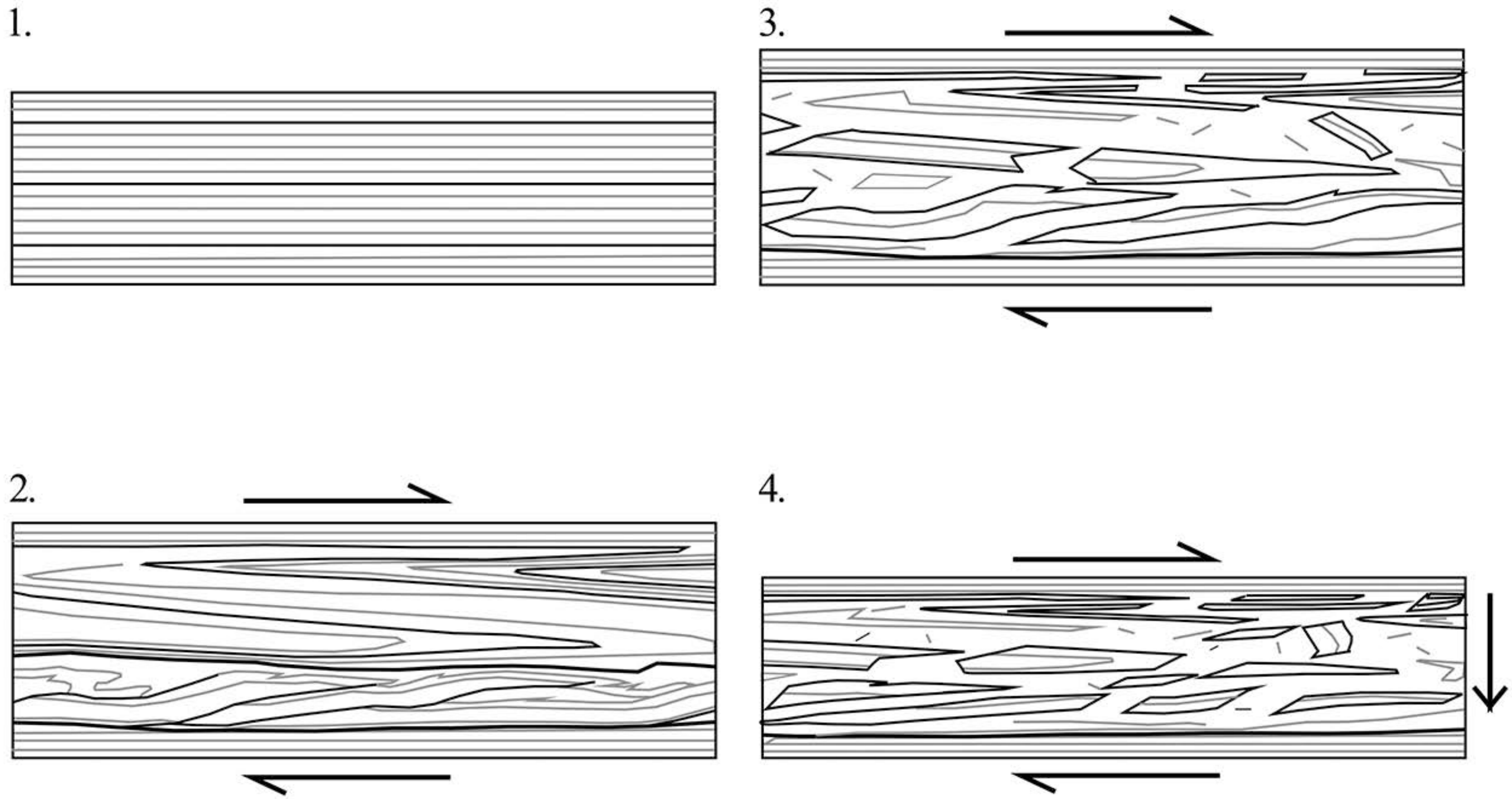
1.
2.
3.
4.

Can be confused with:

Mass movement units: but should have indications of a free upper surface with indications of sedimentation on an irregular surface or erosion.

Seismites: should have some influence or relation to surface (sand pipes, intrusions); a sequence of these melanges need have no relationship to sequence of events.

Evaporite dissolution breccias: need not show a sense of shear; should show a pattern of replacement consistent with dissolution. Pseudomorphs shouldl be present.

Late bedding-plane fault: should have mineralized fractures and faults planes; no mud matrix; but faults can cut melage later.

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1) Melanges originate as bedding parallel shear.

2) In siltier facies beds remain largely intact with thrust fault duplexes and recumbent folds with duplications of beds in vertical succession common.

3) In finer grained facies folds and duplexes re-sheared with some much mud liquefaction matrix between clasts in a melange.

4) Clasts that are oriented vertical show strong compaction indication early formation of melange.

5) In finest grained, often organic rich facies, clasts are derived from immediately local stratigraphy and are are not far transported.

6) They are not slumps, mass-transported beds, surface erosion rip up clasts, seismites in the usual sense, evaporite dissolution breccias, or brittle faults. ***Clear criteria are needed!***

7) Their sense of shear does NOT indicate downhill - could be uphill.

8) They do record a rheological history, but not a history of depositional or seismic events.

GSA Annual Meeting in Denver, Colorado, USA - 2016
Paper No. 125-7
Presentation Time: 3:05 PM

EARLY POST-DEPOSITIONAL BEDDING-PLANE-PARALLEL MELANGES CREATED BY SHEAR AND LIQUEFACTION: A COMMON BUT LARGELY MISINTERPRETED ORGANIC-RICH MUDROCK FACIES

OLSEN, Paul E. and KINNEY, Sean T., Department of Earth and Environmental Sciences, Lamont-Doherty Earth Observatory of Columbia University, 61 Route 9W, Palisades, NY 10964-1000, polsen@ldeo.columbia.edu

Many organic-rich mudstone sequences contain cm- to m-scale beds of cryptic mélange consisting of small (usually <20 cm) quadrangular to rounded or folded clasts with truncated oblique-to-bedding laminae floating in a poorly-bedded matrix. Clasts at high angles to bedding have thickened and crinkled laminae indicating deformation preceded full compaction. There is often an upward progression from partly organized masses of clasts with little matrix to isolated clasts in mostly matrix, with less common similar lateral transitions. Parent material can be below and/or above the mélange with downwardly hanging pendants or upwardly projecting “flames”. The massive mudstone matrix suggests partial liquefaction accompanied the bedding-parallel shear producing clasts with both brittle and ductile features. Some beds even resemble augen gneiss with winged porphyroclasts! In 1989, PEO half-jokingly termed the clasts “dead horses” (derived from "horse" for a fault-bounded sliver of rock and its flattened or prone position), hoping in vain to provoke interest.

When noted at all, "dead horse" mélanges have been interpreted as depositional units such as turbidites, rip-up clasts indicating subaerial exposure, slumps, or seismites, but we interpret them as “early” shear and dewatering-related units that did not have a free surface at the time of deformation. These are very common; in lacustrine sequences of the Triassic-Jurassic of the eastern US, nearly every sedimentary cycle with a dark gray to black mudstone has such a layer, amounting to hundreds of beds. Similar beds are abundant in the Eocene Green River Fm and are found in many other organic-rich, laminated mudstone sequences.

Assuming these mélanges are depositional leads to very serious mistakes in environmental interpretation. Moreover, because they formed post-depositionally, between pre-existing beds, and their formation was controlled by a combination of specific rheology at unknown depths and pressures (with or without specific triggers) each bed cannot be treated as resulting from a specific event, and a stratigraphy of sequential beds cannot be interpreted as a history of events. Given their virtual lack of recognition, the effects of these mélanges on diagenesis or fluid and gas generation and migration are wholly unknown.