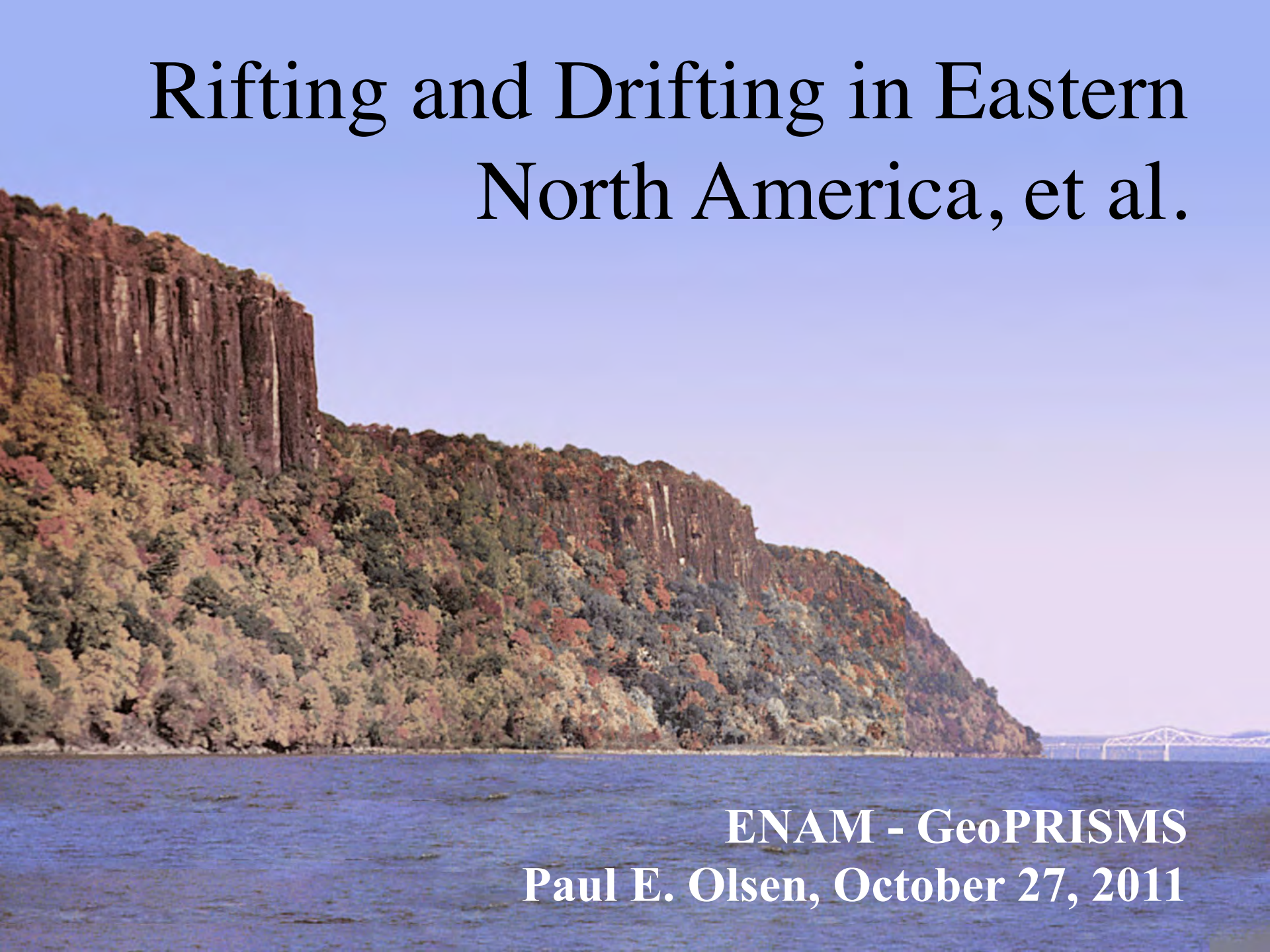
Rifting and Drifting in Eastern North America, et al.



ENAM - GeoPRISMS

Paul E. Olsen, October 27, 2011

1) History of Continental Rifting.

2) The CAMP LIP.

3) Earliest Atlantic Ocean Crust and Drifting.

1) History of Continental Rifting.

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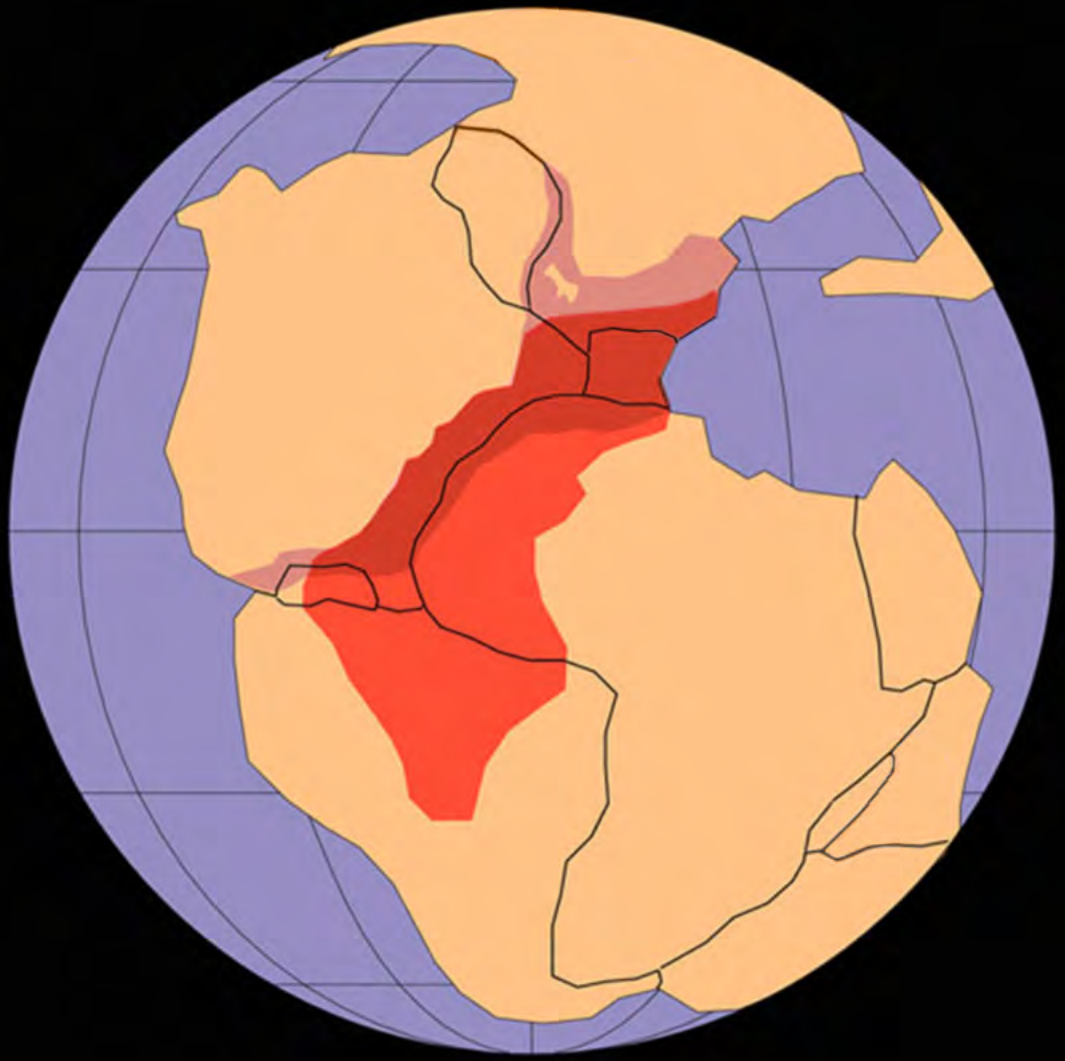
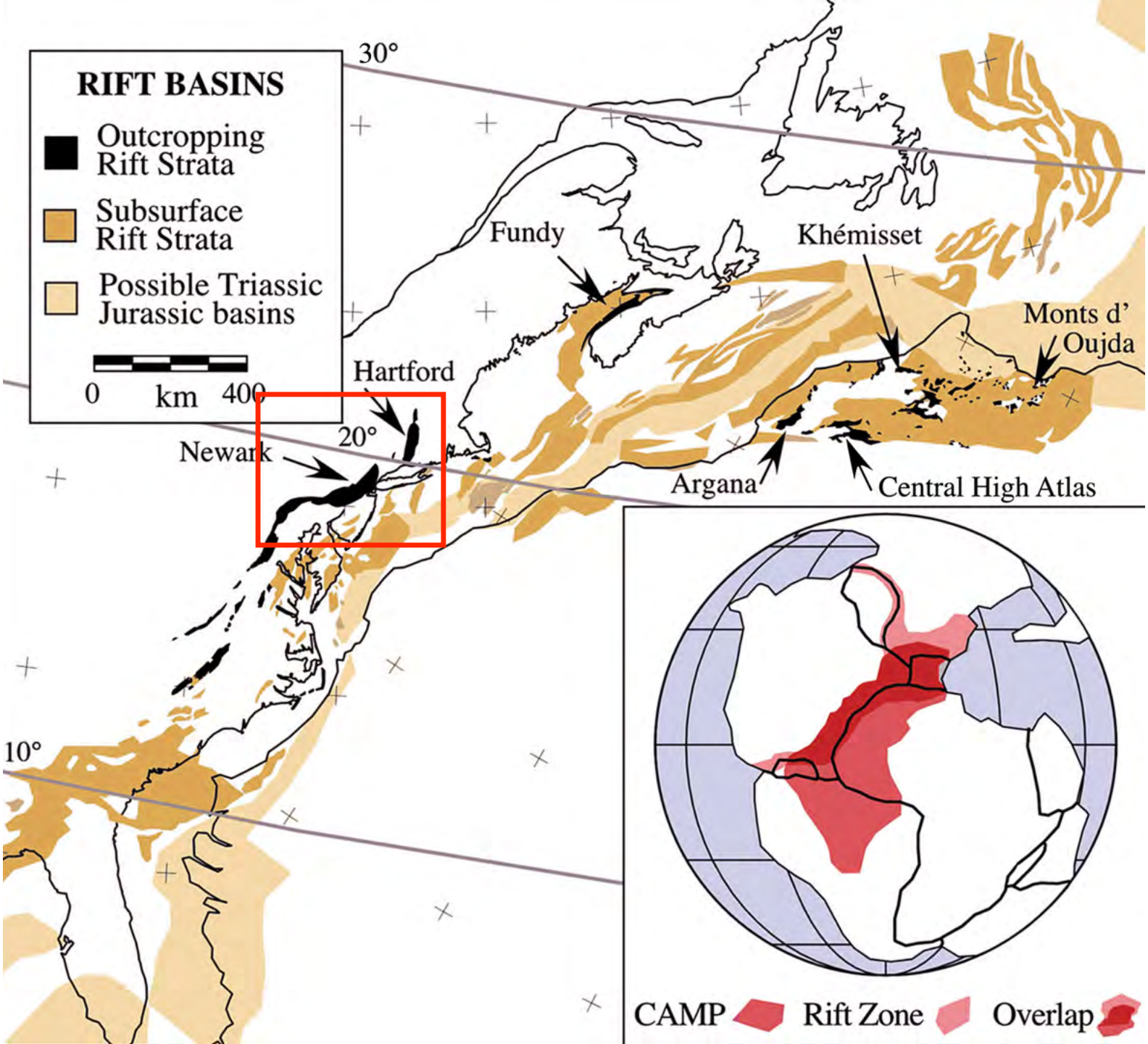
Pangea Rifting and CAMP



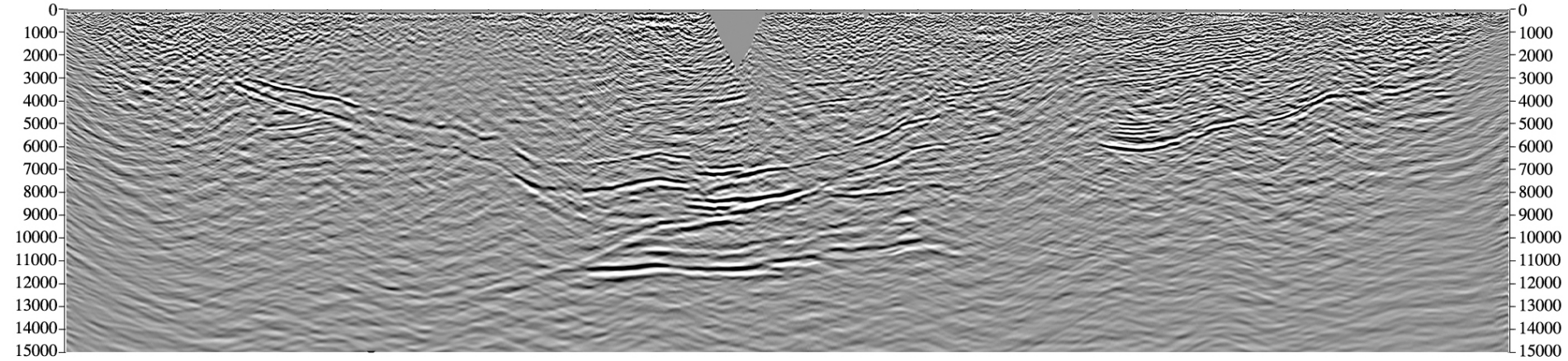
Continental Rift Zone without CAMP

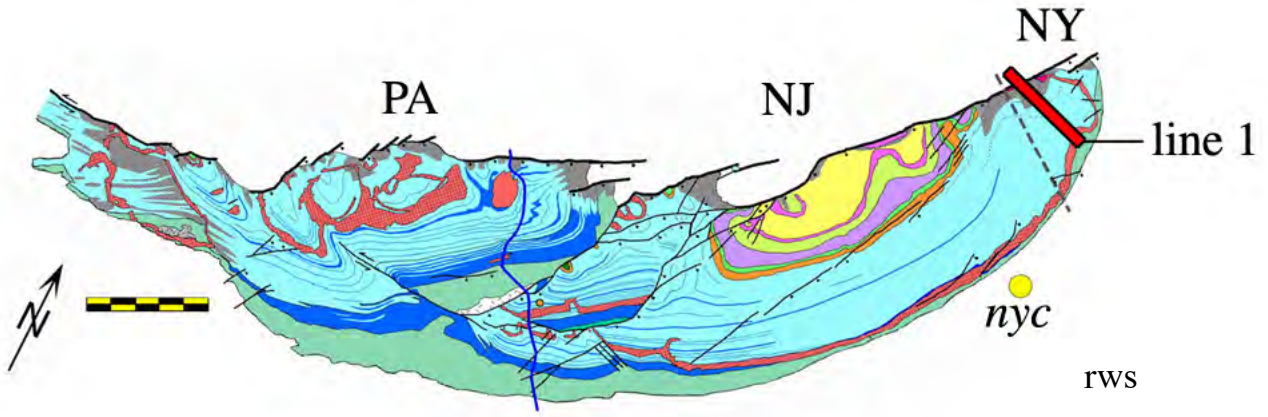
Continental Rift Zone with CAMP

CAMP Outside Rift Zone


RIFT BASINS
Outcropping Rift Strata
Subsurface Rift Strata
Possible Triassic Jurassic basins
0 km 400
30°
20°
10°
Fundy
Khémisset
Monts d' Oujda
Hartford
Newark
Argana
Central High Atlas
CAMP
Rift Zone
Overlap

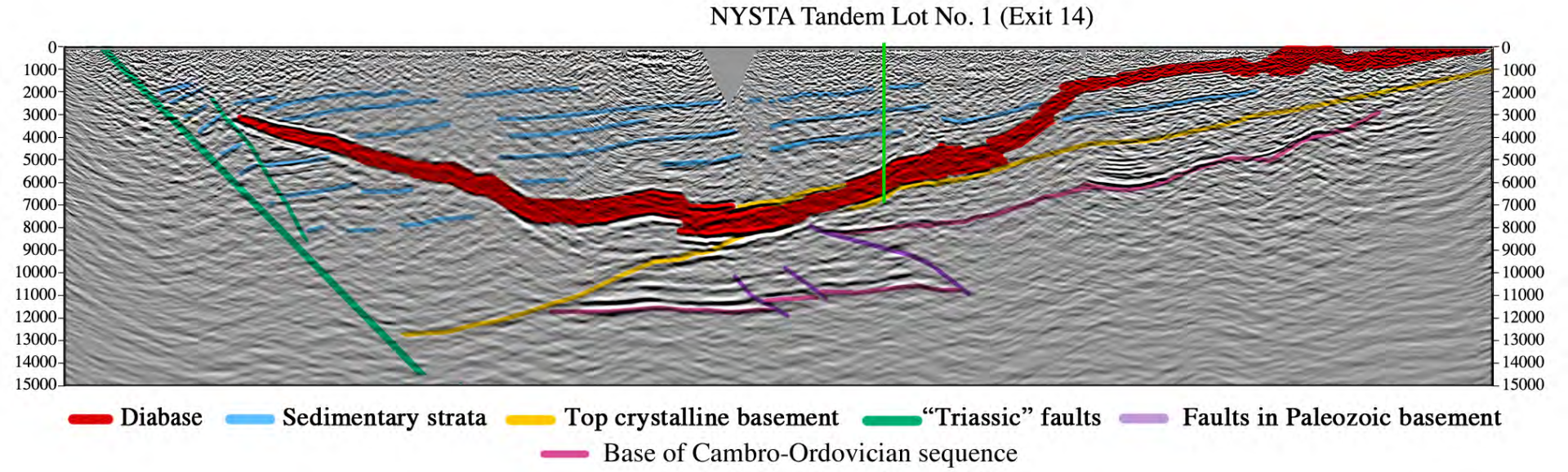
New York TriCarb Seismic Line 1

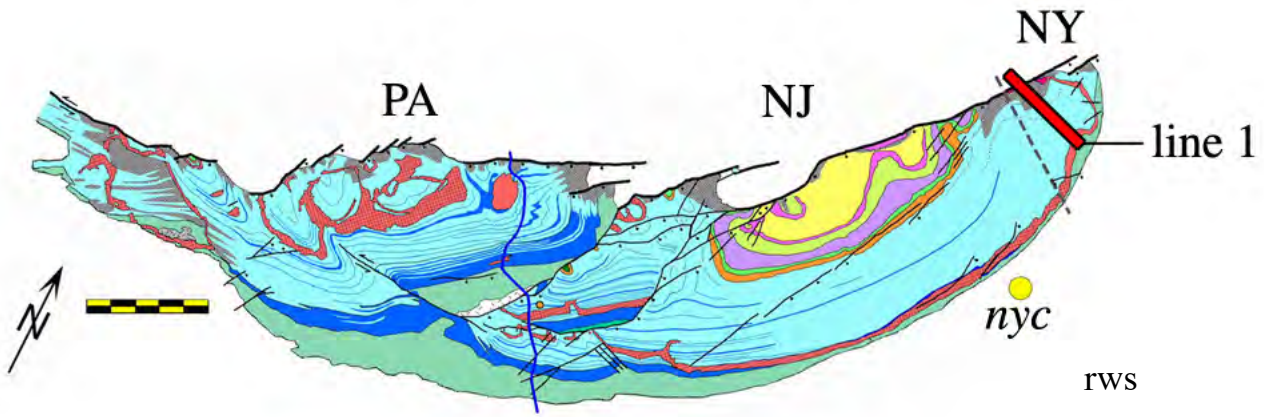




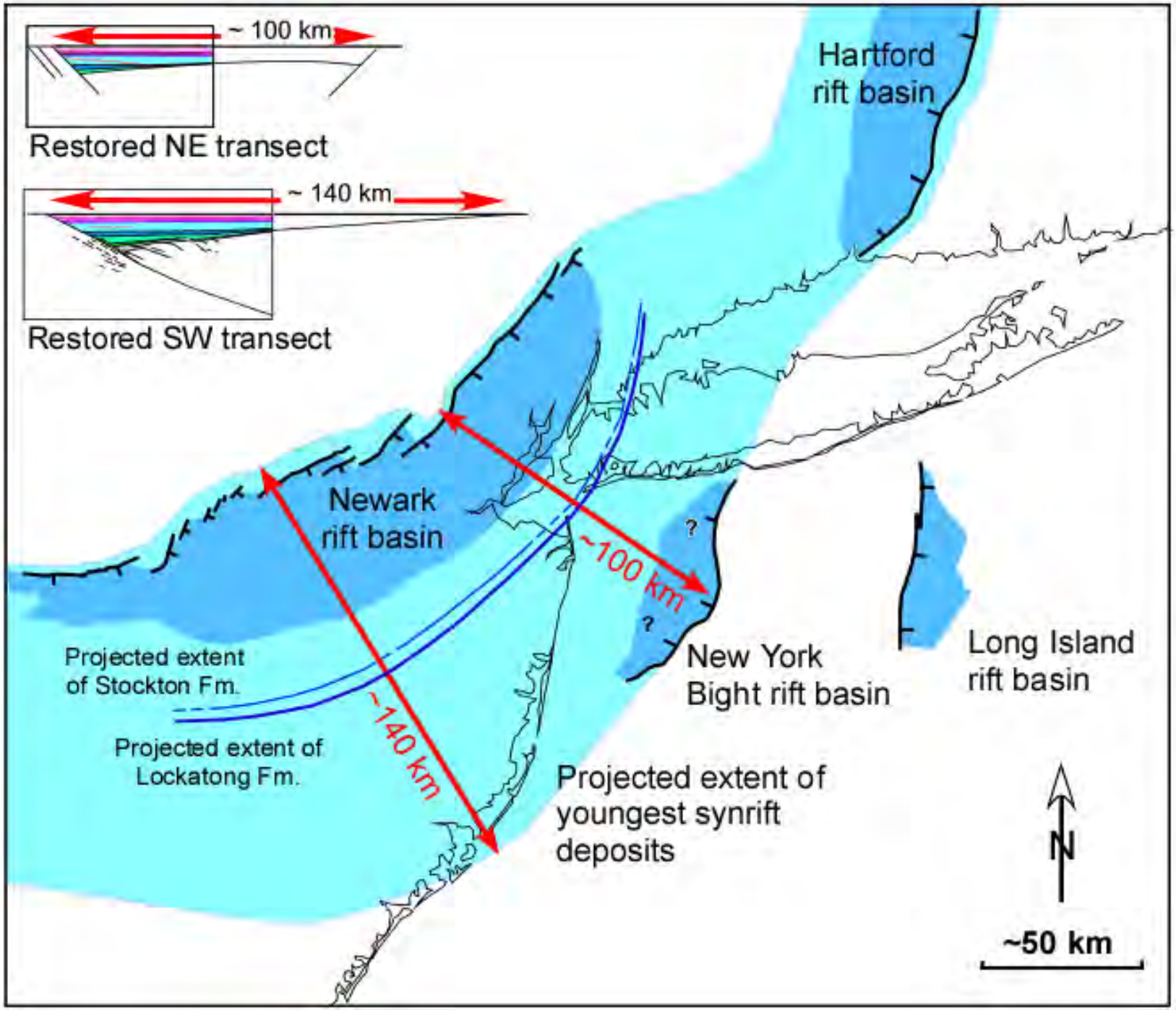
rws

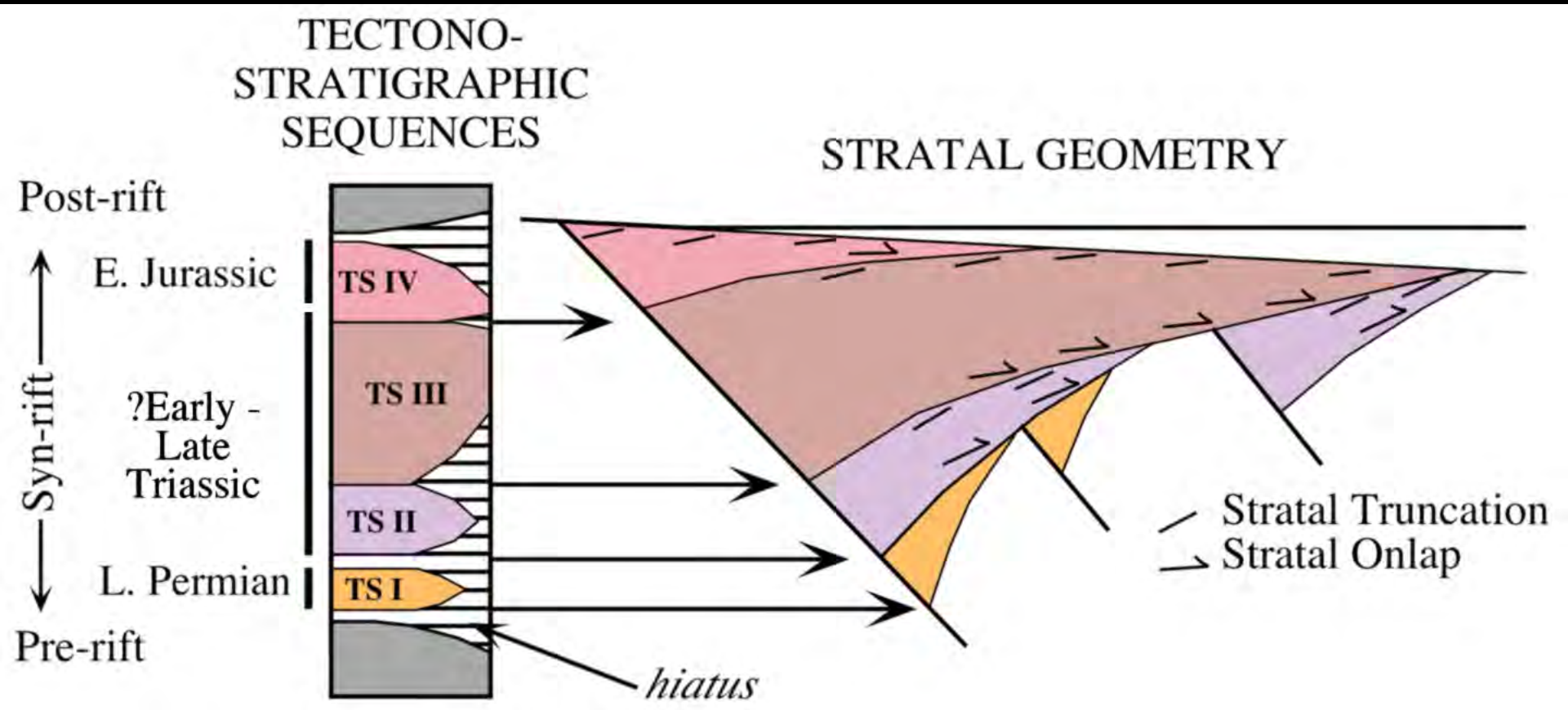
New York TriCarb Seismic Line 1





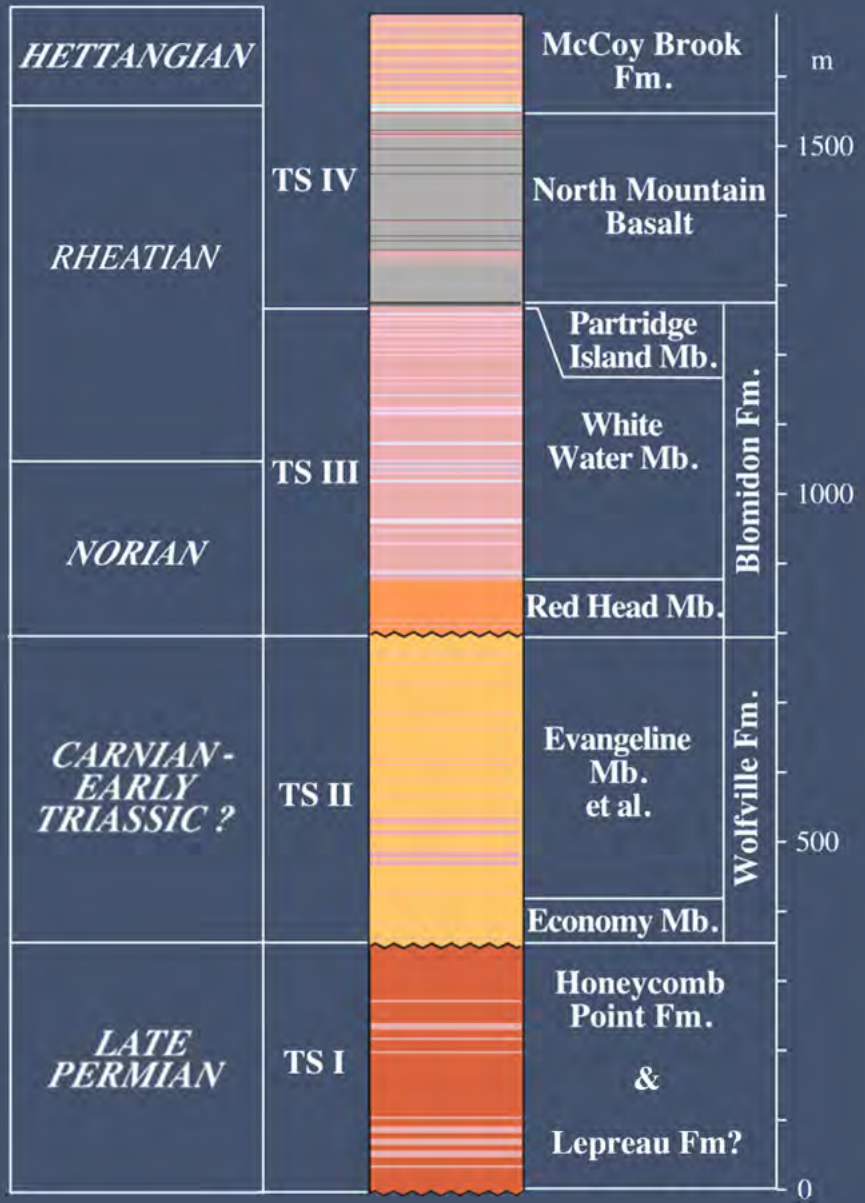
rws


~ 100 km
Restored NE transect
~ 140 km
Restored SW transect
Hartford
rift basin
Newark
rift basin
~100 km
?
?
New York
Bight rift basin
Long Island
rift basin
Projected extent
of Stockton Fm.
Projected extent of
Lockatong Fm.
~140 km
Projected extent of
youngest synrift
deposits
N
~50 km

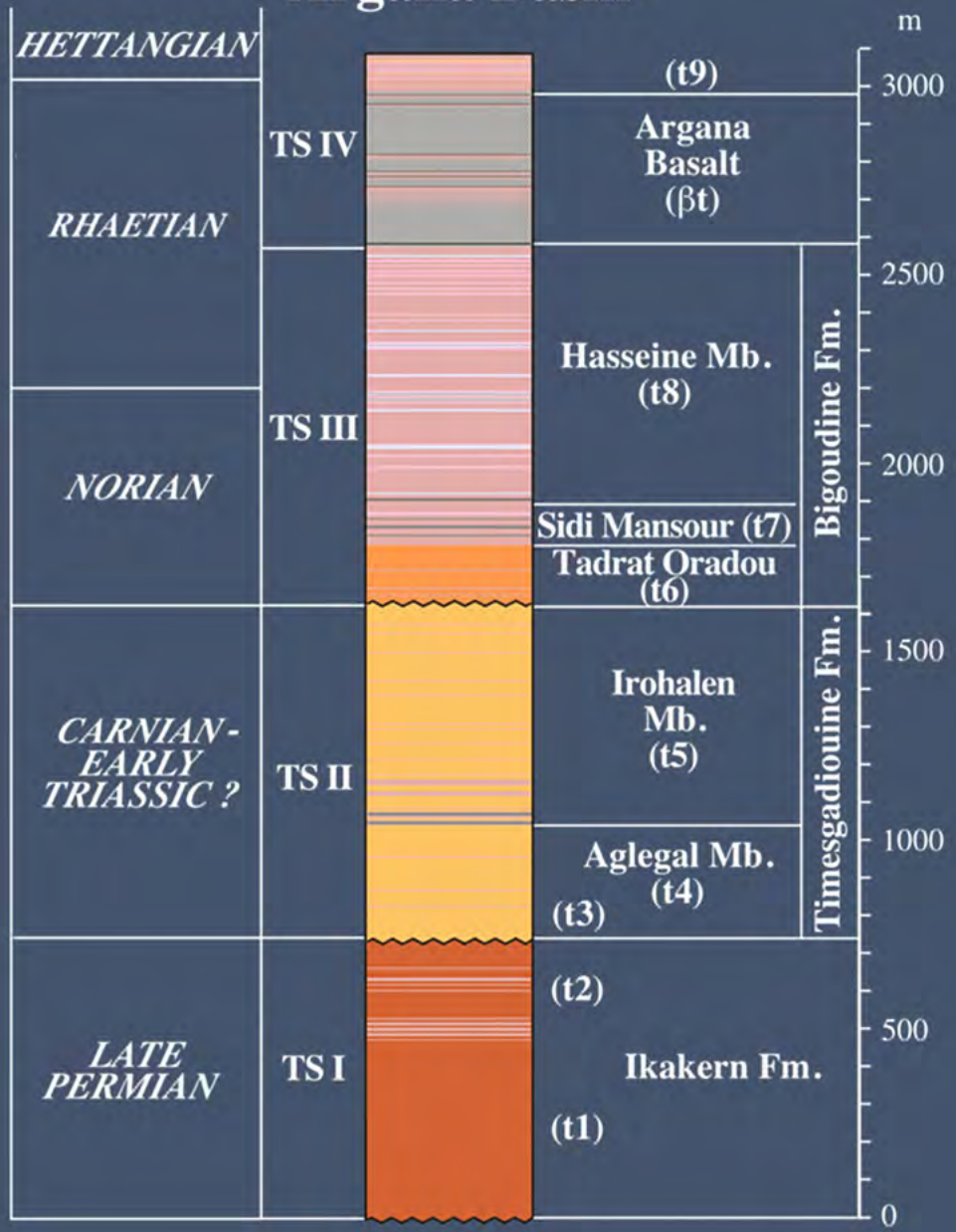


Tectonostratigraphic sequences in CAM basins
(modified after Olsen, 1997)

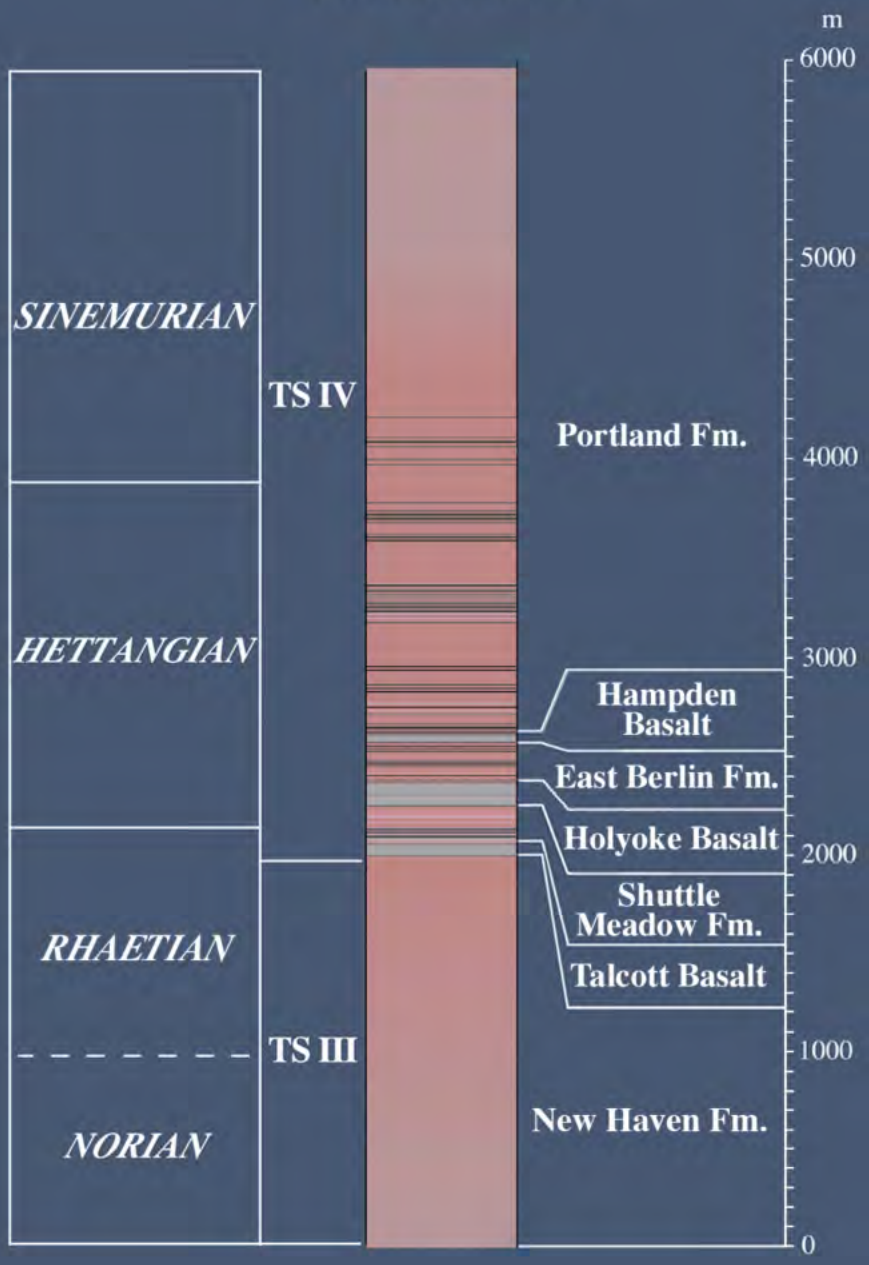
Fundy Basin


HETTANGIAN
RHEATIAN
NORIAN
CARNIAN - EARLY TRIASSIC ?
LATE PERMIAN
TS IV
TS III
TS II
TS I
McCoy Brook Fm.
North Mountain Basalt
Partridge Island Mb.
White Water Mb.
Red Head Mb.
Blomidon Fm.
Evangeline Mb. et al.
Economy Mb.
Wolfville Fm.
Honeycomb Point Fm.
&
Lepreau Fm?
m
1500
1000
500
0

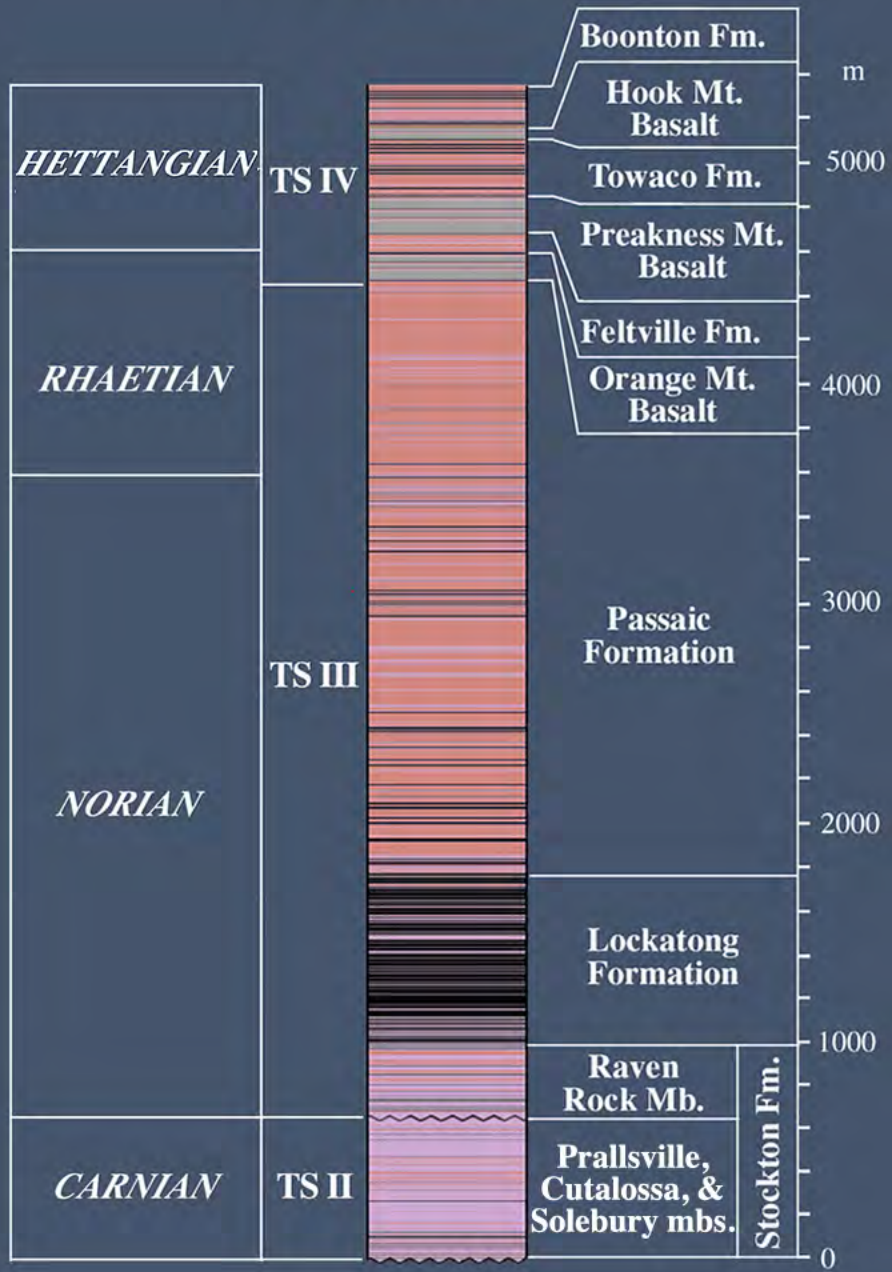
Argana Basin



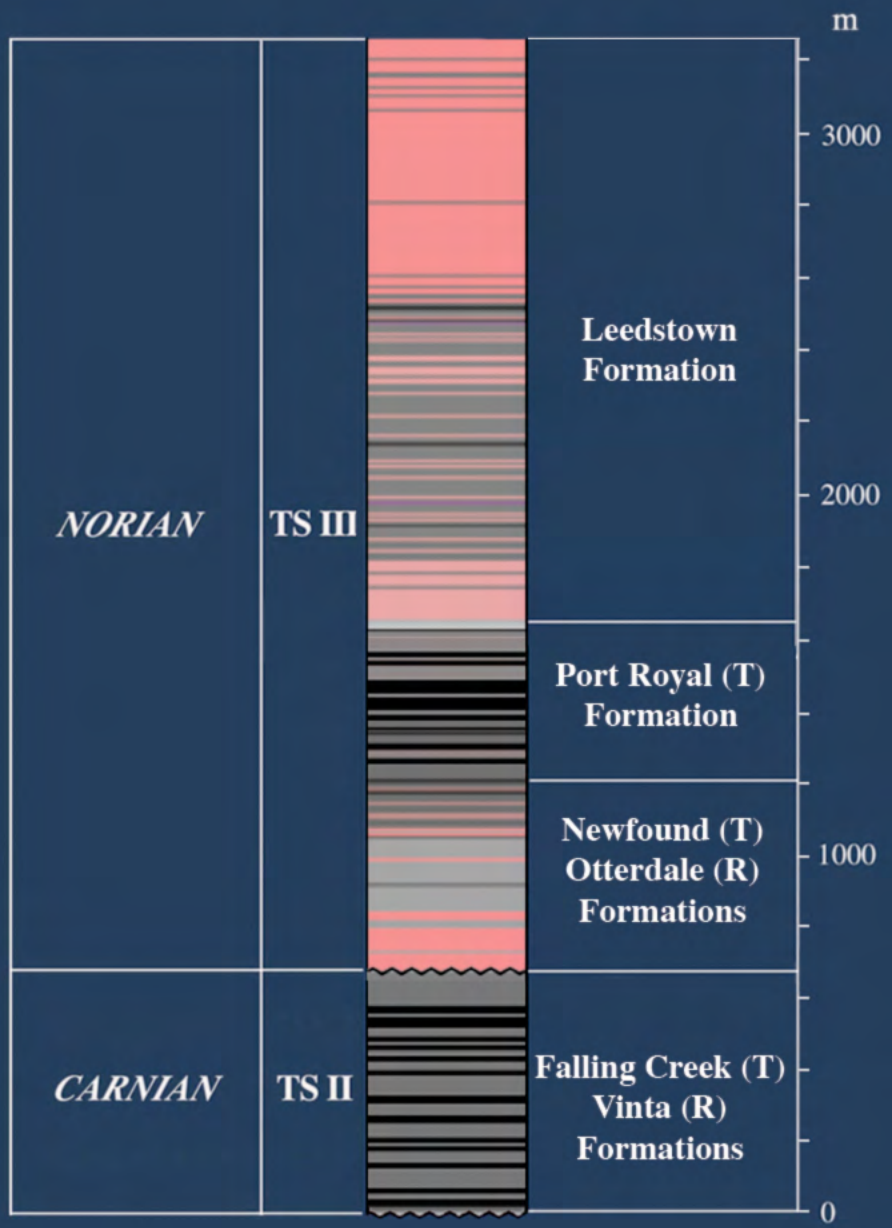
Hartford Basin



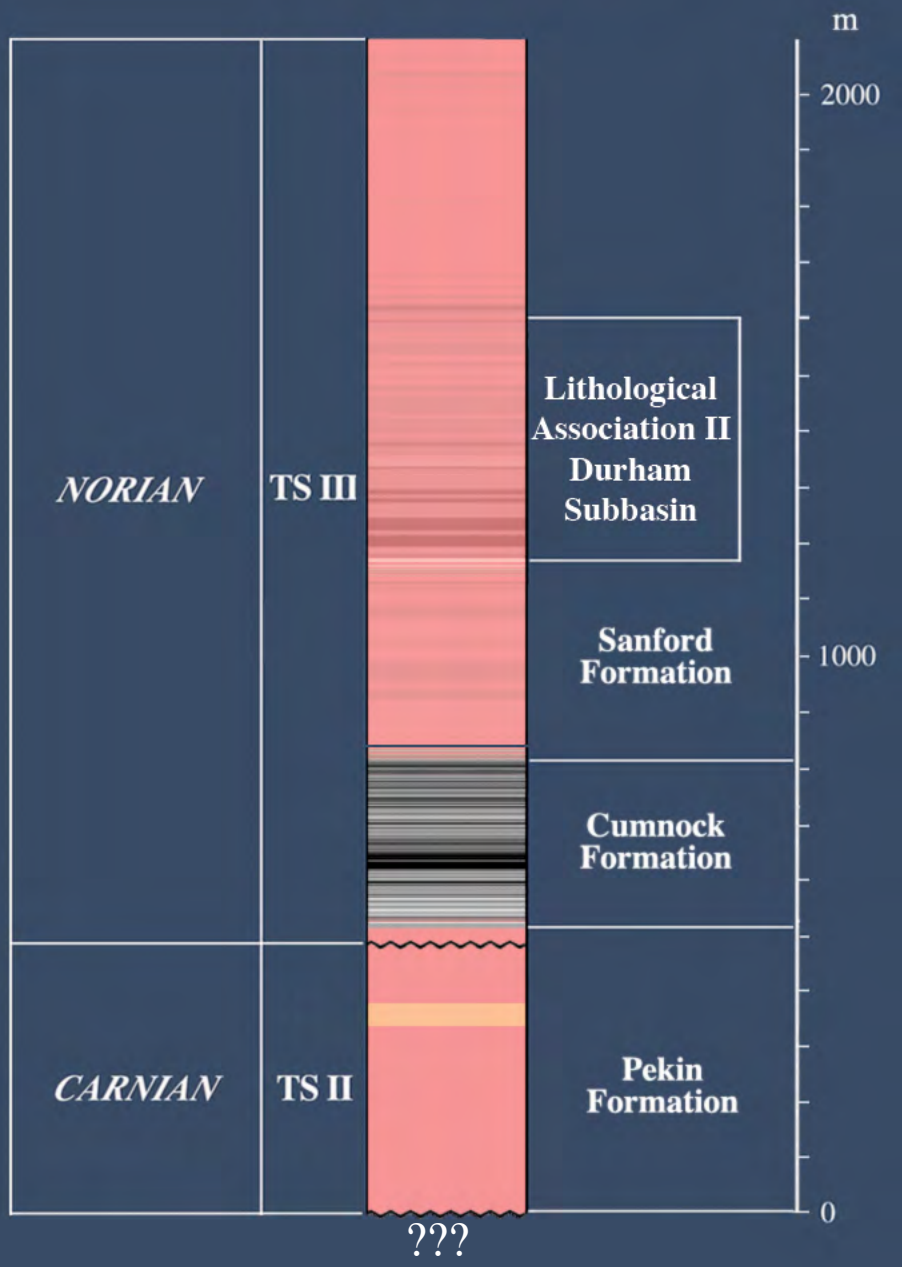
Newark Basin

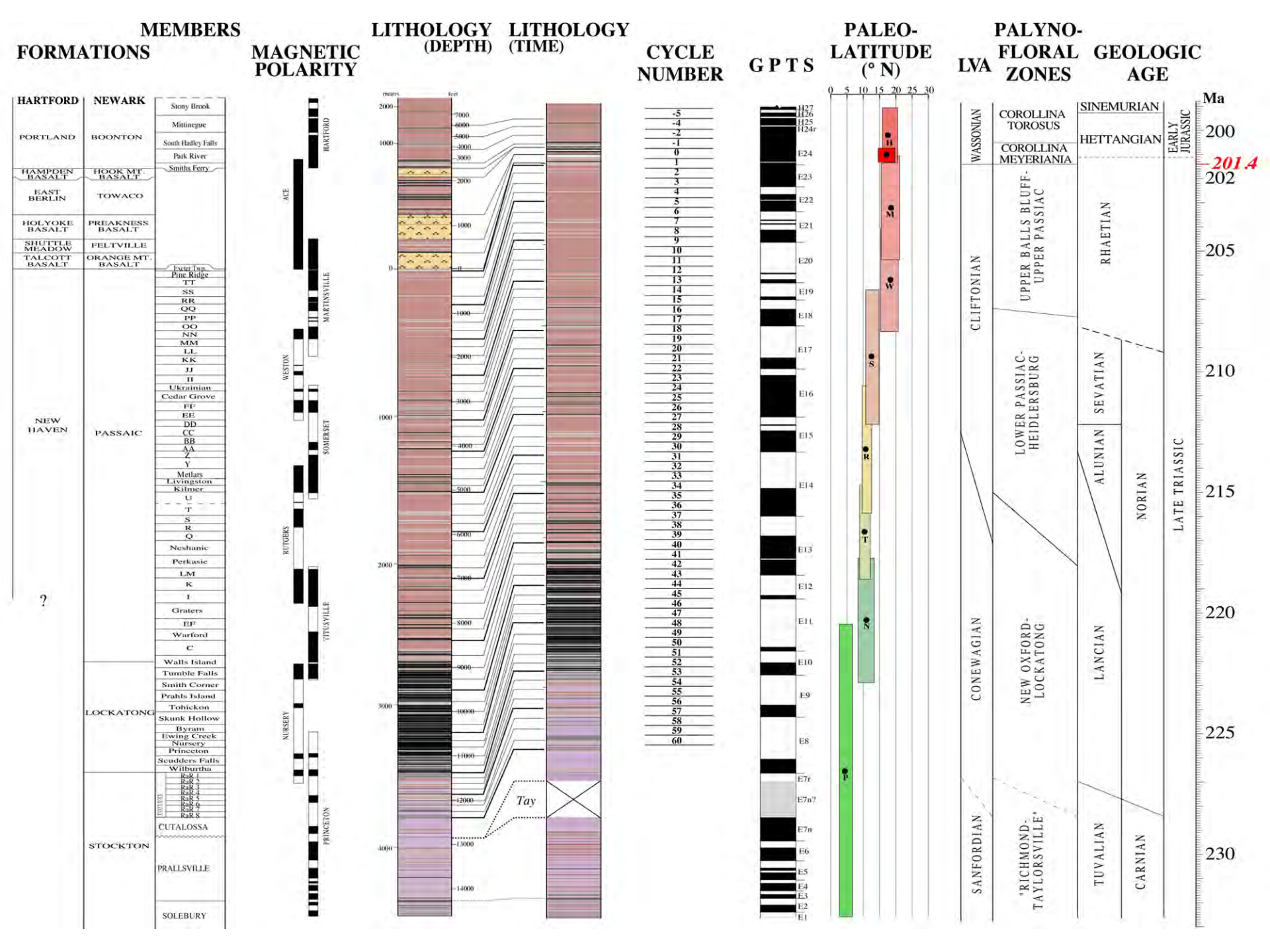


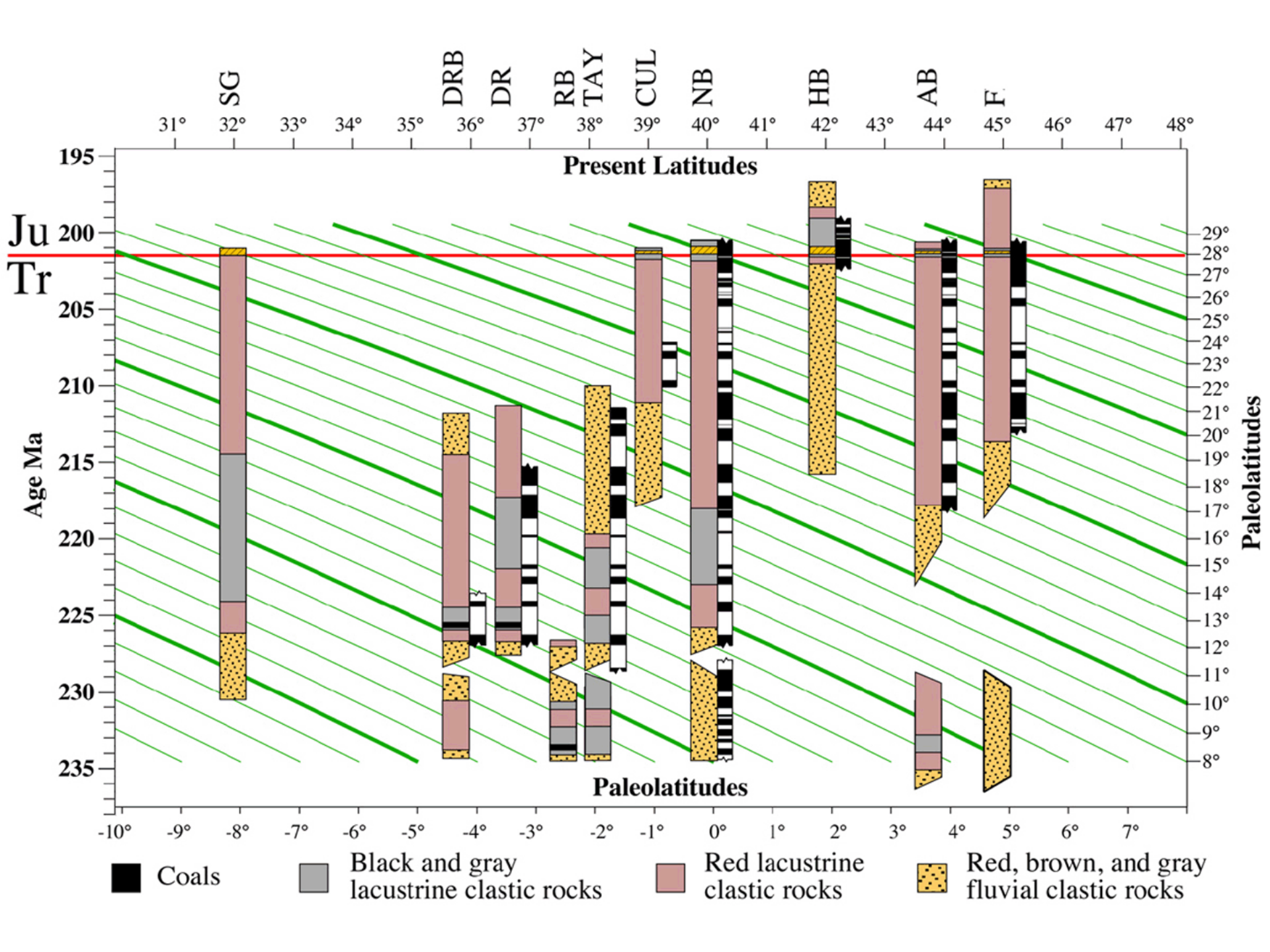
Richmond / Taylorsville Basin

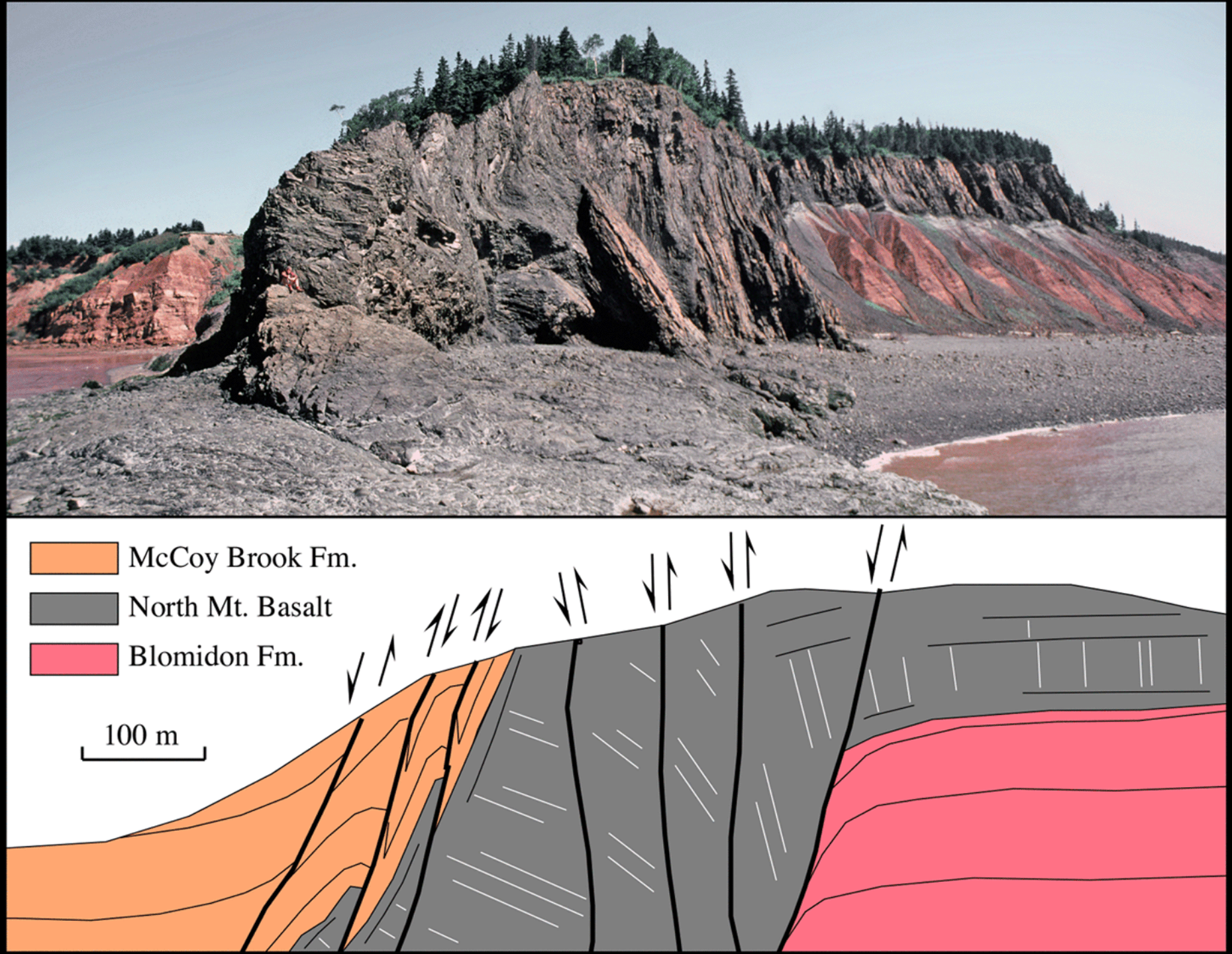


Deep River Basin




FORMATIONS
MEMBERS
MAGNETIC POLARITY
LITHOLOGY (DEPTH)
LITHOLOGY (TIME)
CYCLE NUMBER
G P T S
PALEO-LATITUDE (° N)
LVA
PALYNO-FLORAL ZONES
GEOLOGIC AGE
Ma
HARTFORD
NEWARK
PORTLAND
BOONTON
HAMPDEN BASALT
HOOK MT. BASALT
EAST BERLIN
TOWACO
HOLYOKE BASALT
PREAKNESS BASALT
SHUTTLE MEADOW
FELTVILLE
TALCOTT BASALT
ORANGE MT. BASALT
NEW HAVEN
PASSAIC
LOCKATONG
STOCKTON
Stony Brook
Mittinegue
South Hadley Falls
Park River
Smiths Ferry
Pine Ridge
TT
SS
RR
QQ
PP
OO
NN
MM
LL
KK
JJ
II
Ukrainian
Cedar Grove
FF
EE
DD
CC
BB
AA
Z
Y
Metlars
Livingston
Kilmer
U
T
S
R
Q
Neshanic
Perkasie
LM
K
I
Graters
EF
Warford
C
Walls Island
Tumble Falls
Smith Corner
Prahls Island
Tohickon
Skunk Hollow
Byram
Ewing Creek
Nursery
Princeton
Scudders Falls
Wilburtha
CUTALOSSA
PRALLSVILLE
SOLEBURY
HARTFORD
ACE
MARTINSVILLE
WESTON
SOMERSET
RUTGERS
TITUSVILLE
NURSERY
PRINCETON
Tay
WASSONIAN
CLIFTONIAN
CONEWAGIAN
SANFORDIAN
COROLLINA TOROSUS
COROLLINA MEYERIANIA
UPPER BALLS BLUFF-UPPER PASSAIC
LOWER PASSAIC-HEIDLERSBURG
NEW OXFORD-LOCKATONG
"RICHMOND-TAYLORSVILLE"
SINEMURIAN
HETTANGIAN
RHAETIAN
SEVATIAN
ALUNIAN
LANCIAN
TUVALIAN
NORIAN
CARNIAN
EARLY JURASSIC
LATE TRIASSIC
201.4


SG
DRB
DR
RB
TAY
CUL
NB
HB
AB
F
31°
32°
33°
34°
35°
36°
37°
38°
39°
40°
41°
42°
43°
44°
45°
46°
47°
48°
Present Latitudes
Ju
Tr
195
200
205
210
215
220
225
230
235
Age Ma
29°
28°
27°
26°
25°
24°
23°
22°
21°
20°
19°
18°
17°
16°
15°
14°
13°
12°
11°
10°
9°
8°
Paleolatitudes
Paleolatitudes
-10°
-9°
-8°
-7°
-6°
-5°
-4°
-3°
-2°
-1°
0°
1°
2°
3°
4°
5°
6°
7°
Coals
Black and gray lacustrine clastic rocks
Red lacustrine clastic rocks
Red, brown, and gray fluvial clastic rocks


McCoy Brook Fm.
North Mt. Basalt
Blomidon Fm.
100 m

1) Most remnant ENA rifts are half graben, but prior to erosion they were much broader and probably interconnected over giant rift zone.
2) Oldest syn-rift strata Late Permian (post Variscan), verified in ENA only in Fundy rift. But no apparent age progression in onset of rifting evident.
3) There is a trend in termination, with youngest synrift strata being Late Triassic and pre-CAMP.

What We Don't Know

1) Mechanism for initiating rifting and geometry of initial conditions.
2) How big and interconnected were the actual basins and sediments.
3) Why no rift volcanism for the entire stretch in Permo-Triassic.
4) What controls the tectonstratigraphic sequences.
5) Relation to the New England Coastal Province and White Mountain magmatism.
6) Why rifting turns off in southern rifting area.
7) Why tectononic inversion.

1) History of Continental Rifting.

2) The CAMP LIP.

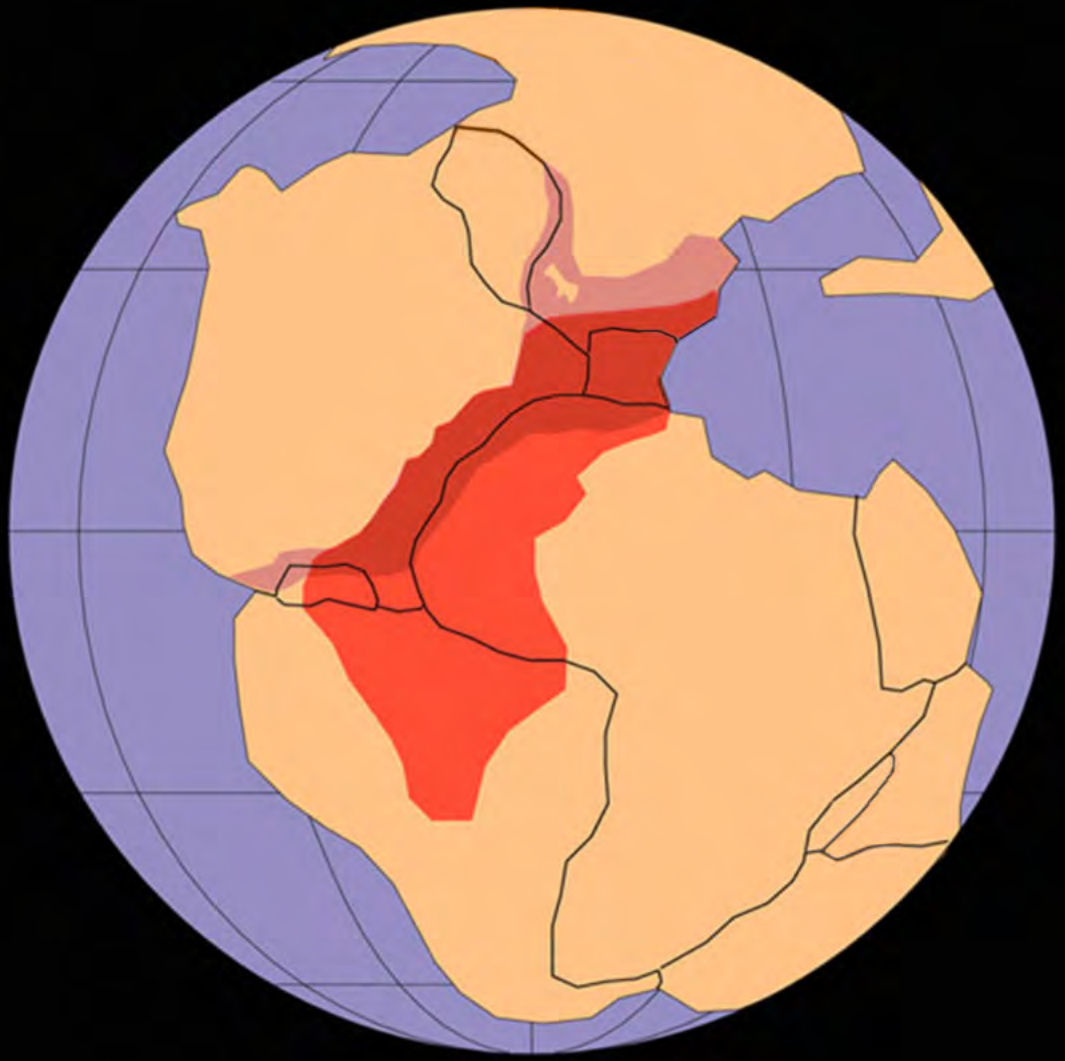
3) Earliest Atlantic Ocean Crust and Drifting.

CAMP

Central Atlantic Magmatic Province

Massive exchange of materials among magma, the oceans and atmosphere.

Pangea Rifting and CAMP



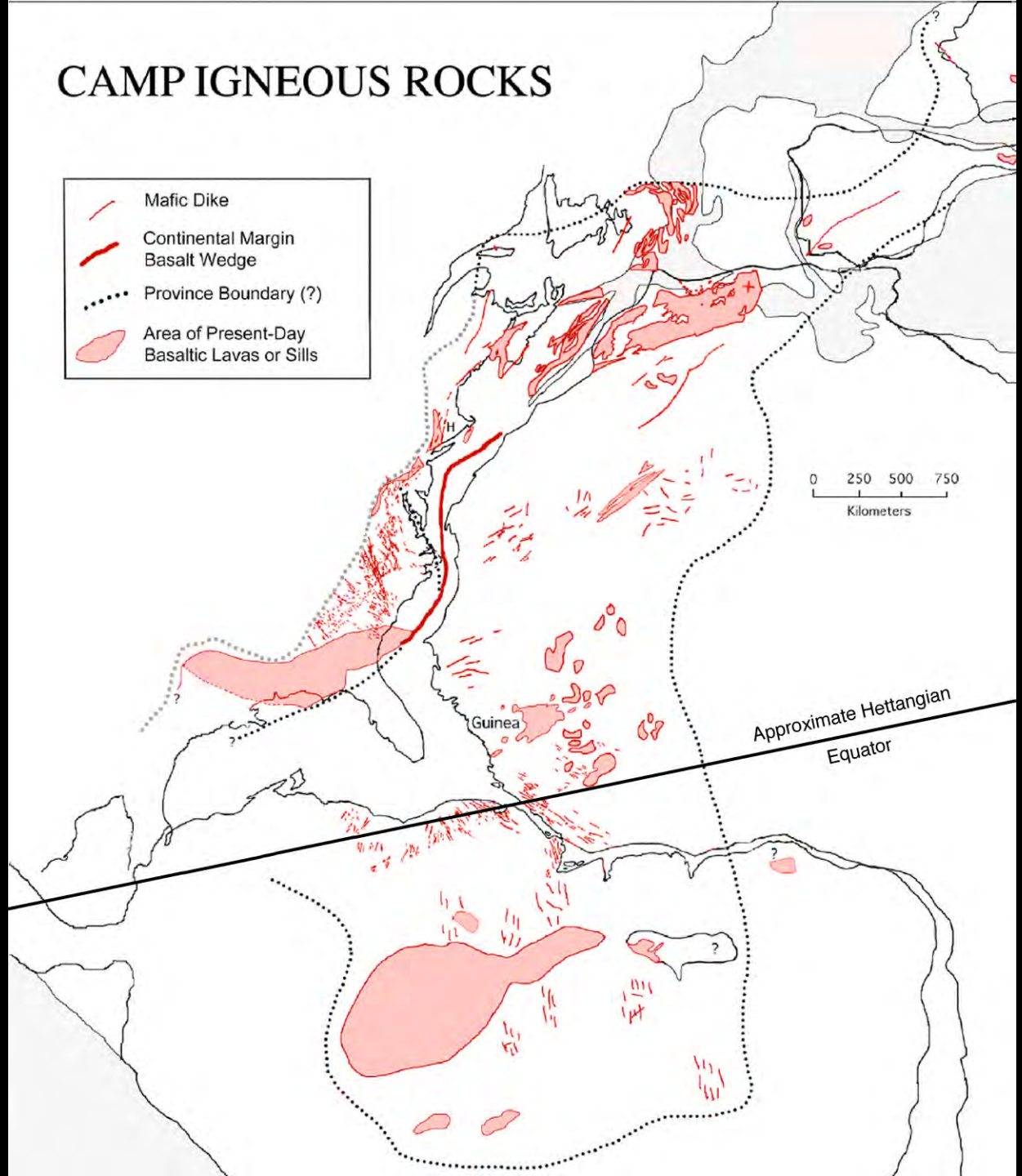
Continental Rift Zone without CAMP

Continental Rift Zone with CAMP

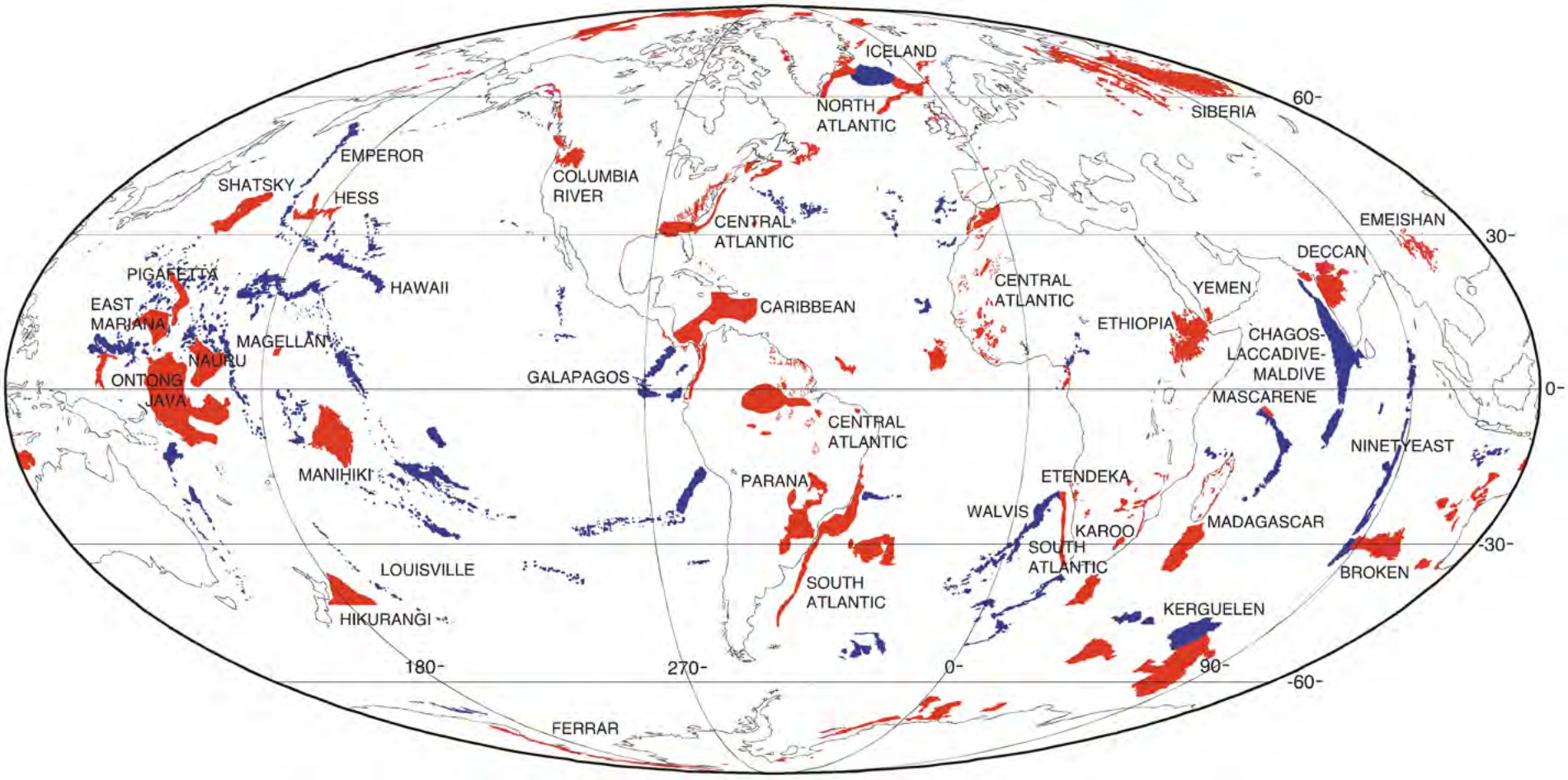
CAMP Outside Rift Zone

Palisade Sill, Alpine, New Jersey

North Mountain Basalt, Fundy Basin, Nova Scotia, Canada


CAMP IGNEOUS ROCKS
Mafic Dike
Continental Margin Basalt Wedge
Province Boundary (?)
Area of Present-Day Basaltic Lavas or Sills
0 250 500 750
Kilometers
Guinea
Approximate Hettangian Equator

LIPs Large Igneous Provinces



Areas and Volumes

McHone (2002)

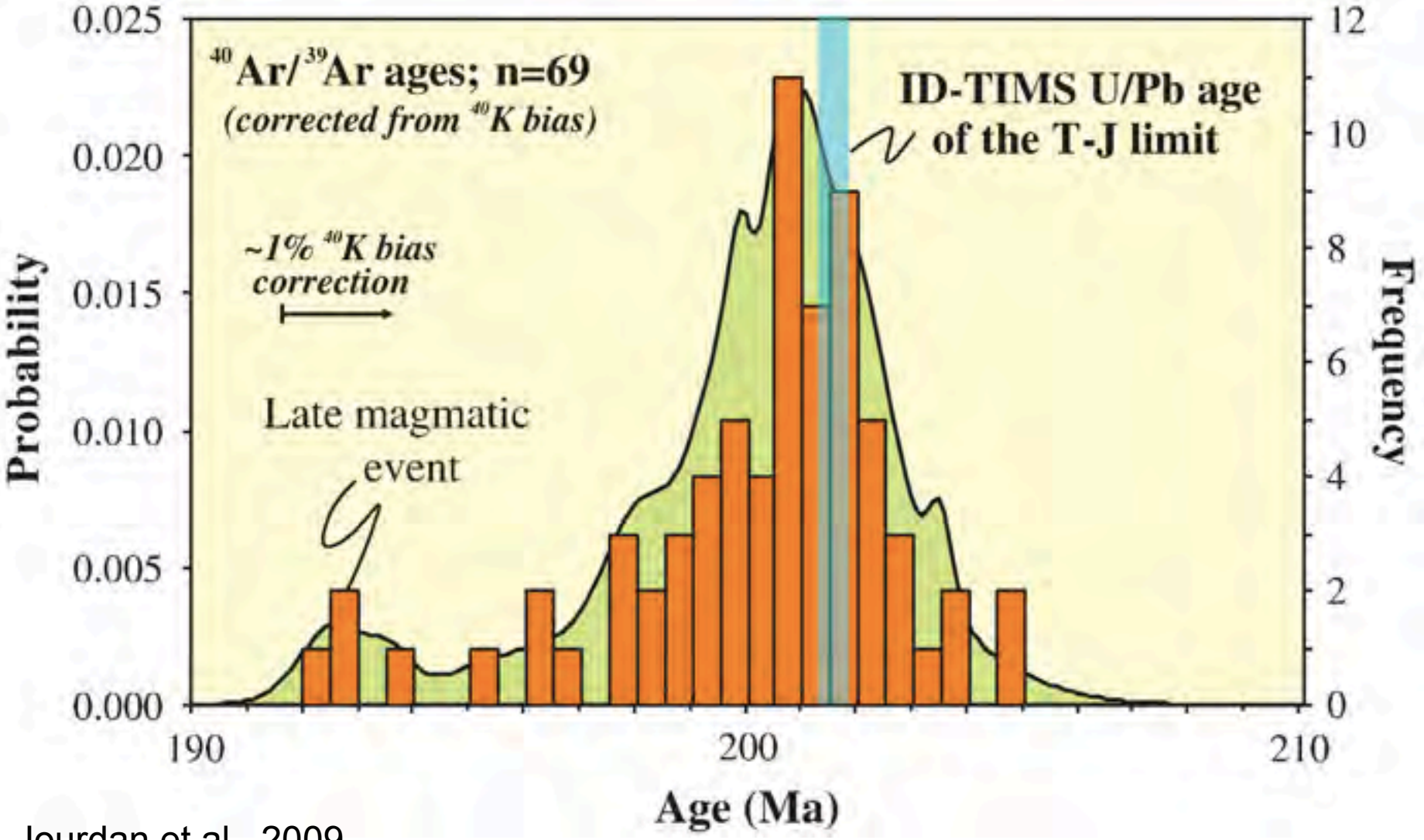
Area **~11 x 10^6 km^2**

Assuming half of the continental CAMP area was originally covered by 200 m of lava, the total volume of CAMP and ECMIP basalt exceeded ***2.4 x 10^6 km^3***

Marzoli (1999)

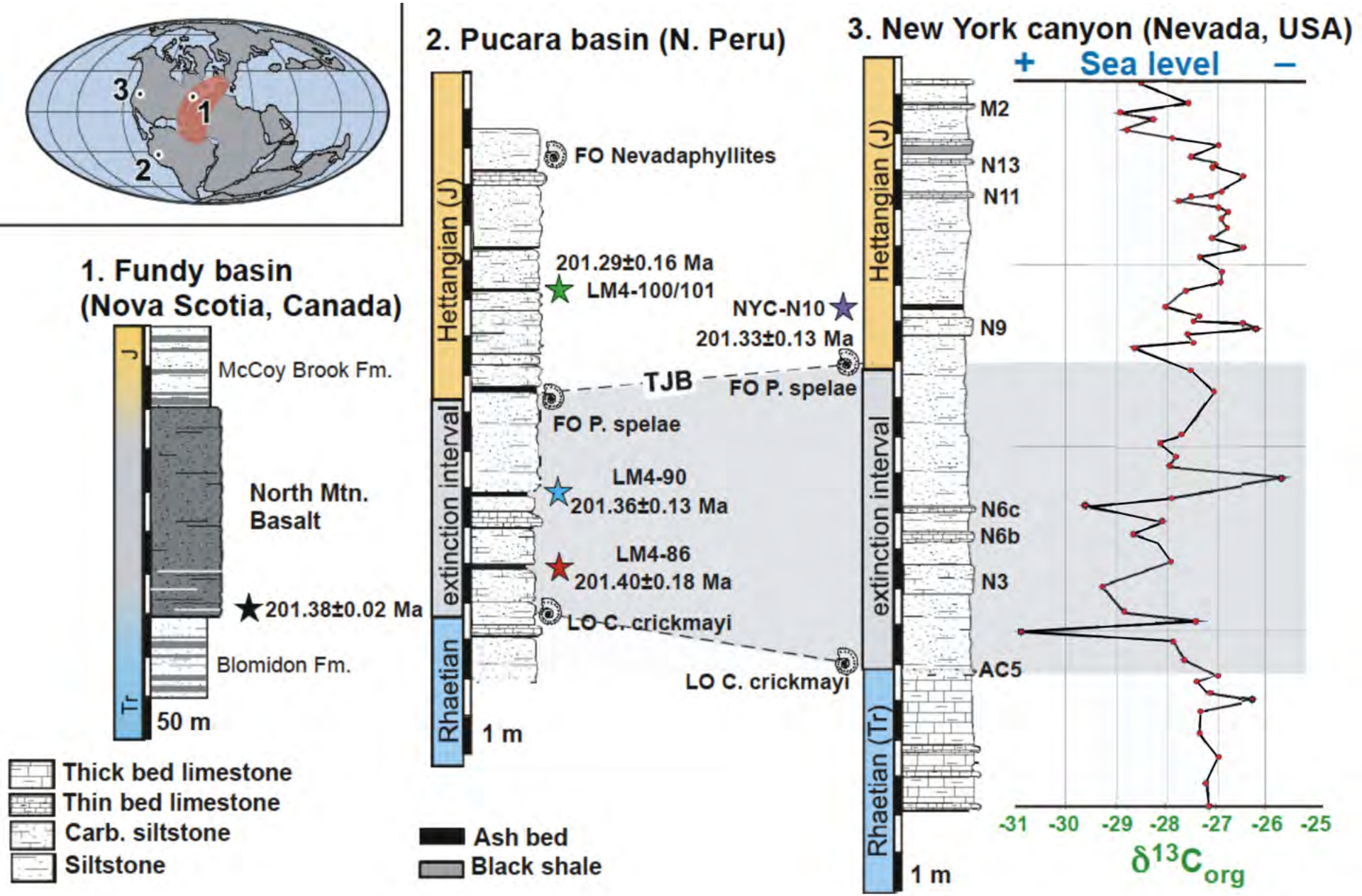
Area **7 x 10^6 km^2**

Assuming that preserved volcanic sections averaging 200 to 300 m thick in distal portions of the CAMP are representative, an original volume of ***2 x 10^6 km^3*** is implied.



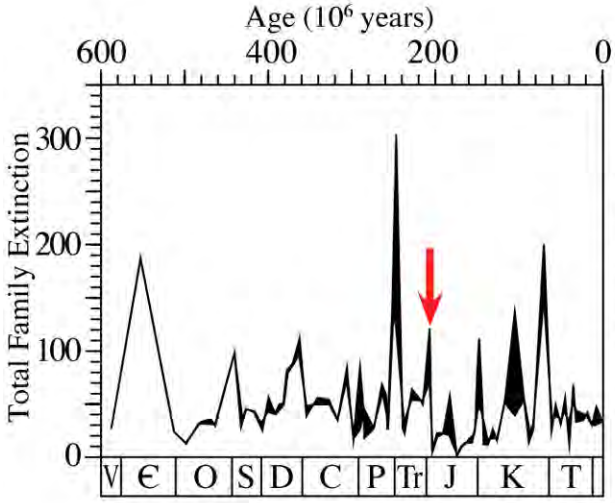
Jourdan et al., 2009

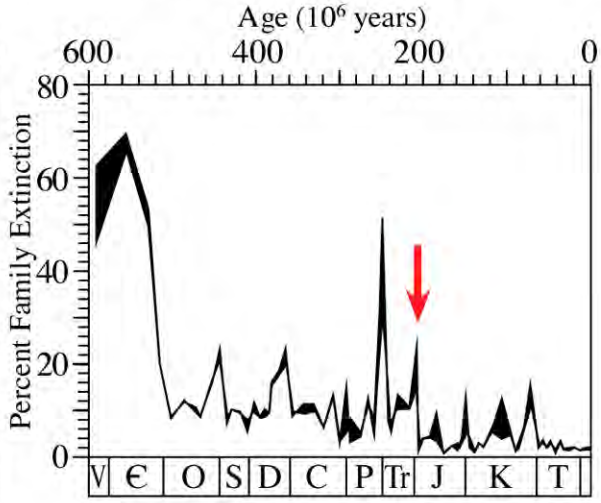

$^{206}Pb/^{238}U$
201.38±0.02
Schoene et al., 2010
Blackburn et al., 2011

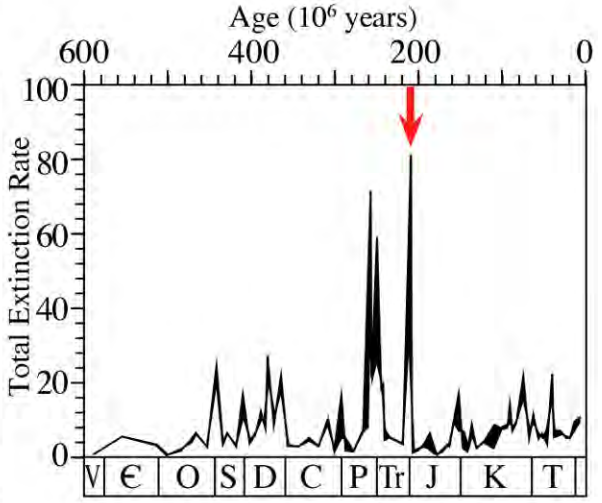


Schoene et al., 2010

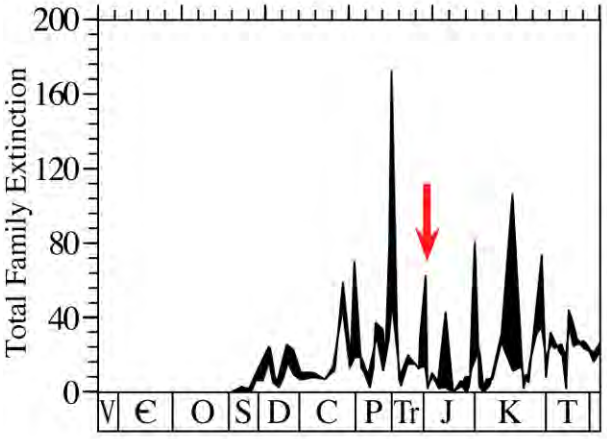
All Organisms

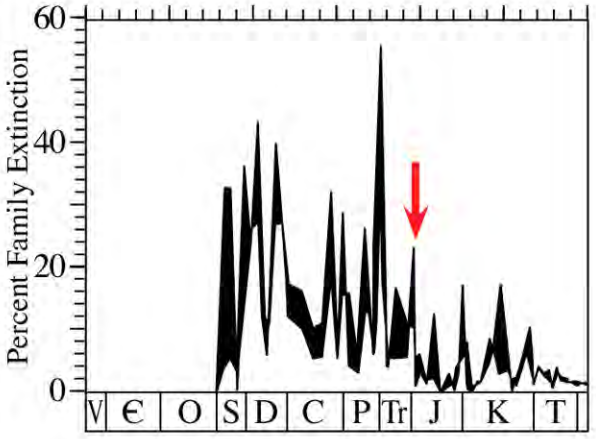


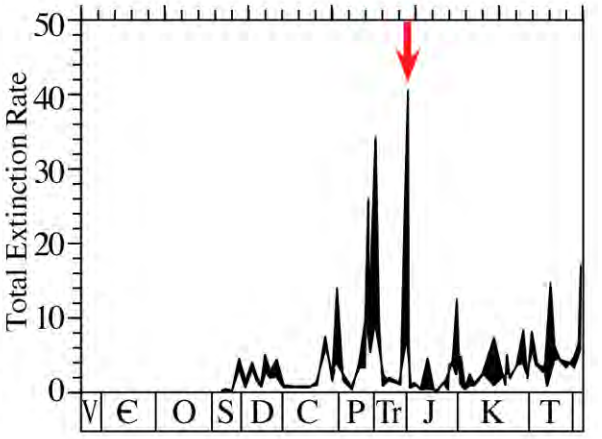




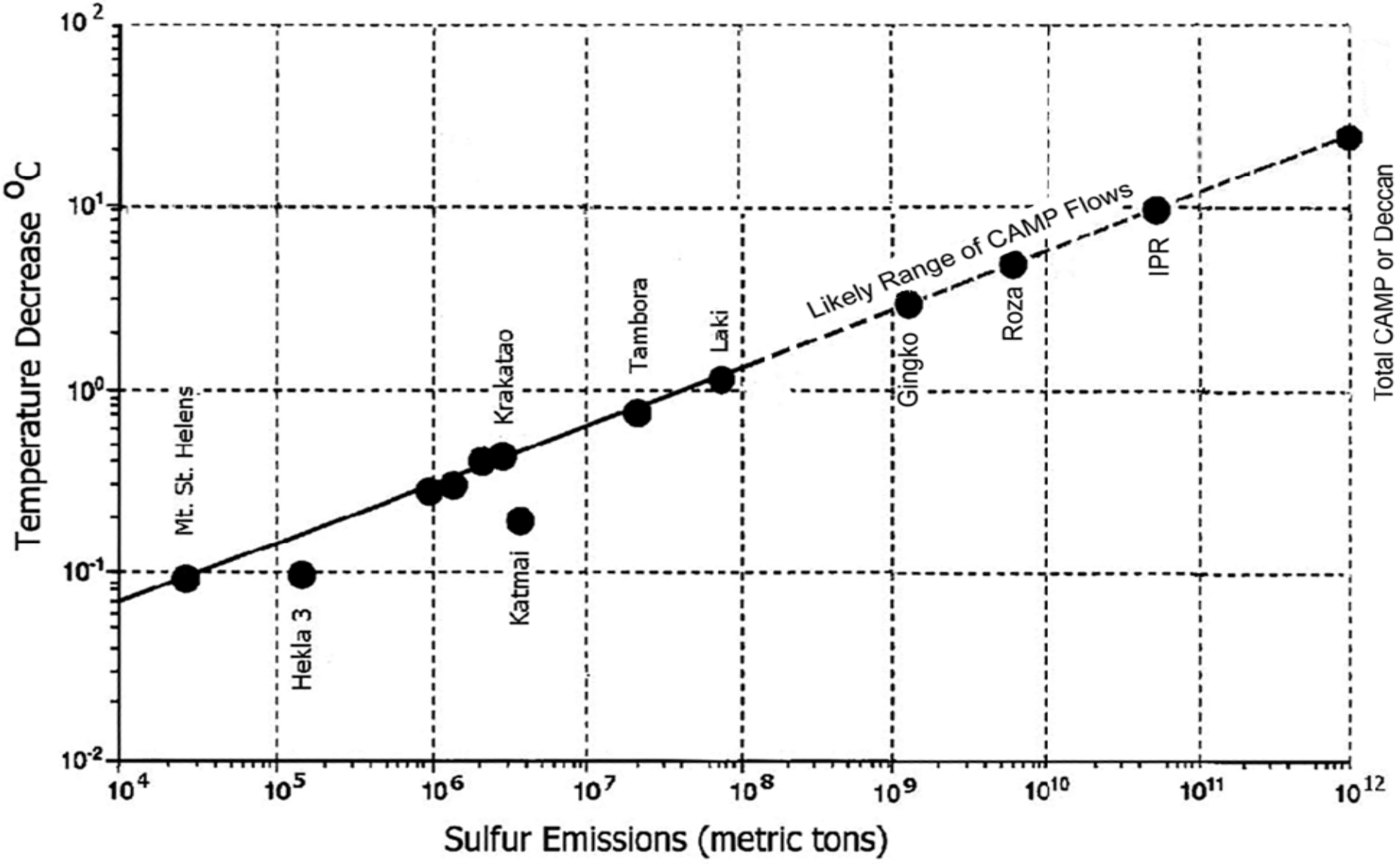
Continental Organisms





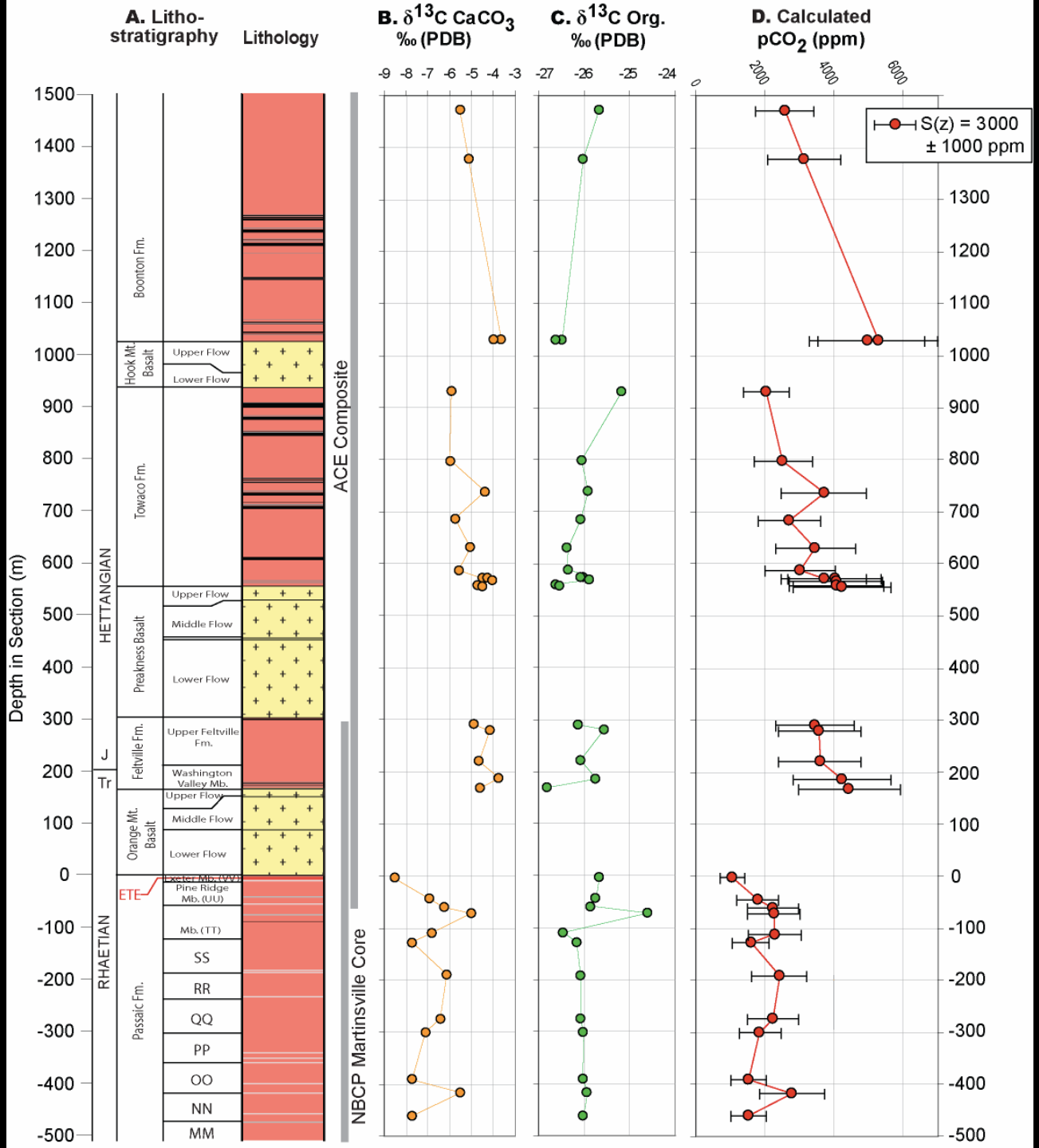


Benton, 1995



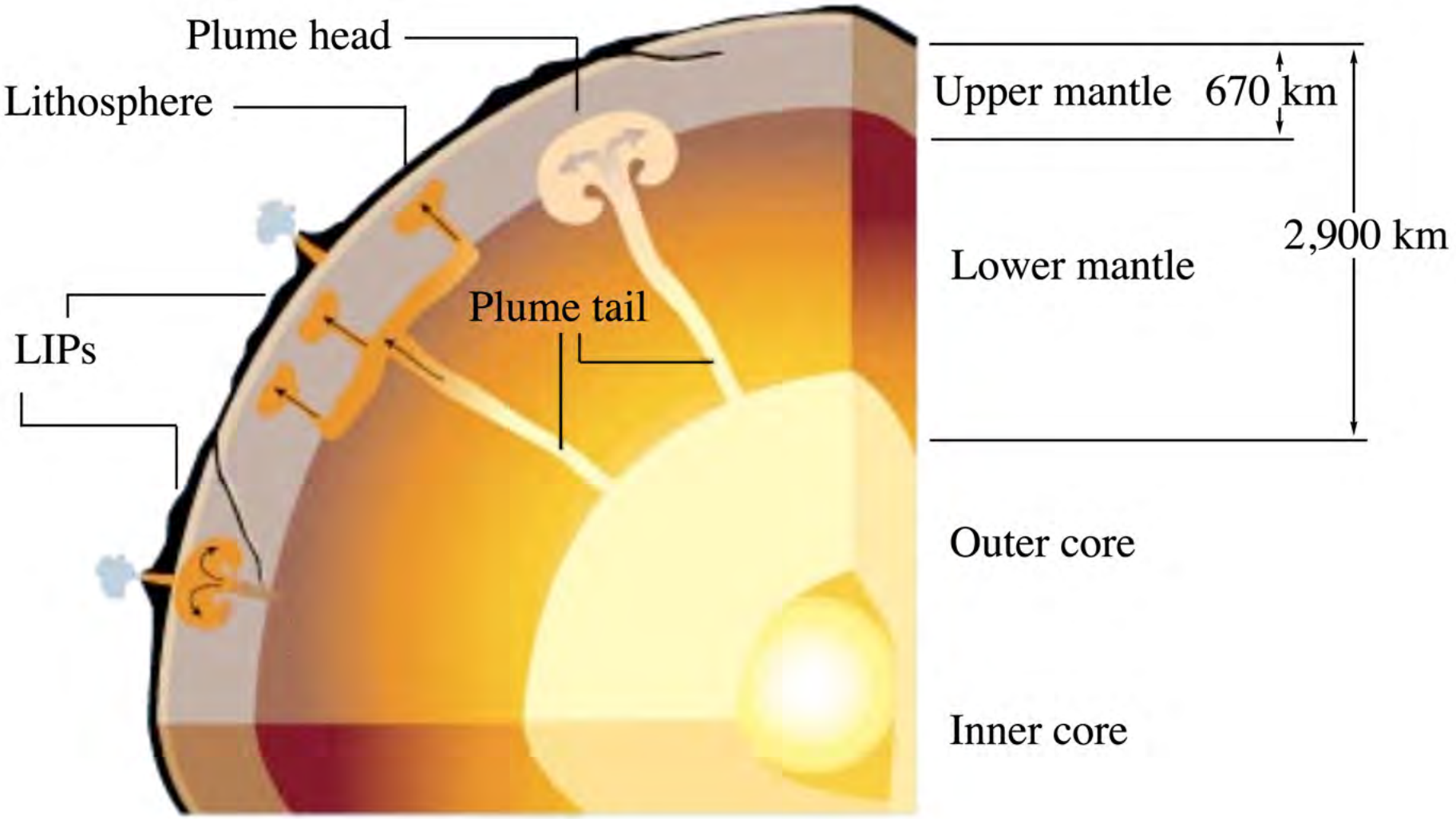
McHone, 2002 adapted from Palais and Sigurdsson [1989].

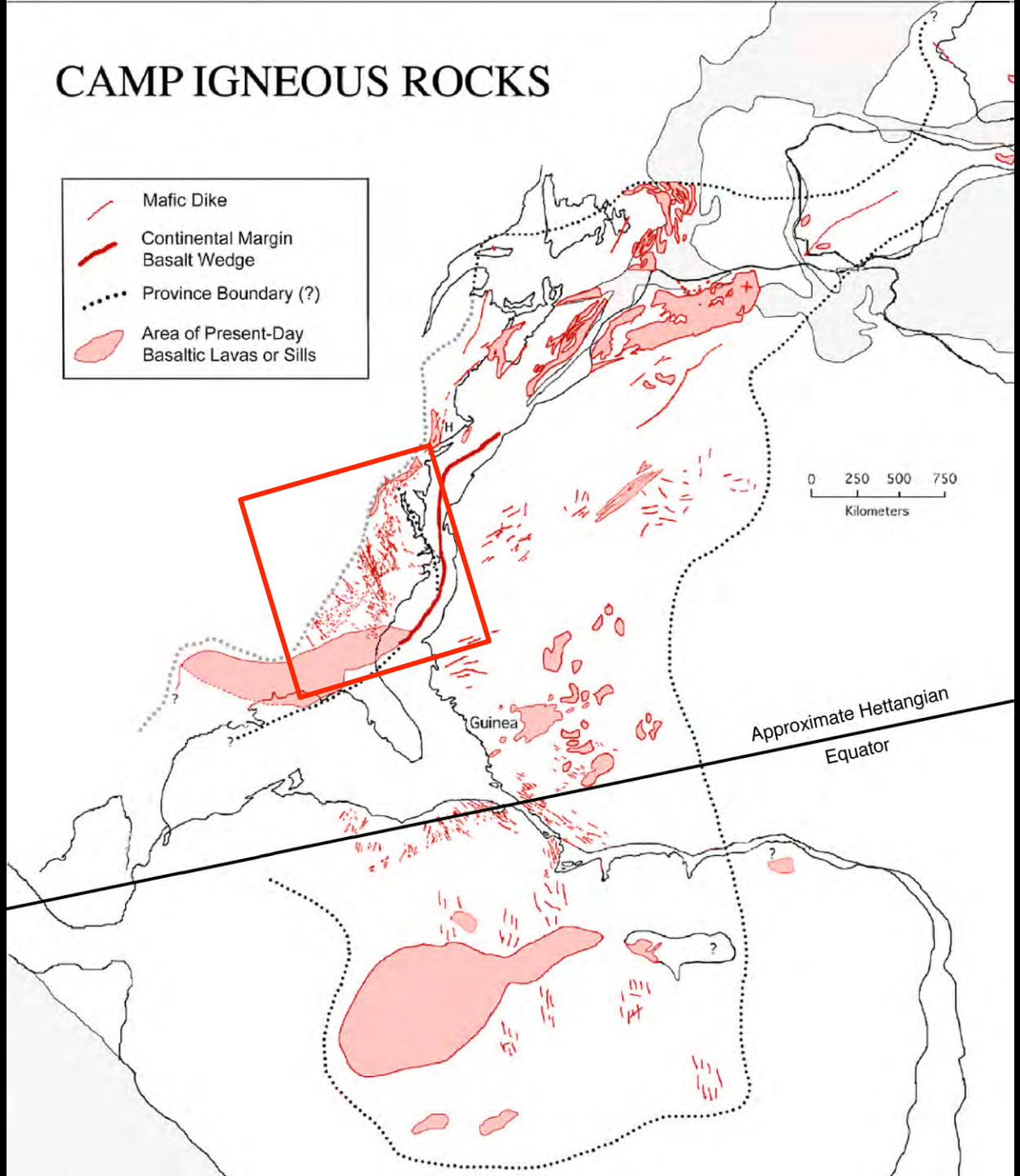
Schaller et al. 2011

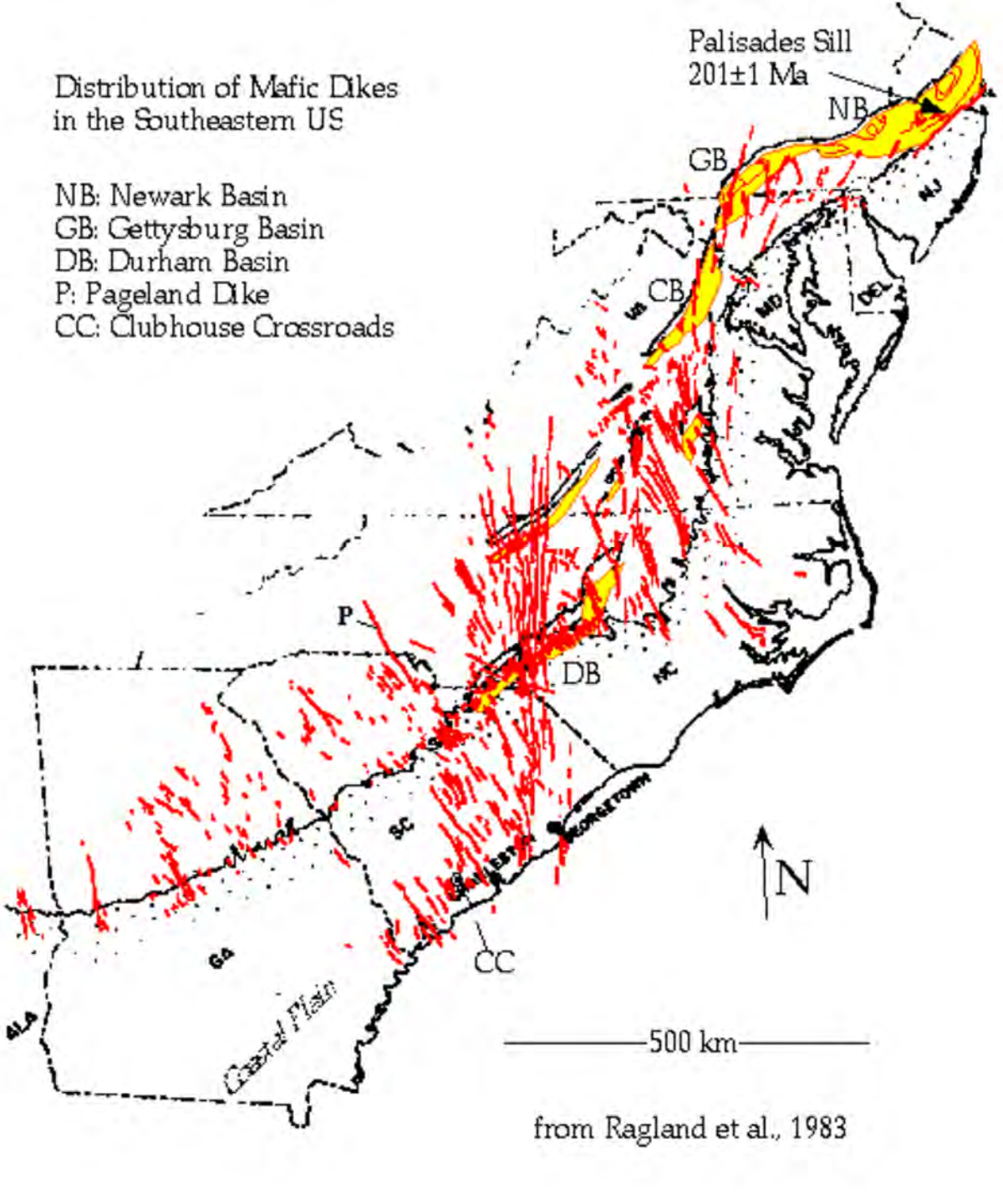


Newark Basin

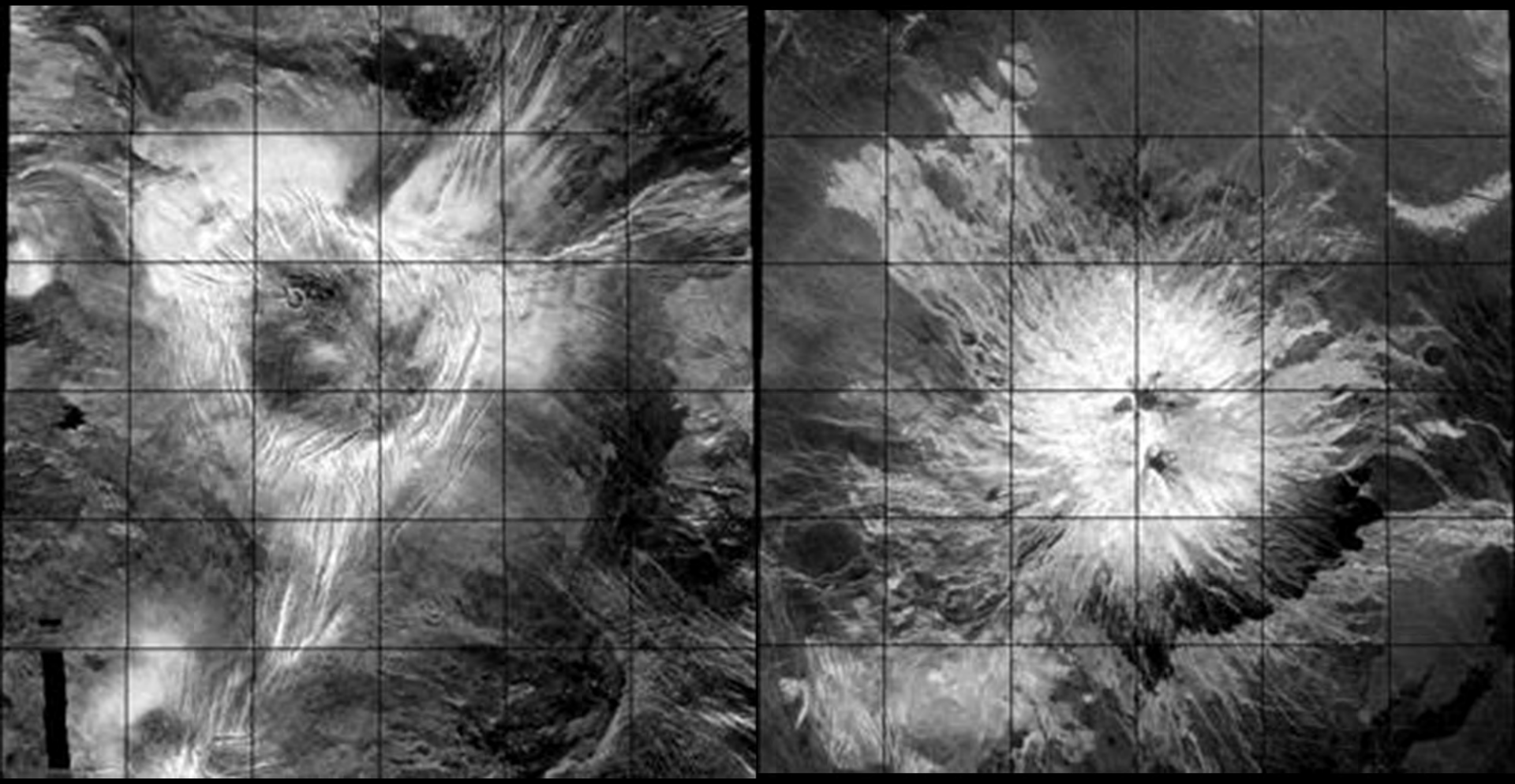
Mantle Plumes




CAMP IGNEOUS ROCKS
Mafic Dike
Continental Margin Basalt Wedge
Province Boundary (?)
Area of Present-Day Basaltic Lavas or Sills
0 250 500 750
Kilometers
Guinea
Approximate Hettangian Equator


Distribution of Mafic Dikes
in the Southeastern US
NB: Newark Basin
GB: Gettysburg Basin
DB: Durham Basin
P: Pageland Dike
CC: Clubhouse Crossroads
Palisades Sill
201±1 Ma
NB
GB
CB
P
DB
CC
N
500 km
Coastal Plain
from Ragland et al., 1983

Magellan Synthetic Aperture Radar (SAR) mosaics

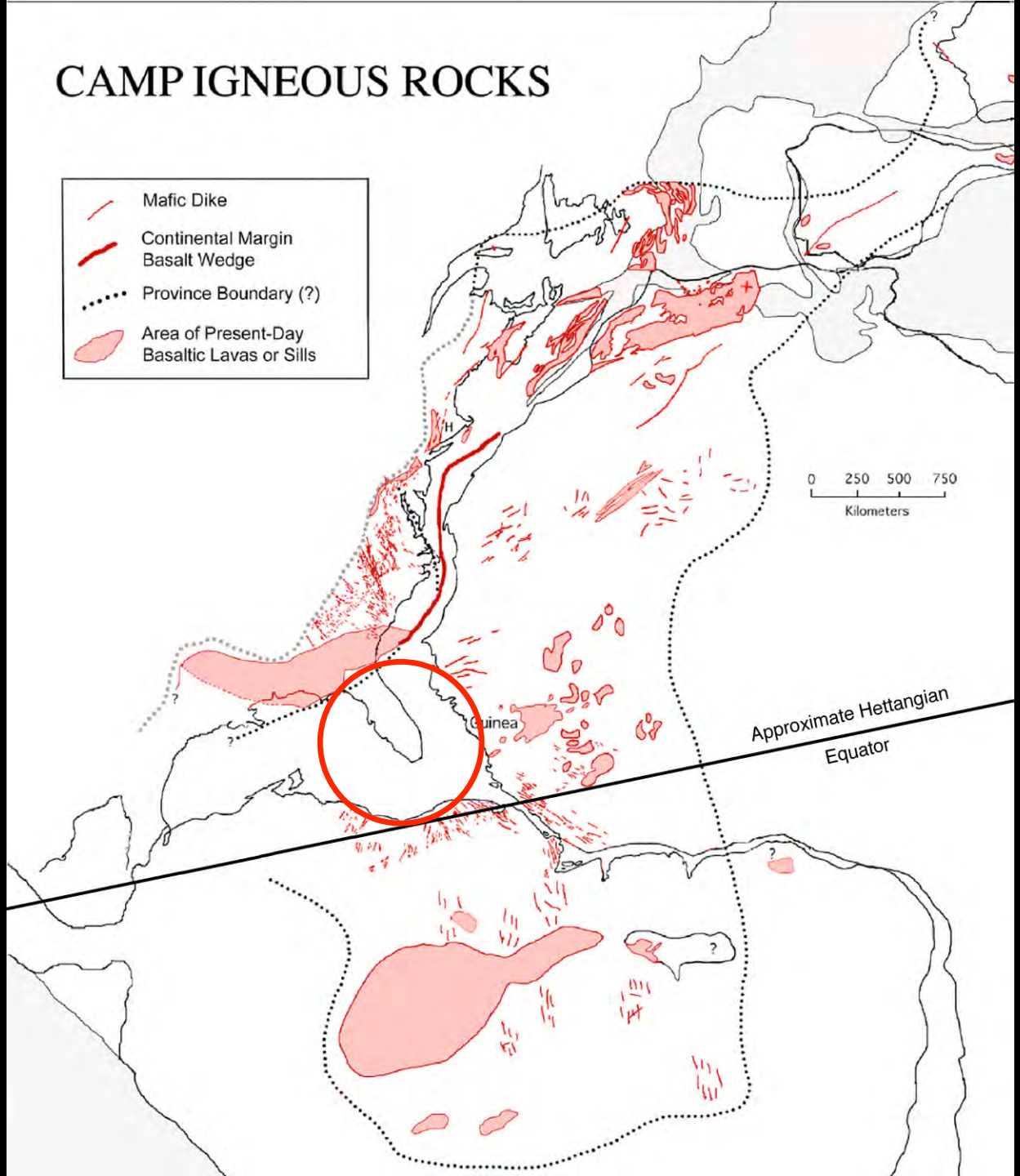


50 km

Irnini Mons

Sapas Mons

http://www.geology.pomona.edu/research/Faculty/Grosfils/Venus/Volcano/large_volcanoes.htm


CAMP IGNEOUS ROCKS
Mafic Dike
Continental Margin Basalt Wedge
Province Boundary (?)
Area of Present-Day Basaltic Lavas or Sills
0 250 500 750
Kilometers
Guinea
Approximate Hettangian Equator

1) CAMP is most areally extensive continetal LIP.
2) Duration of extrusion < 1 m.y. beginning at 201.4 Ma.
3) CAMP fed by giant radial dike swarm.
4) CAMP likely produced many short-lived massive S aerosol coolings and apparently fewer but much more prolonged CO_2-driven global warmings resulting in end-Triassic mass extinction.
5) Geometry and chemistry consistant with localized source in Florida-Bahama region – Dietz's Bahama Nexus, plausibly a plume

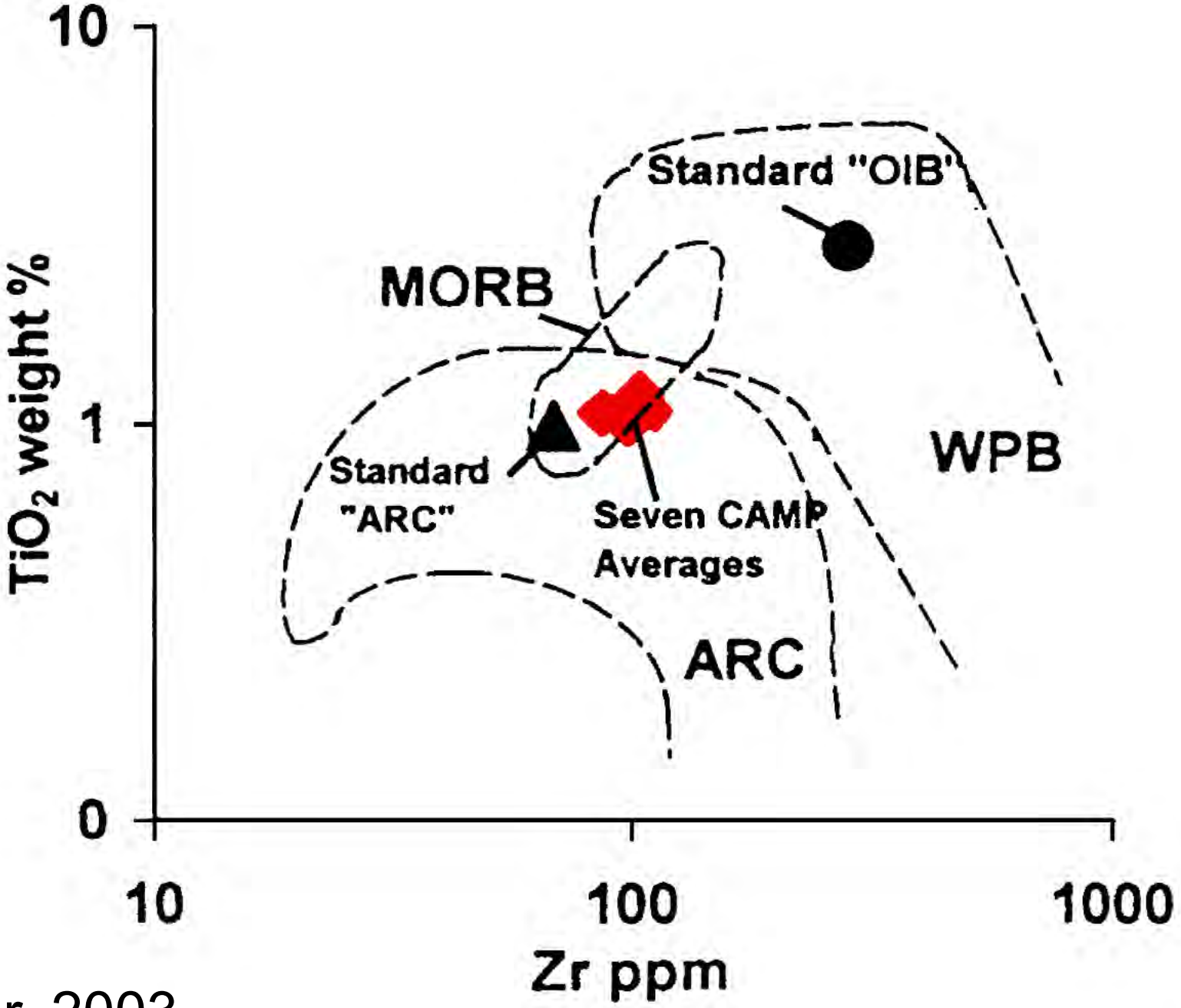
What We Don't Know

1) Its real origin: plume or non-plume.
2) Vertical or lateral feeding.
3) Concomitant geodynamic processes – uplift?
4) Mechanism of increased accommodation in rifts.
5) Continuity and duration of plumbing system and effects on heat flow.
6) Relation to cessation of rifting and inversion.
7) Relationship to Atlantic seafloor.
8) Present crustal and mantle inheritance.

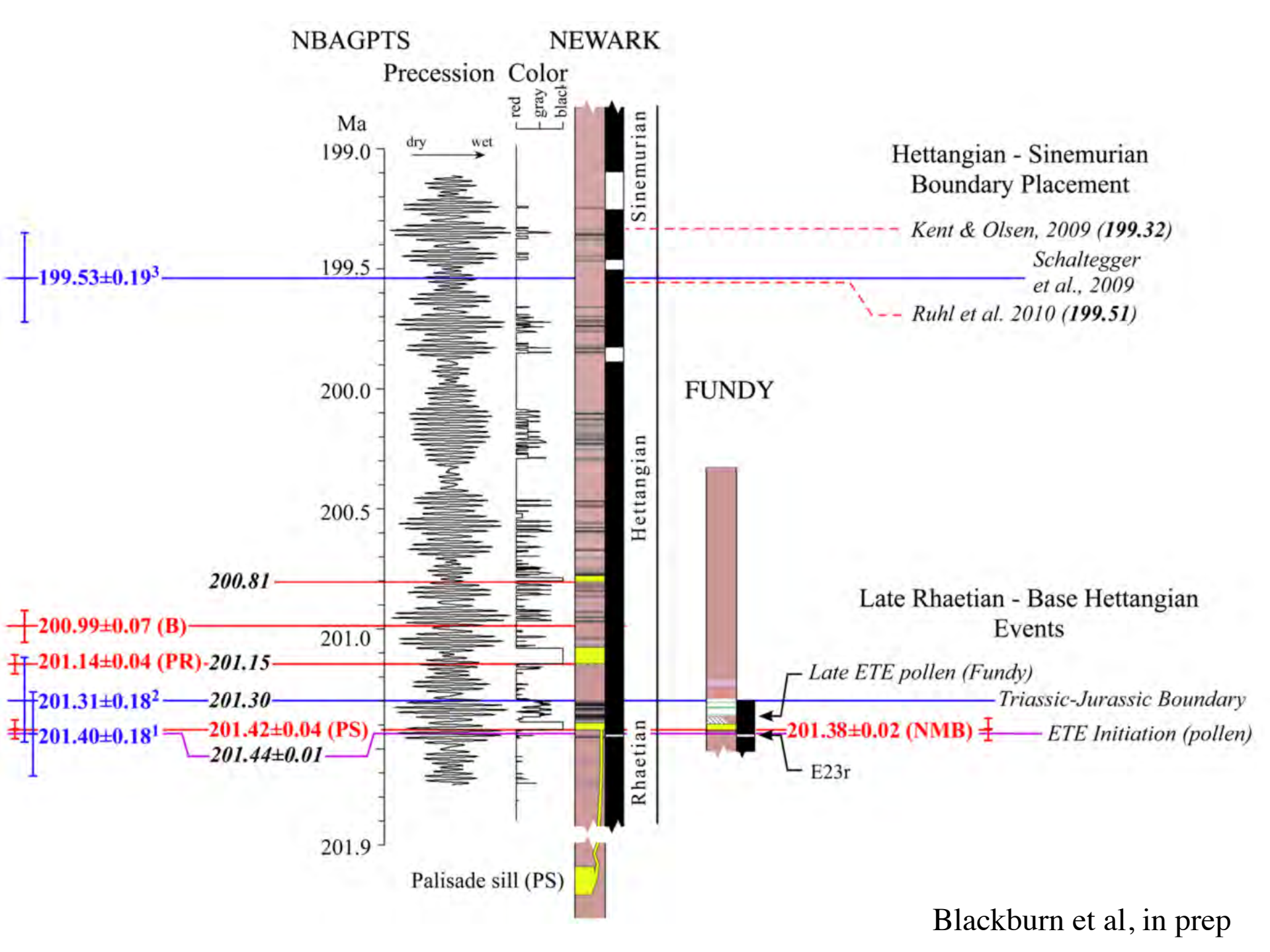
1) History of Continental Rifting.

2) The CAMP LIP.

3) Earliest Atlantic Ocean Crust and Drifting.

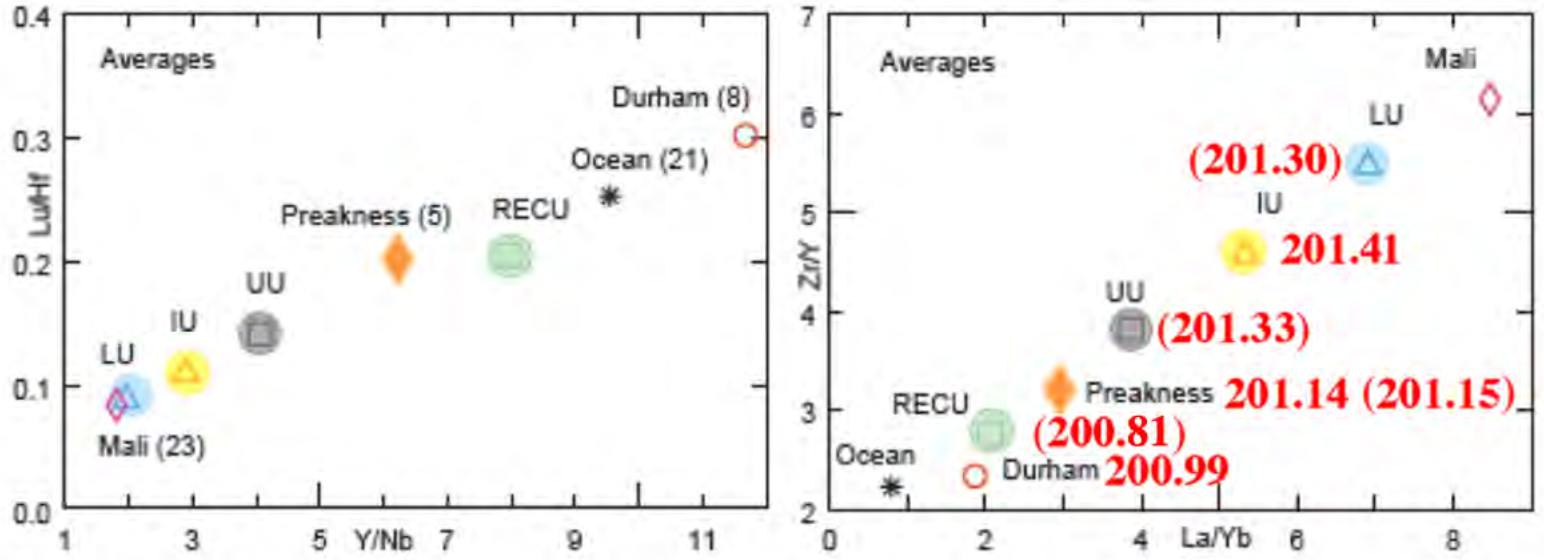

10
1
0
TiO_2 weight %
Standard "OIB"
MORB
WPB
Standard
"ARC"
Seven CAMP
Averages
ARC
10
100
1000
Zr ppm

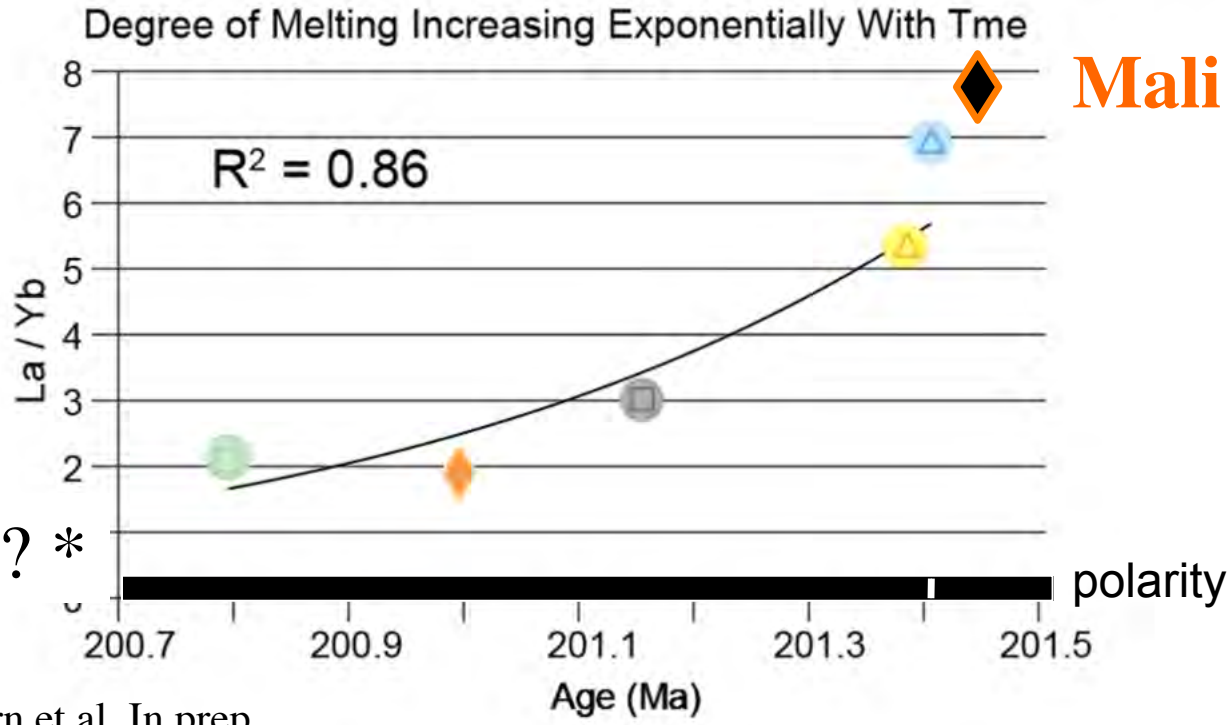
Puffer, 2003



Blackburn et al, in prep

Trace Element Correlations (Deenen, 2010)

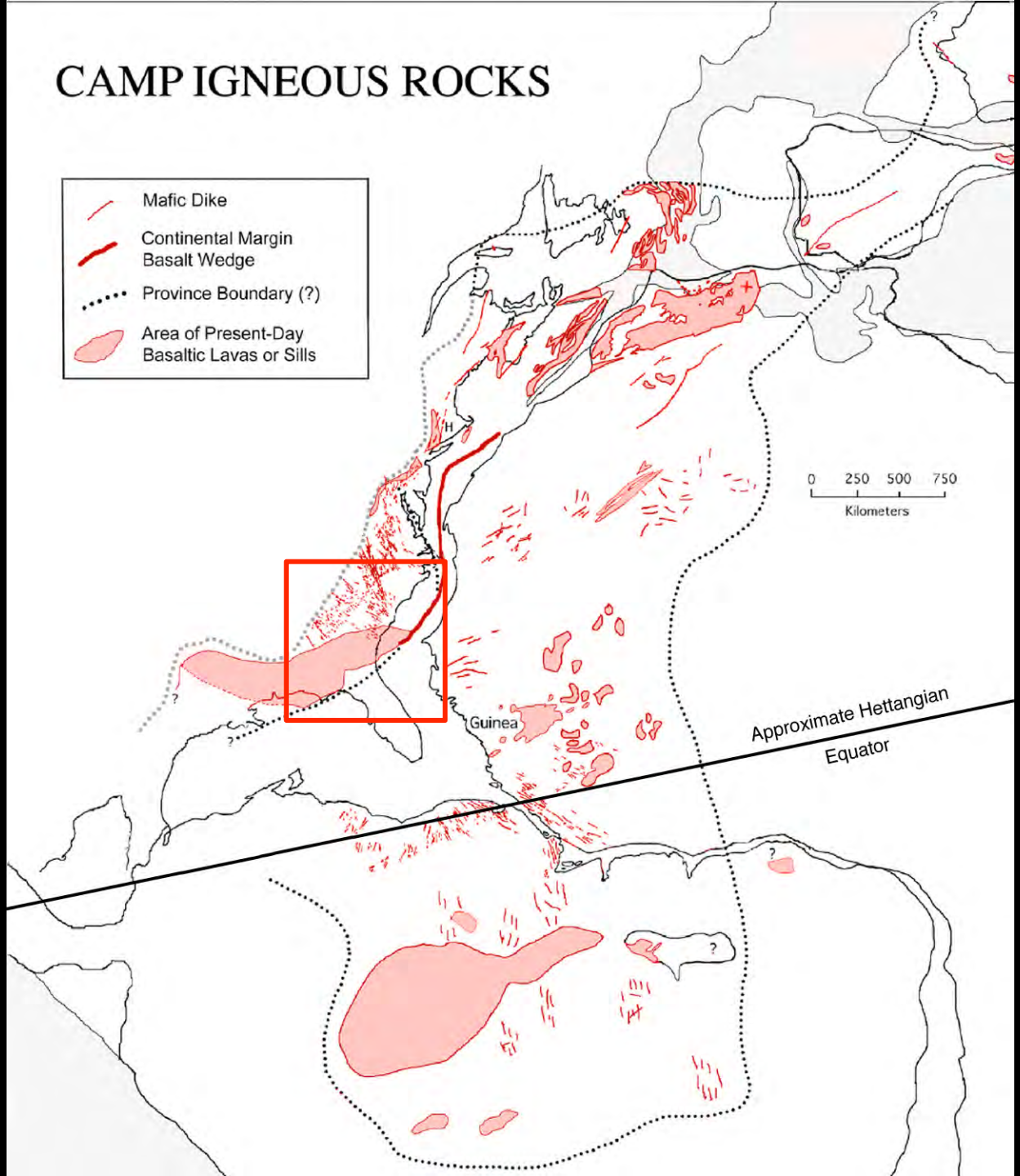


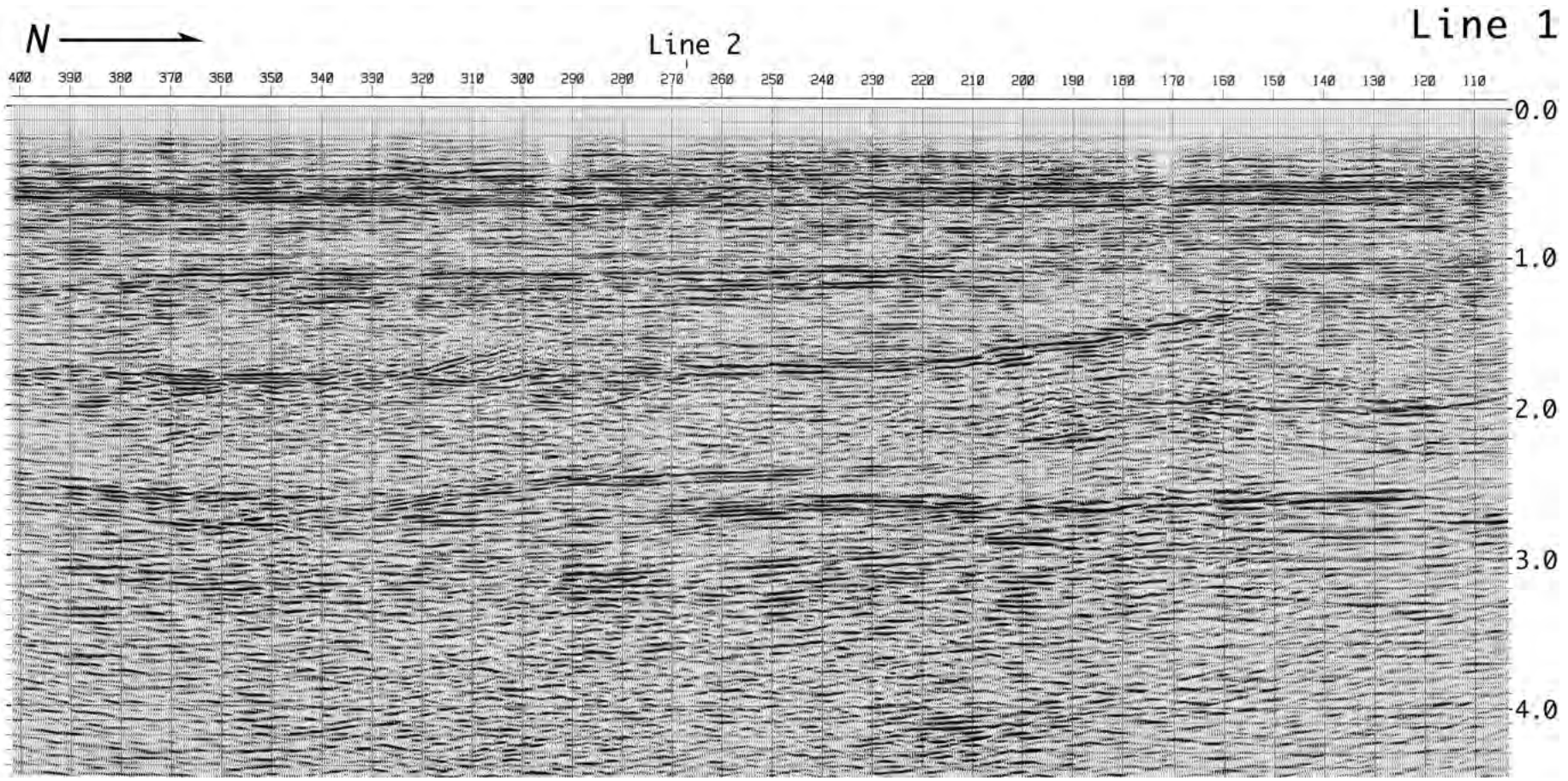


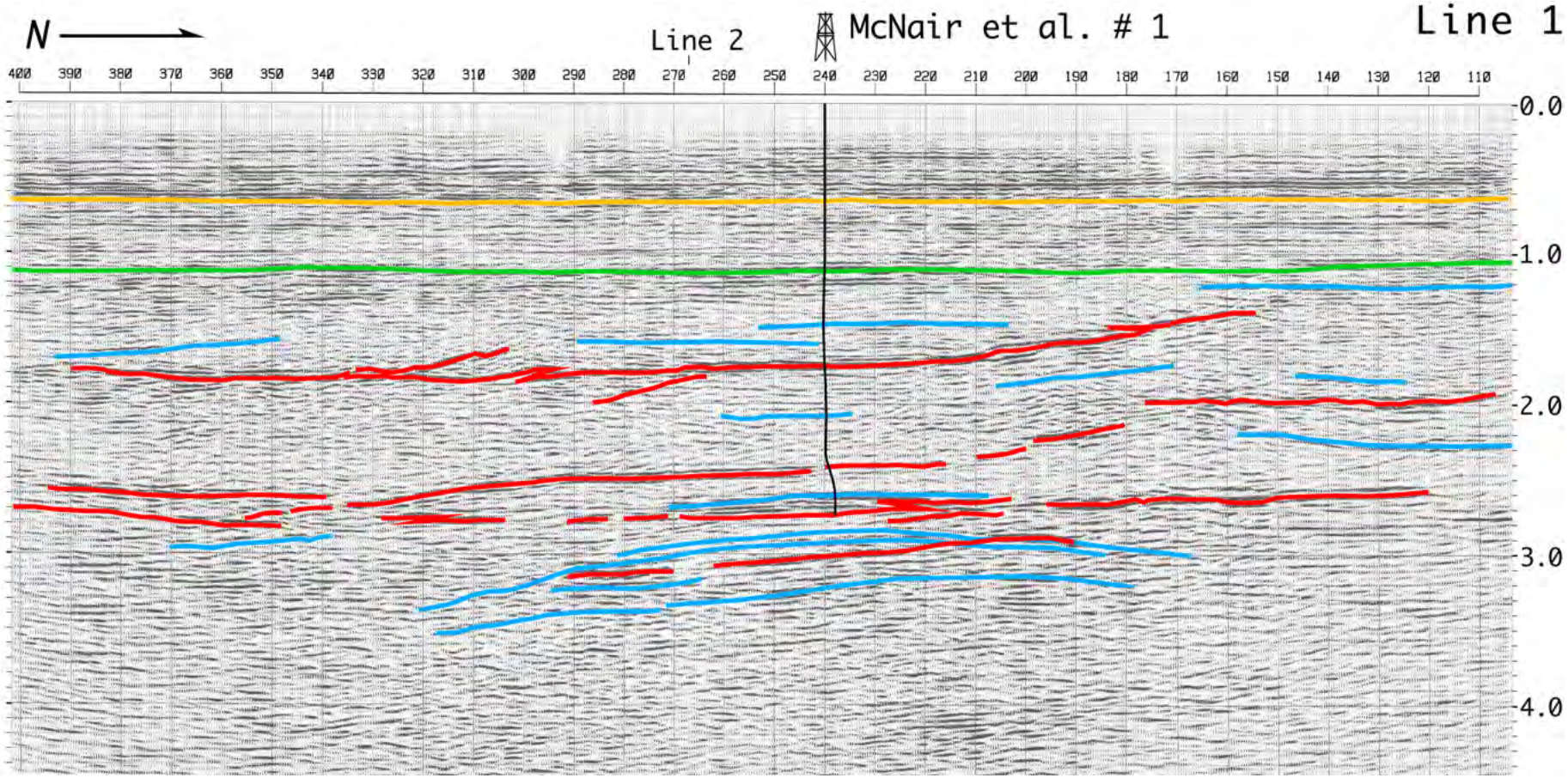
Mali ?

Ocean? *

Dates from Blackburn et al. In prep.


CAMP IGNEOUS ROCKS
Mafic Dike
Continental Margin Basalt Wedge
Province Boundary (?)
Area of Present-Day Basaltic Lavas or Sills
0 250 500 750
Kilometers
Guinea
Approximate Hettangian Equator


N
Line 2
Line 1
400 390 380 370 360 350 340 330 320 310 300 290 280 270 260 250 240 230 220 210 200 190 180 170 160 150 140 130 120 110
0.0
1.0
2.0
3.0
4.0


N
Line 2
McNair et al. # 1
Line 1
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0.0
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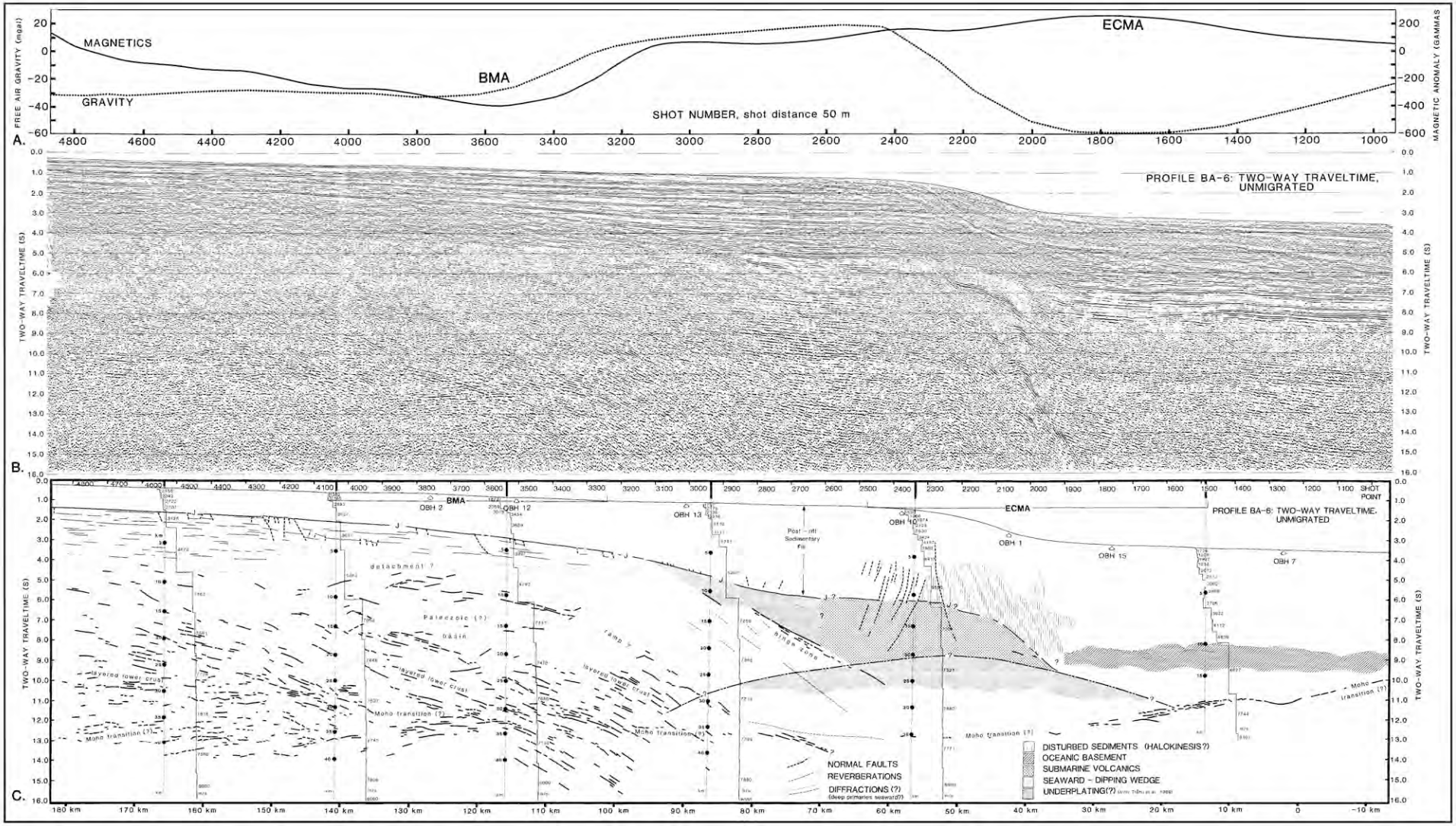
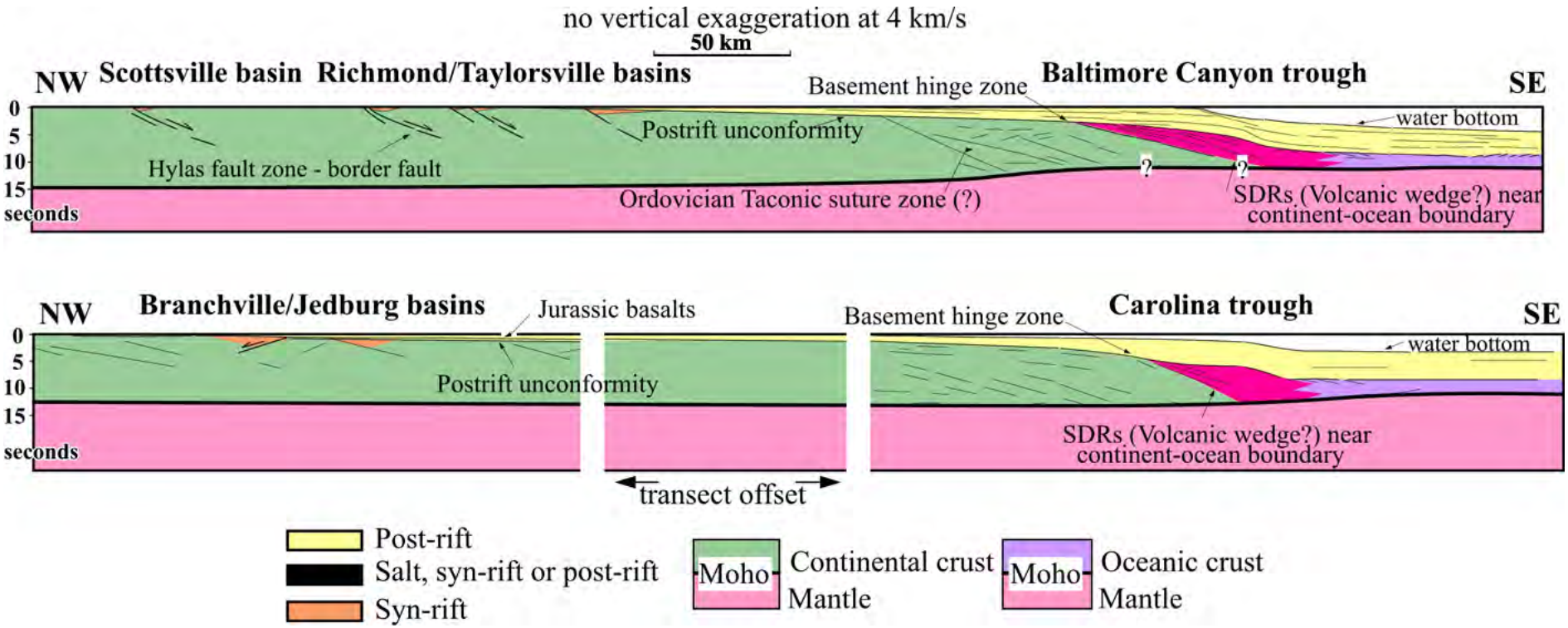


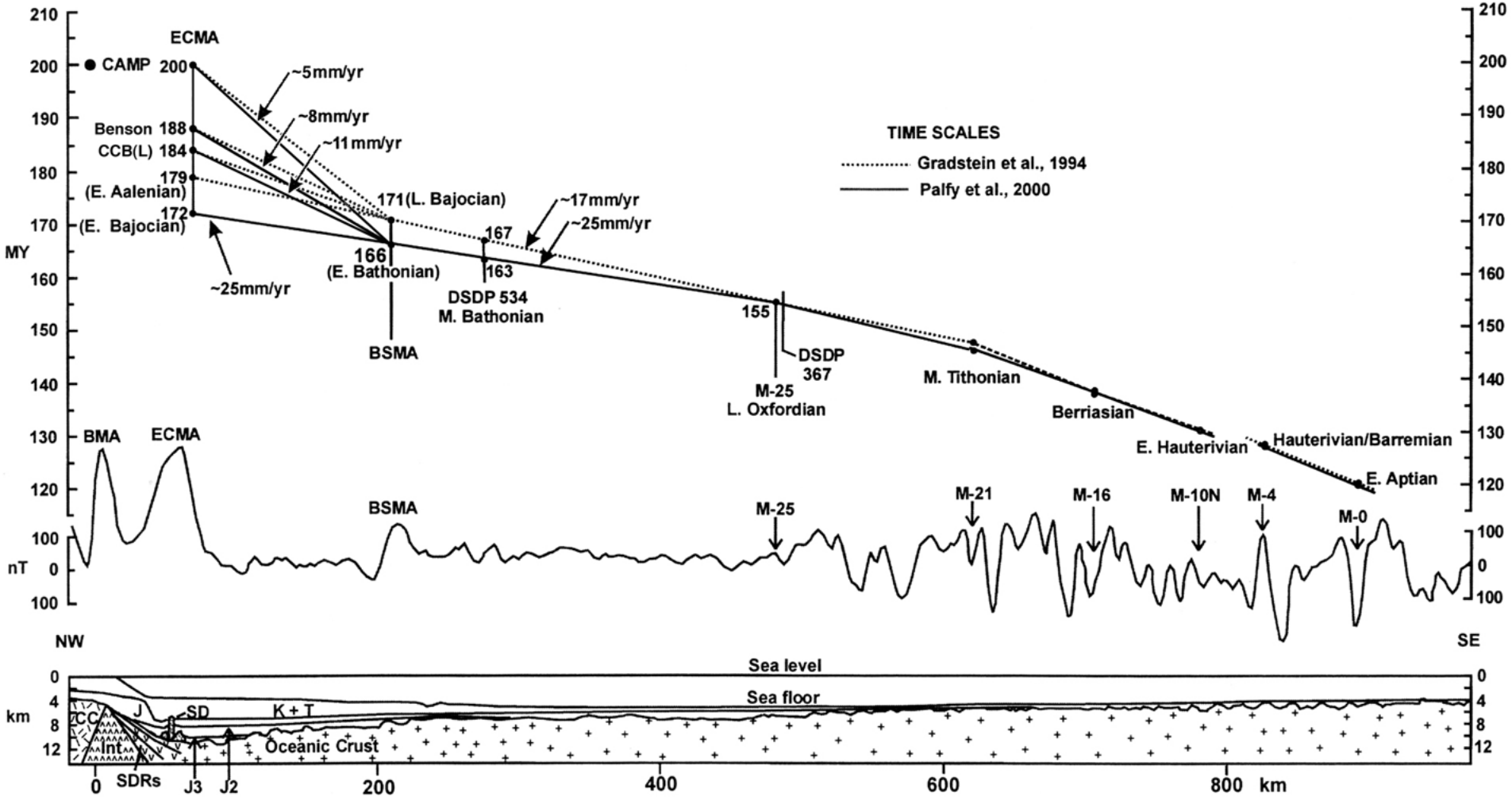
Austin et al. 1990

Southeast US, Continental Margin

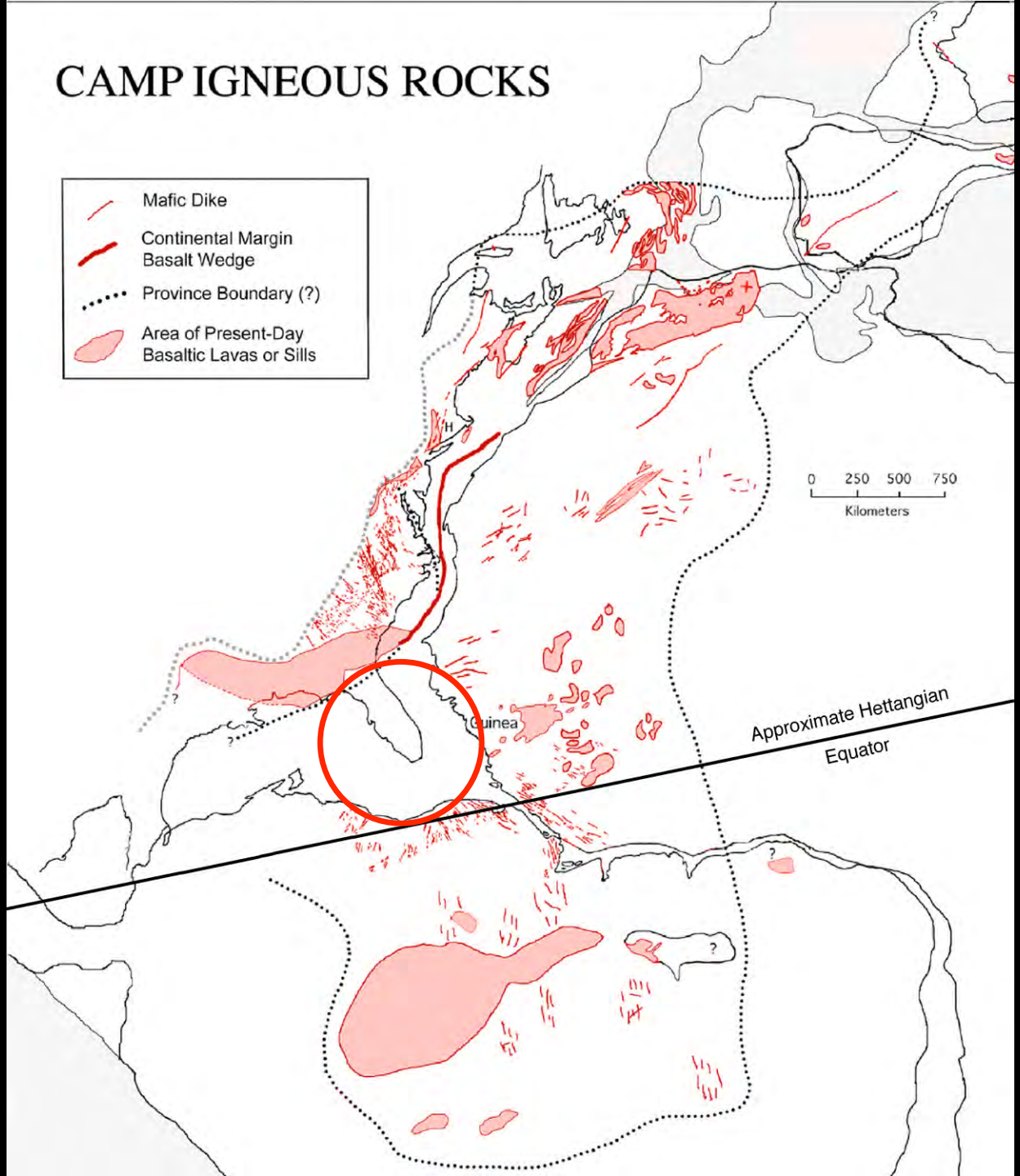


Modified from Withjack & Schlische, 2005

Age of initial Atlantic Ocean Crust and SDRs



Modified from Benson, 2003 and Sheridan, 1980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Approximate Hettangian Equator

Schettino and Turco, 2009

1) Age of oldest Atlantic seafloor and SDRs unknown.
2) Chemistry of CAMP trends very rapidly, and exponentially, to ocean basalt.
3) Non-rifted basalt flows on South Georgia Rift may be related to SDRs even if j-reflector not reliable.
4) SDRs are plausible part of CAMP.
5) Both ECMA and BSMA may be conjugate sdrs, stranded by ridge jump.

What We Don’t Know

1) All of the above.