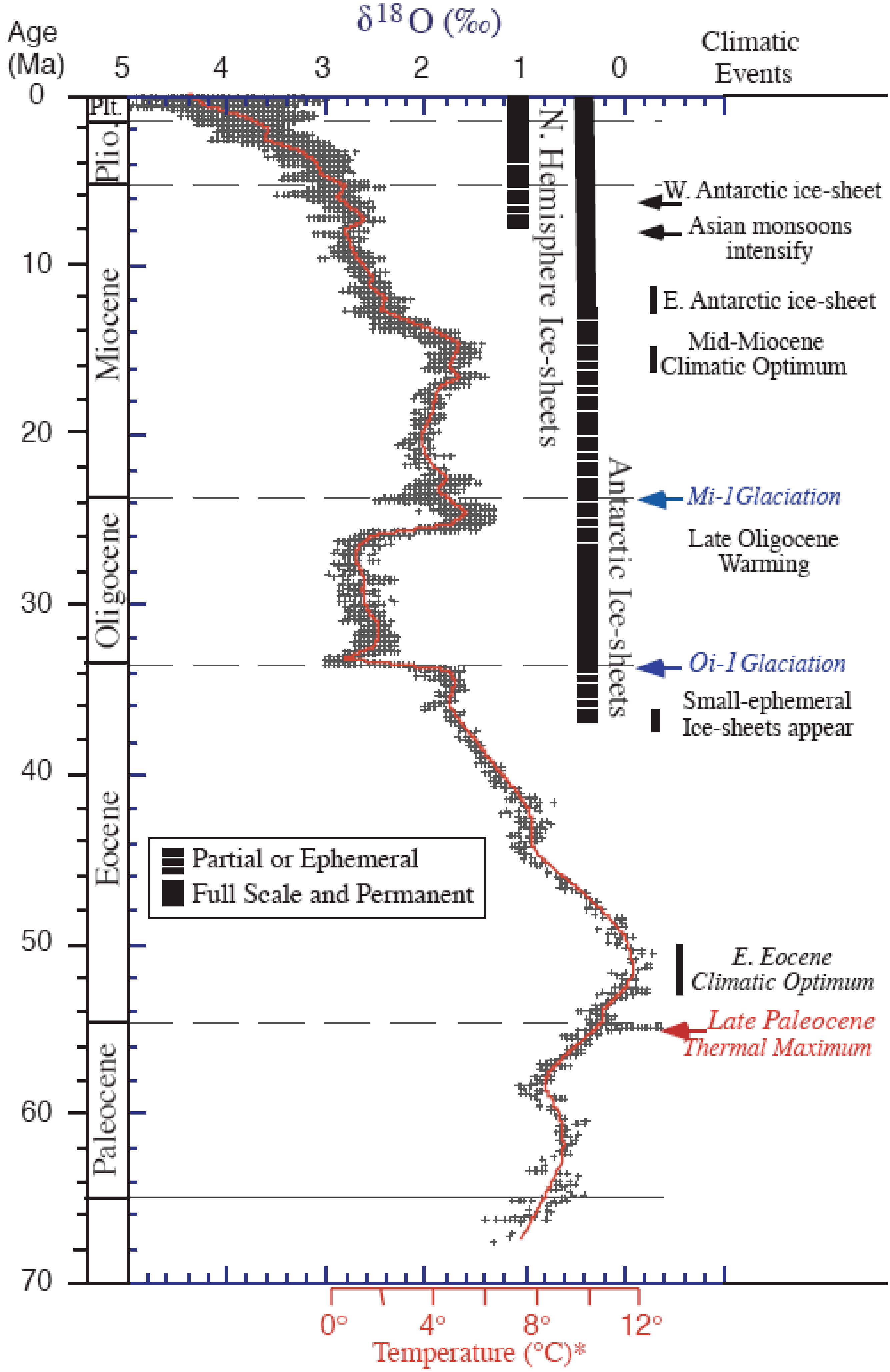
Cenozoic climate

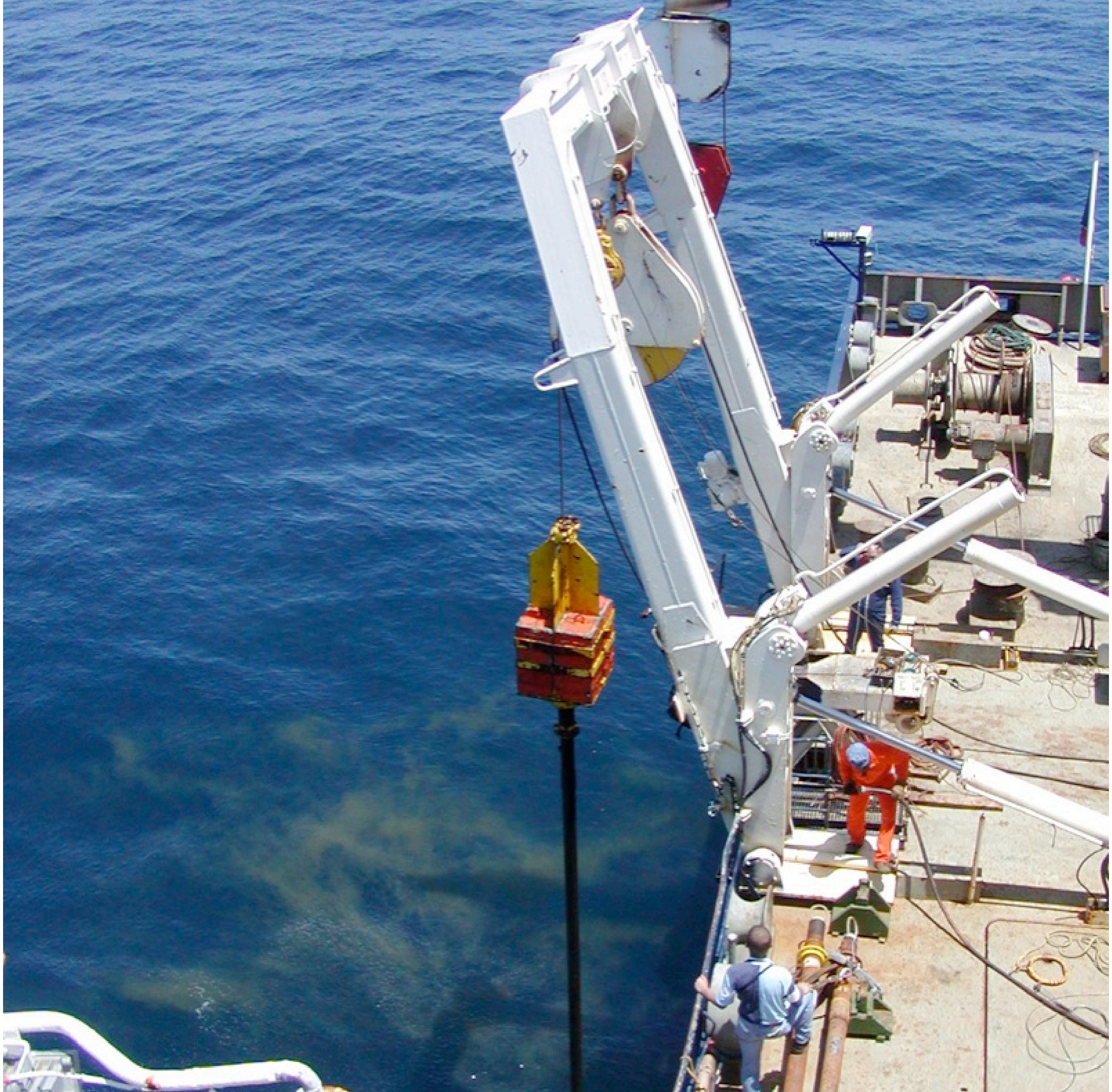
- Geological time, timescale
- Importance of signal size: contrast to historical climate change
-

Climate determinants on geological timescales

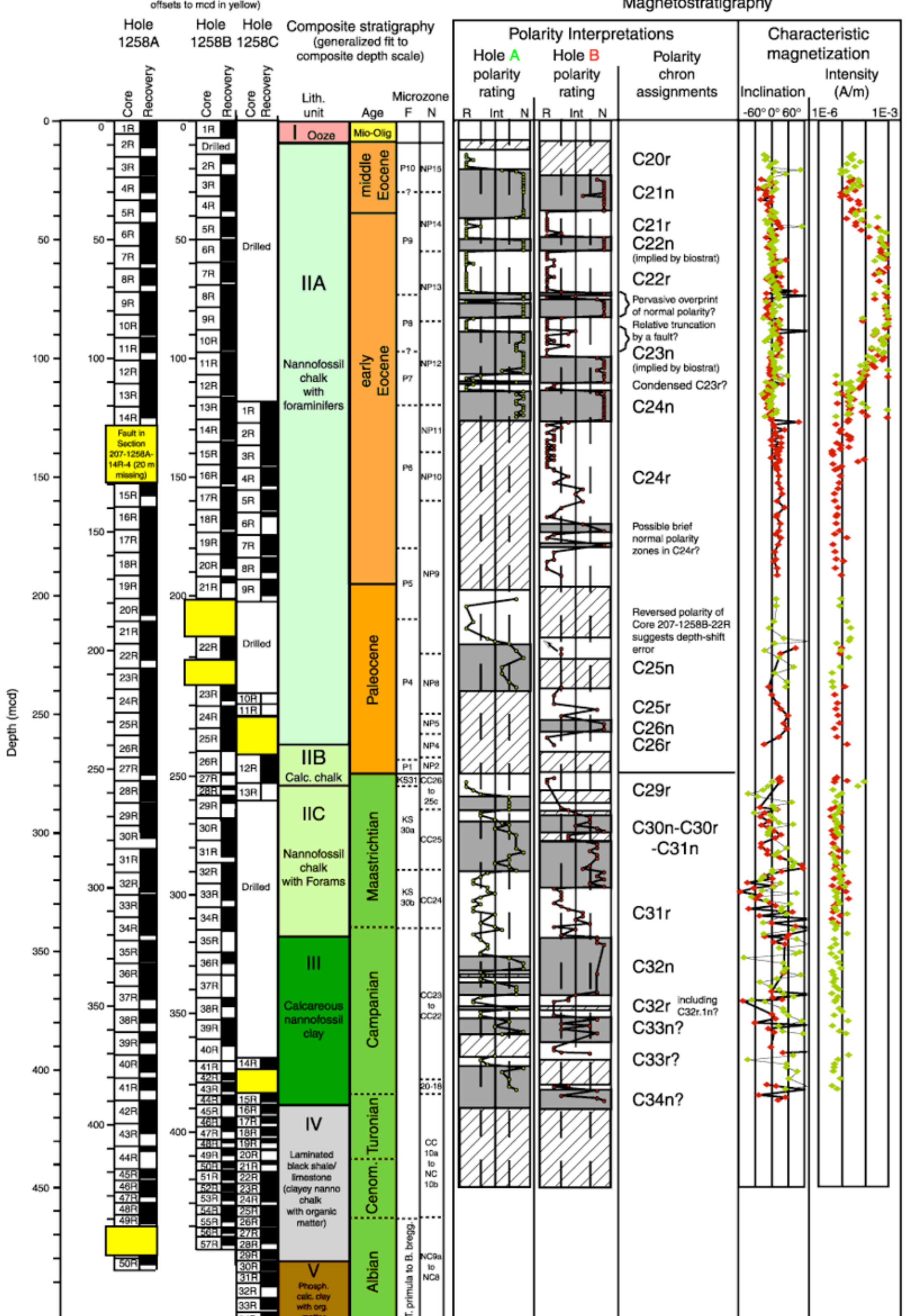
- Continental geography
- Ocean gateways and bathymetry
- Greenhouse gases



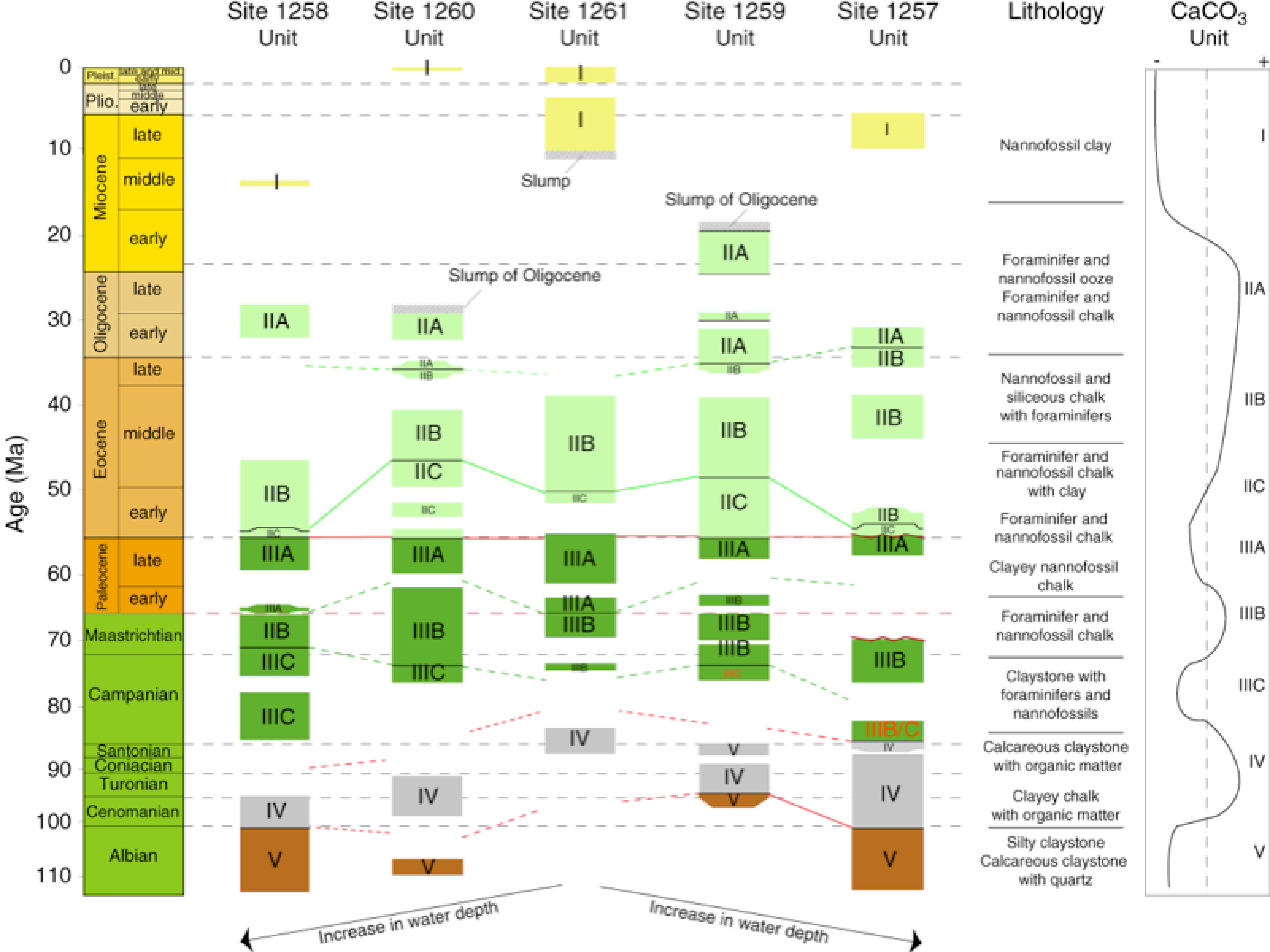
Age (Ma)
δ18O (‰)
Climatic Events
0
10
20
30
40
50
60
70
5
4
3
2
1
0
Plt.
Plio.
Miocene
Oligocene
Eocene
Paleocene
N. Hemisphere Ice-sheets
Antarctic Ice-sheets
W. Antarctic ice-sheet
Asian monsoons intensify
E. Antarctic ice-sheet
Mid-Miocene Climatic Optimum
Mi-1 Glaciation
Late Oligocene Warming
Oi-1 Glaciation
Small-ephemeral Ice-sheets appear
E. Eocene Climatic Optimum
Late Paleocene Thermal Maximum
Partial or Ephemeral
Full Scale and Permanent
0°
4°
8°
12°
Temperature (°C)*




NO
SMOKING



offsets to mcd in yellow)
Hole 1258A
Hole 1258B
Hole 1258C
Core
Recovery
Composite stratigraphy
(generalized fit to composite depth scale)
Lith. unit
Age
Microzone
F
N
Magnetostratigraphy
Polarity Interpretations
Hole A polarity rating
Hole B polarity rating
R
Int
N
Polarity chron assignments
Characteristic magnetization
Inclination
-60° 0° 60°
Intensity (A/m)
1E-6
1E-3
Depth (mcd)
Drilled
Fault in Section 207-1258A-14R-4 (20 m missing)
I
Ooze
Mio-Olig
IIA
Nannofossil chalk with foraminifers
middle Eocene
early Eocene
Paleocene
IIB
Calc. chalk
IIC
Nannofossil chalk with Forams
Maastrichtian
III
Calcareous nannofossil clay
Campanian
IV
Laminated black shale/ limestone (clayey nanno chalk with organic matter)
Turonian
Cenom.
Albian
V
Phosph. calc. clay with org.
T. primula to B. bregg.
C20r
C21n
C21r
C22n
(implied by biostrat)
C22r
Pervasive overprint of normal polarity?
Relative truncation by a fault?
C23n
(implied by biostrat)
Condensed C23r?
C24n
C24r
Possible brief normal polarity zones in C24r?
Reversed polarity of Core 207-1258B-22R suggests depth-shift error
C25n
C25r
C26n
C26r
C29r
C30n-C30r -C31n
C31r
C32n
C32r
including C32r.1n?
C33n?
C33r?
C34n?



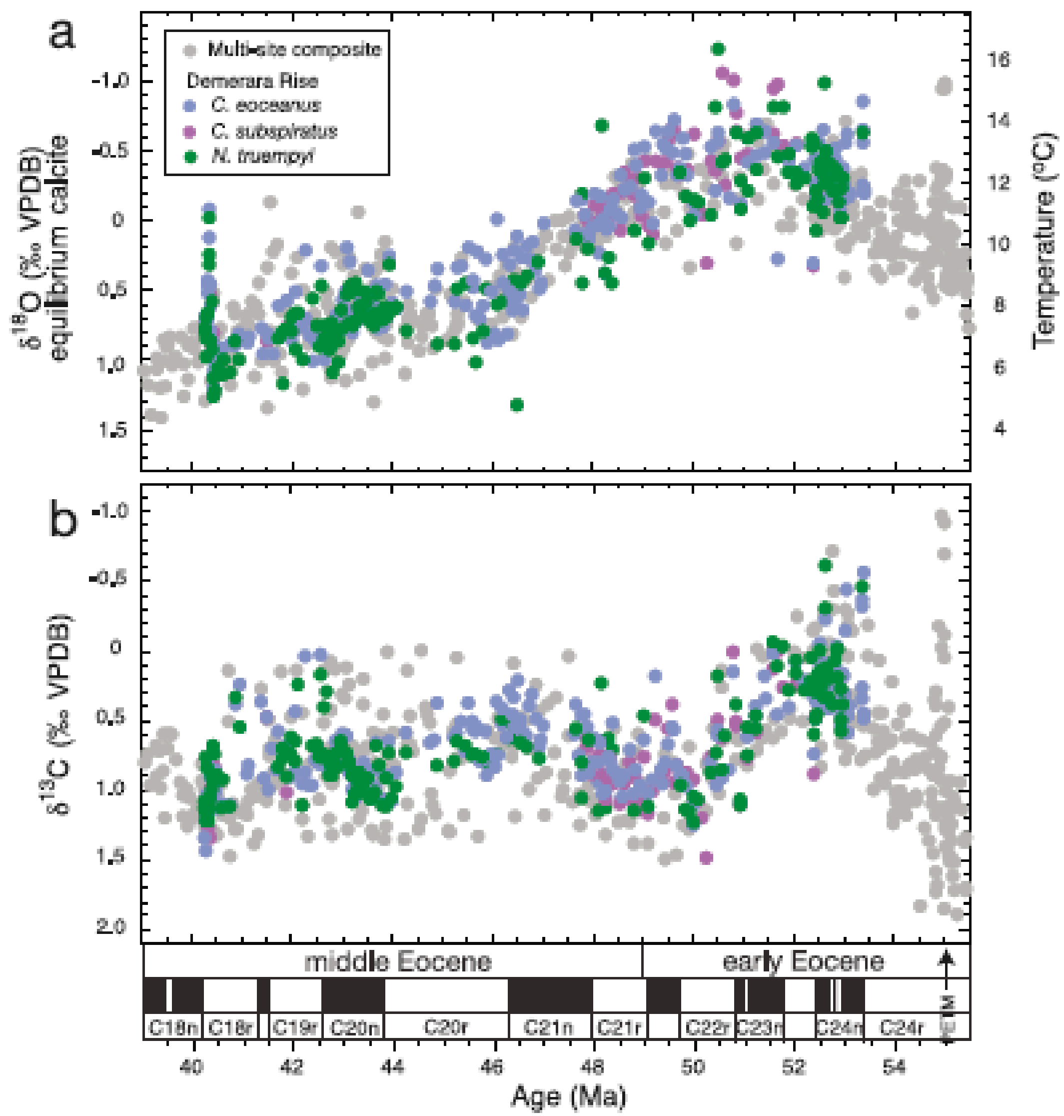
Site 1258 Unit
Site 1260 Unit
Site 1261 Unit
Site 1259 Unit
Site 1257 Unit
Lithology
$CaCO_3$ Unit
Age (Ma)
Pleist.
Plio.
Miocene
Oligocene
Eocene
Paleocene
Maastrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
Albian
Slump
Slump of Oligocene
Slump of Oligocene
Nannofossil clay
Foraminifer and nannofossil ooze Foraminifer and nannofossil chalk
Nannofossil and siliceous chalk with foraminifers
Foraminifer and nannofossil chalk with clay
Foraminifer and nannofossil chalk
Clayey nannofossil chalk
Foraminifer and nannofossil chalk
Claystone with foraminifers and nannofossils
Calcareous claystone with organic matter
Clayey chalk with organic matter
Silty claystone Calcareous claystone with quartz
Increase in water depth
Increase in water depth

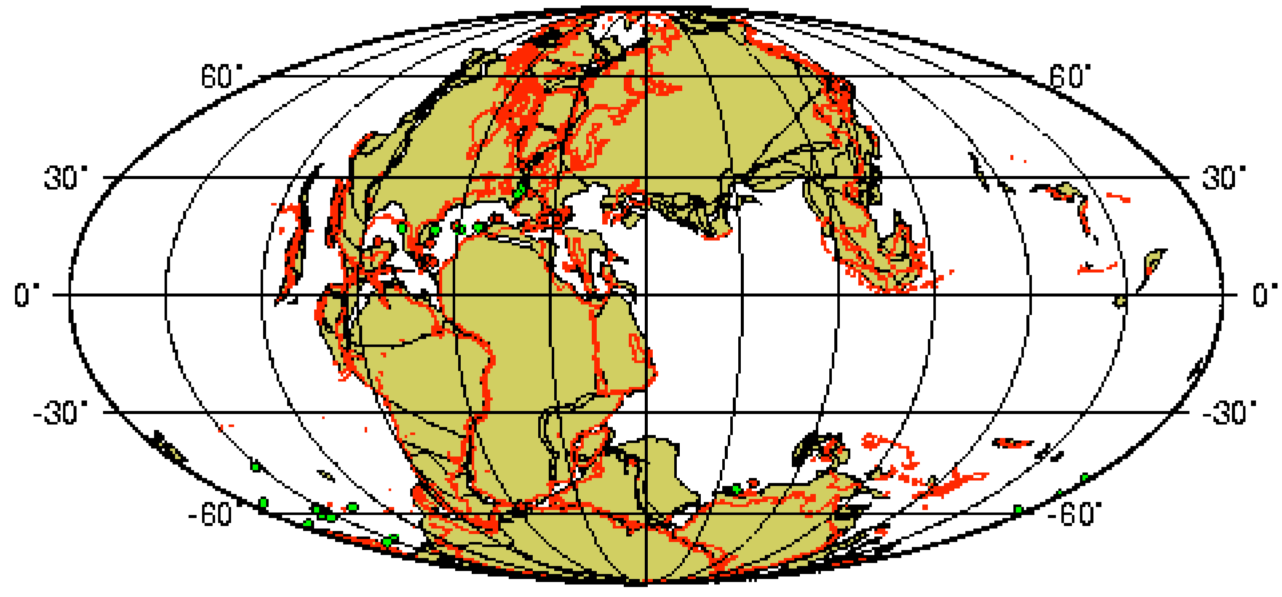
Testing the Cenozoic multisite composite $\delta^{18}O$ and $\delta^{13}C$ curves: New monospecific Eocene records from a single locality, Demerara Rise (Ocean Drilling Program Leg 207)

Philip F. Sexton,[1] Paul A. Wilson,[1] and Richard D. Norris[2]

Received 2 December 2005; revised 16 February 2006; accepted 9 March 2006; published 16 June 2006.

PA2019

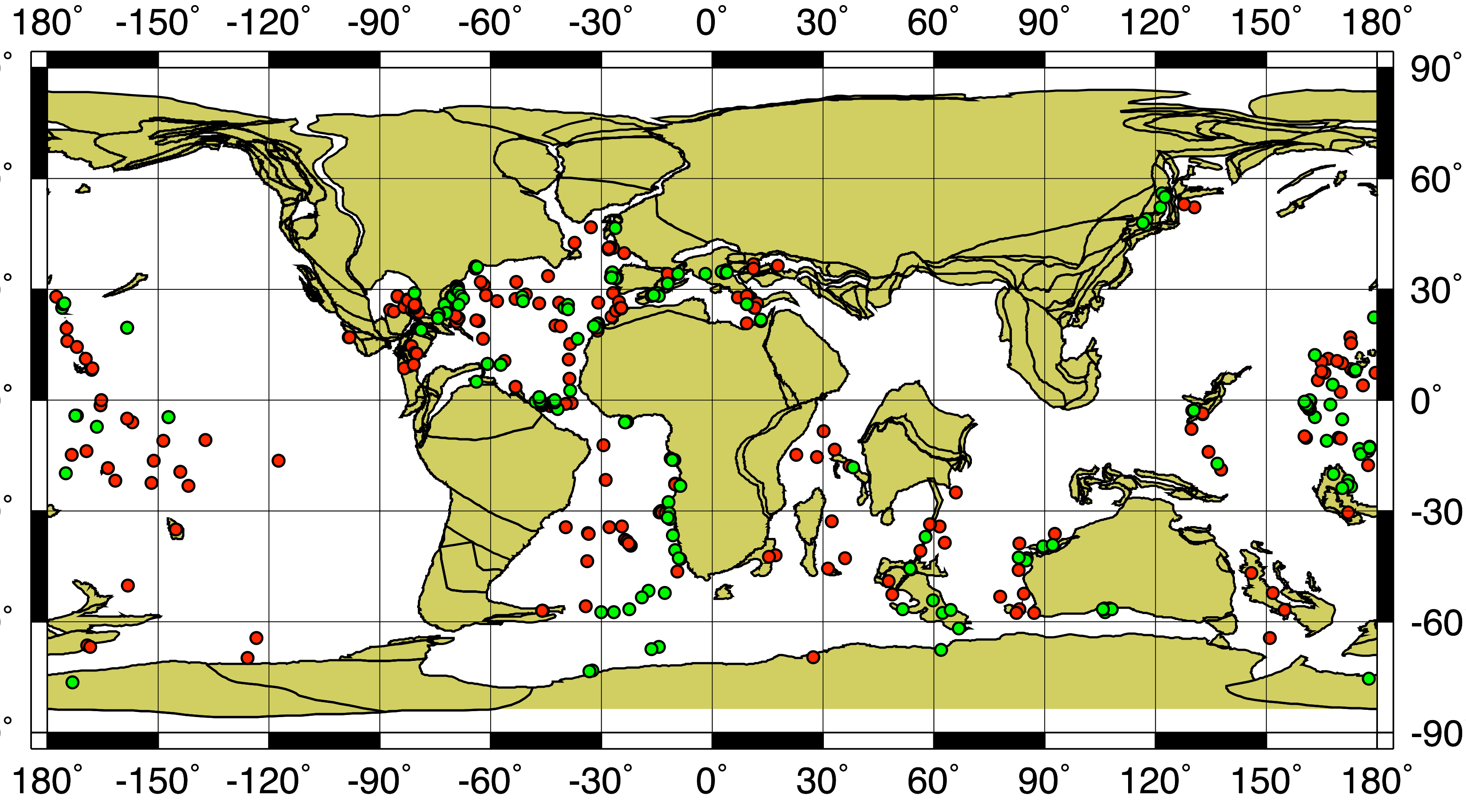




150 My Reconstruction

http://www.odsn.de/odsn/services/paleomap/

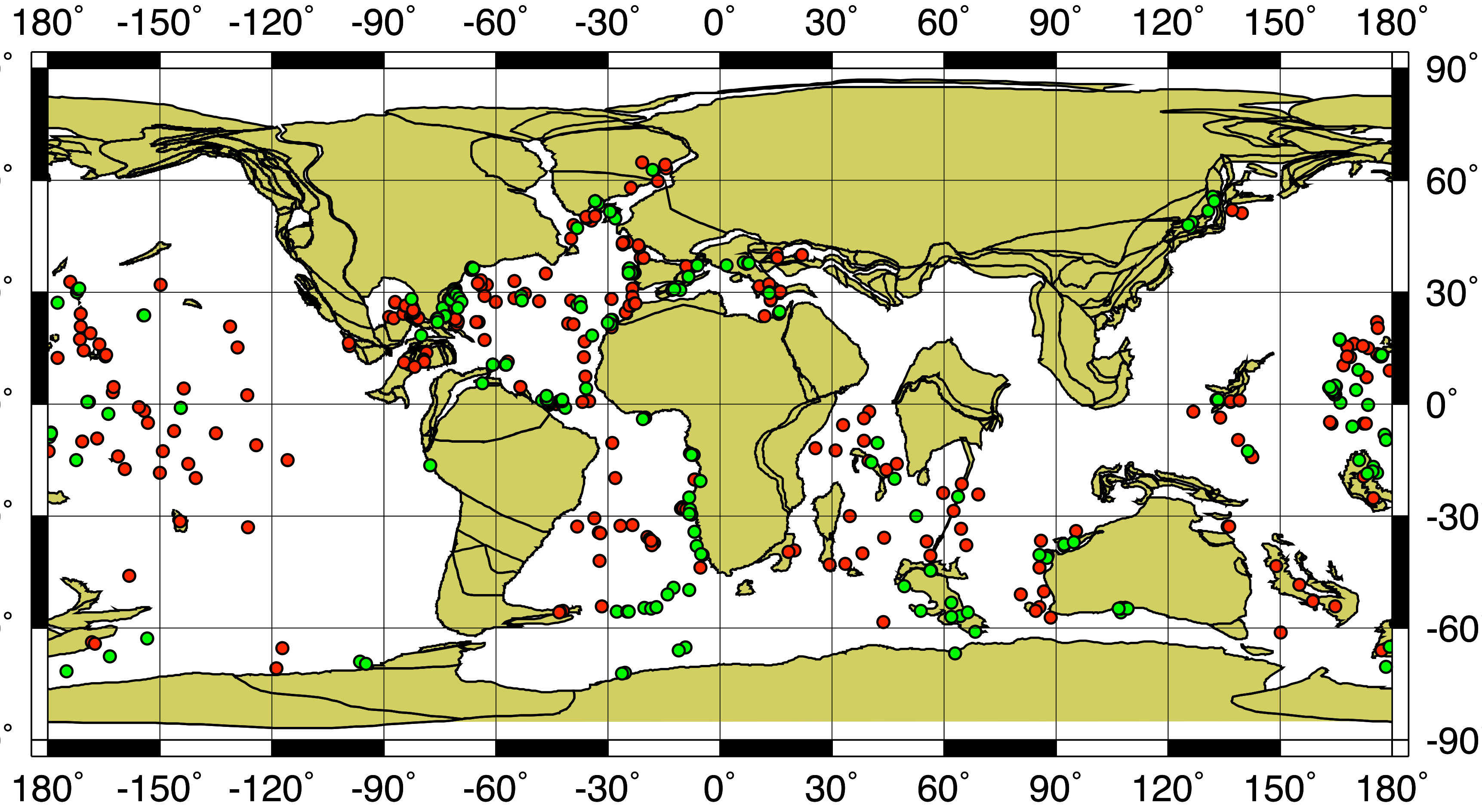
Early Paleocene



65.0 Ma Reconstruction

Widening of North Atlantic, Opening of Tasmanian and Drake Passages, Himalayan orogeny, Closure of Panama seaway

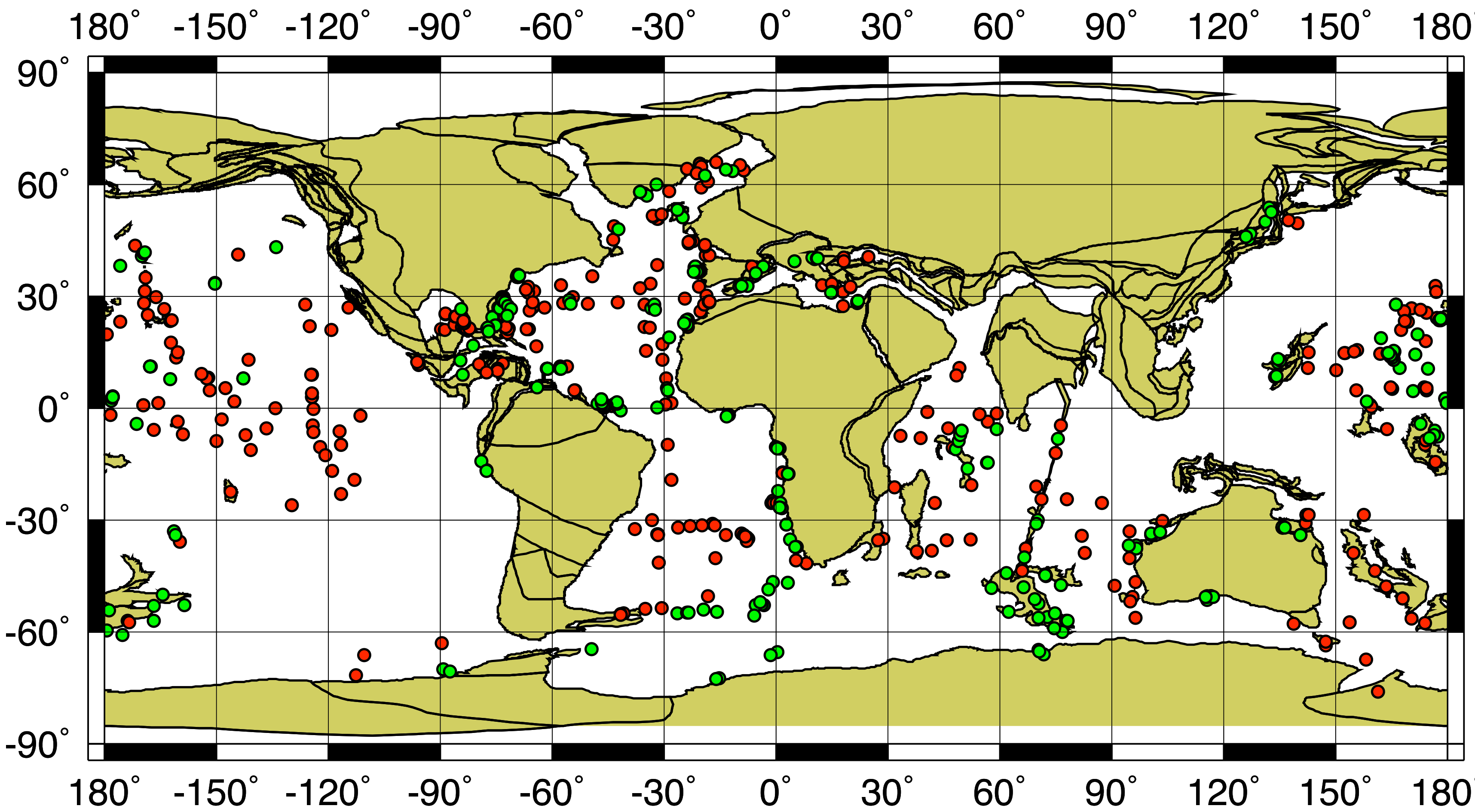
Paleocene-Eocene Boundary (PETM)



55.0 Ma Reconstruction

Widening of North Atlantic, Opening of Tasmanian and Drake Passages, Himalayan orogeny, Closure of Panama seaway

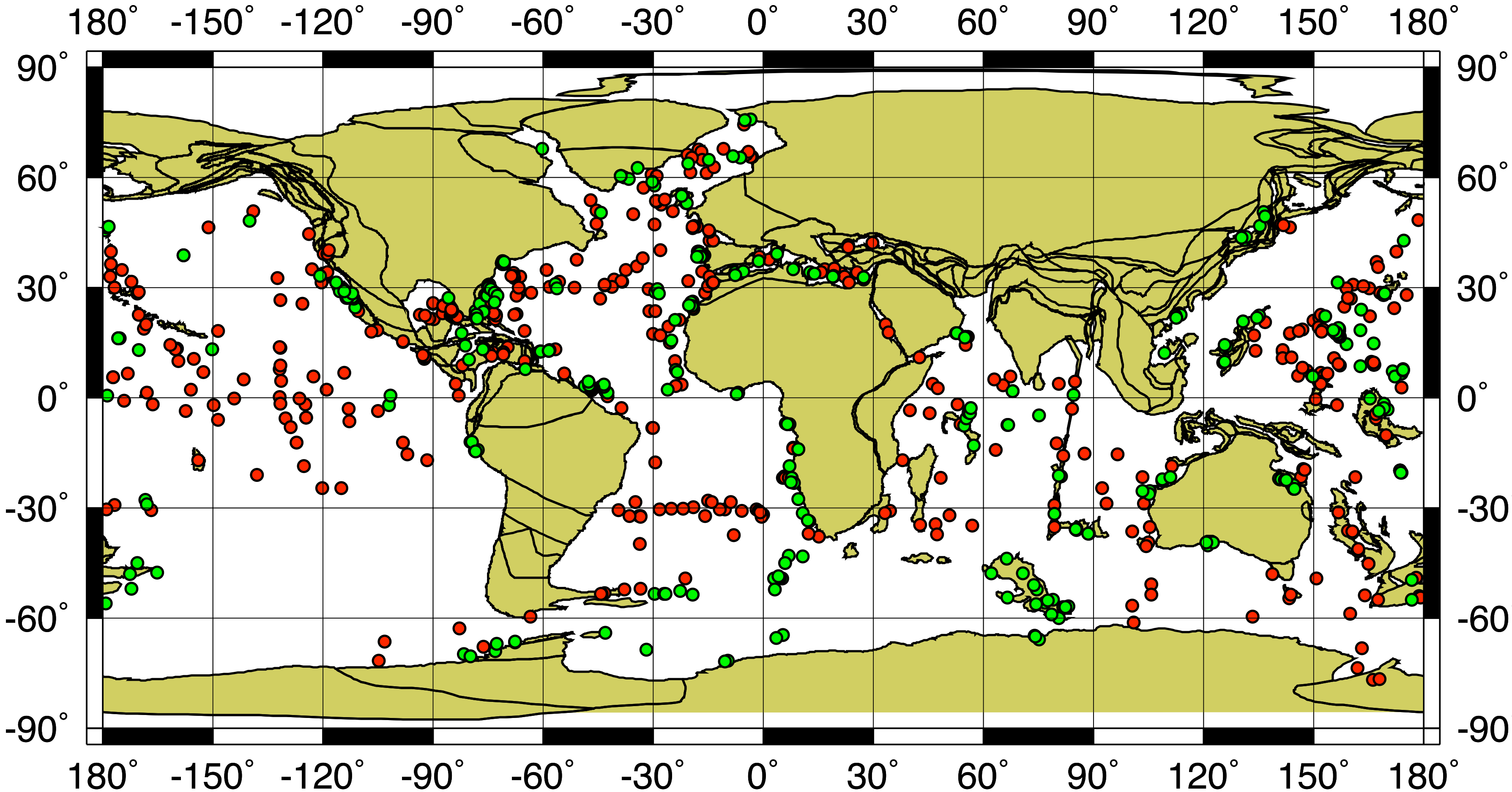
Eocene/Oligocene boundary



34.0 Ma Reconstruction

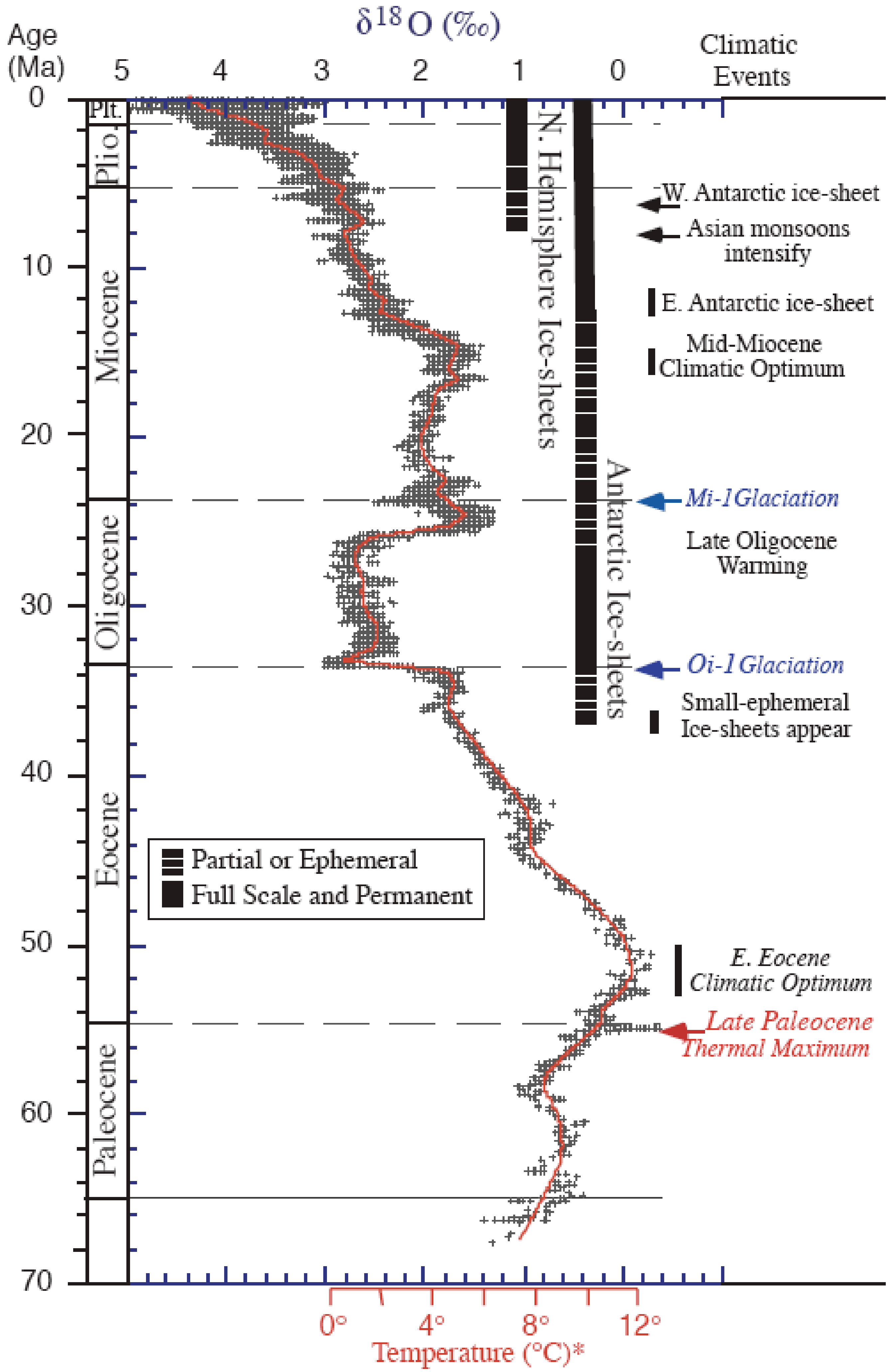
Widening of North Atlantic, Opening of Tasmanian and Drake Passages, Himalayan orogeny, Closure of Panama seaway

Mid-Miocene warm period

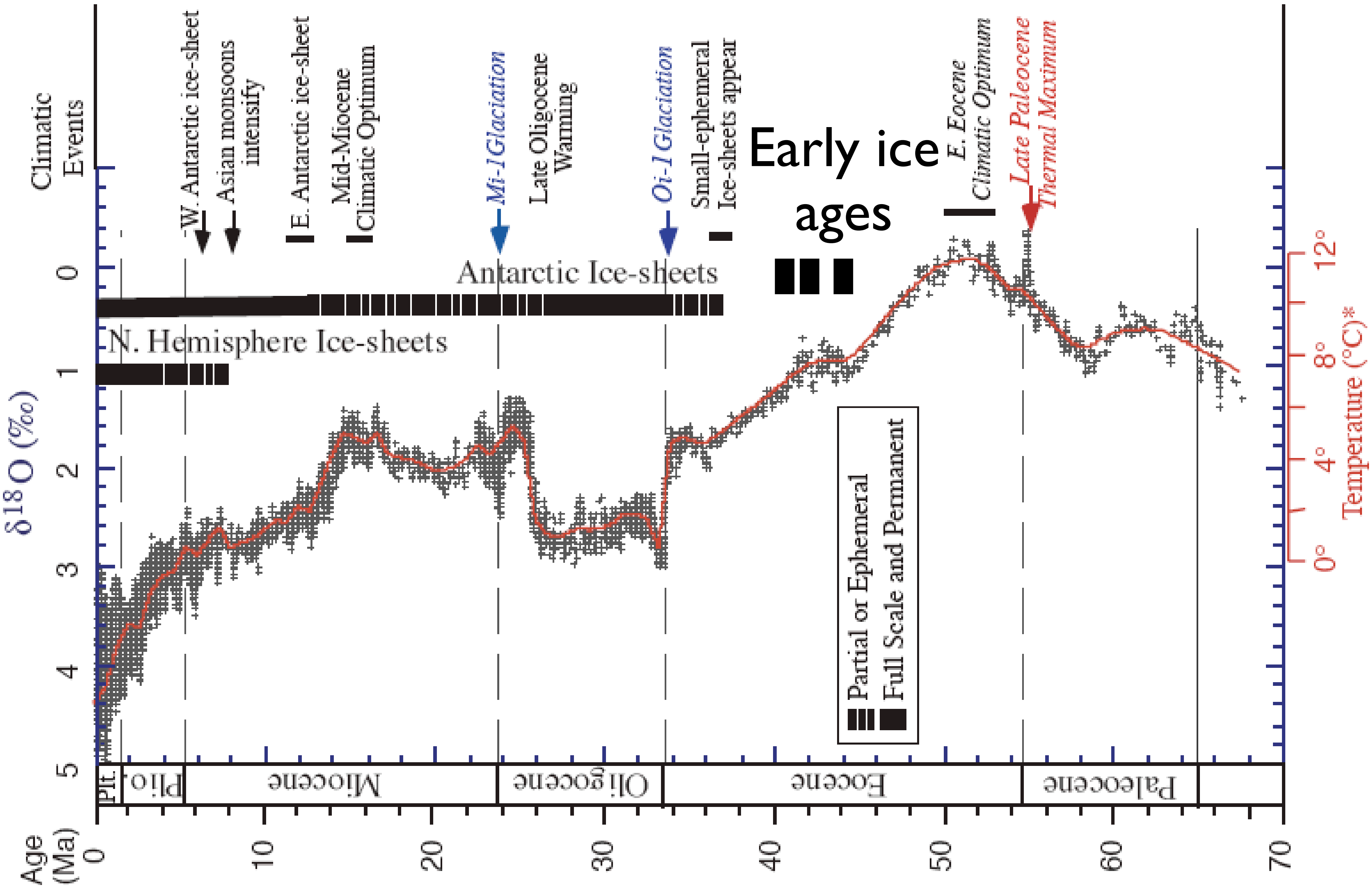


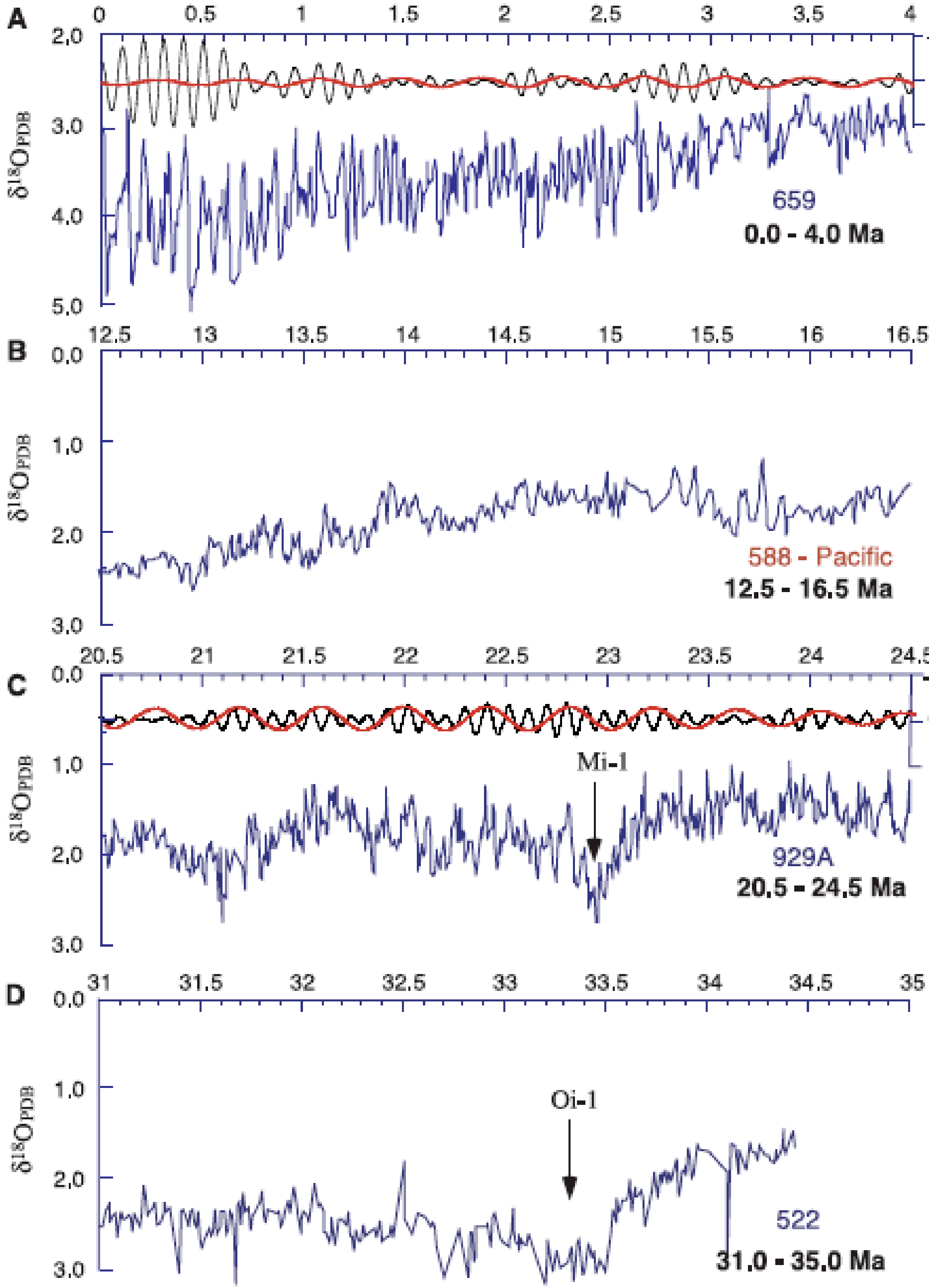
15.0 Ma Reconstruction

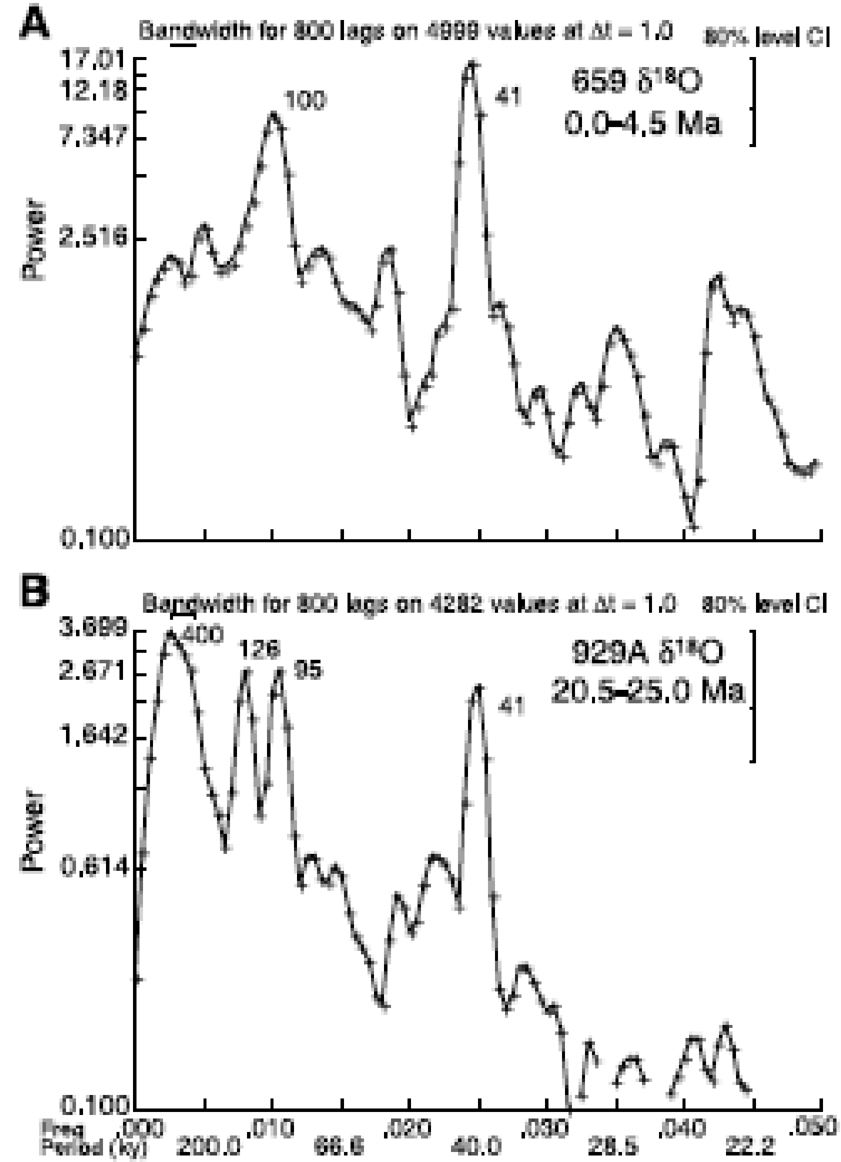
Widening of North Atlantic, Opening of Tasmanian and Drake Passages, Himalayan orogeny, Closure of Panama seaway



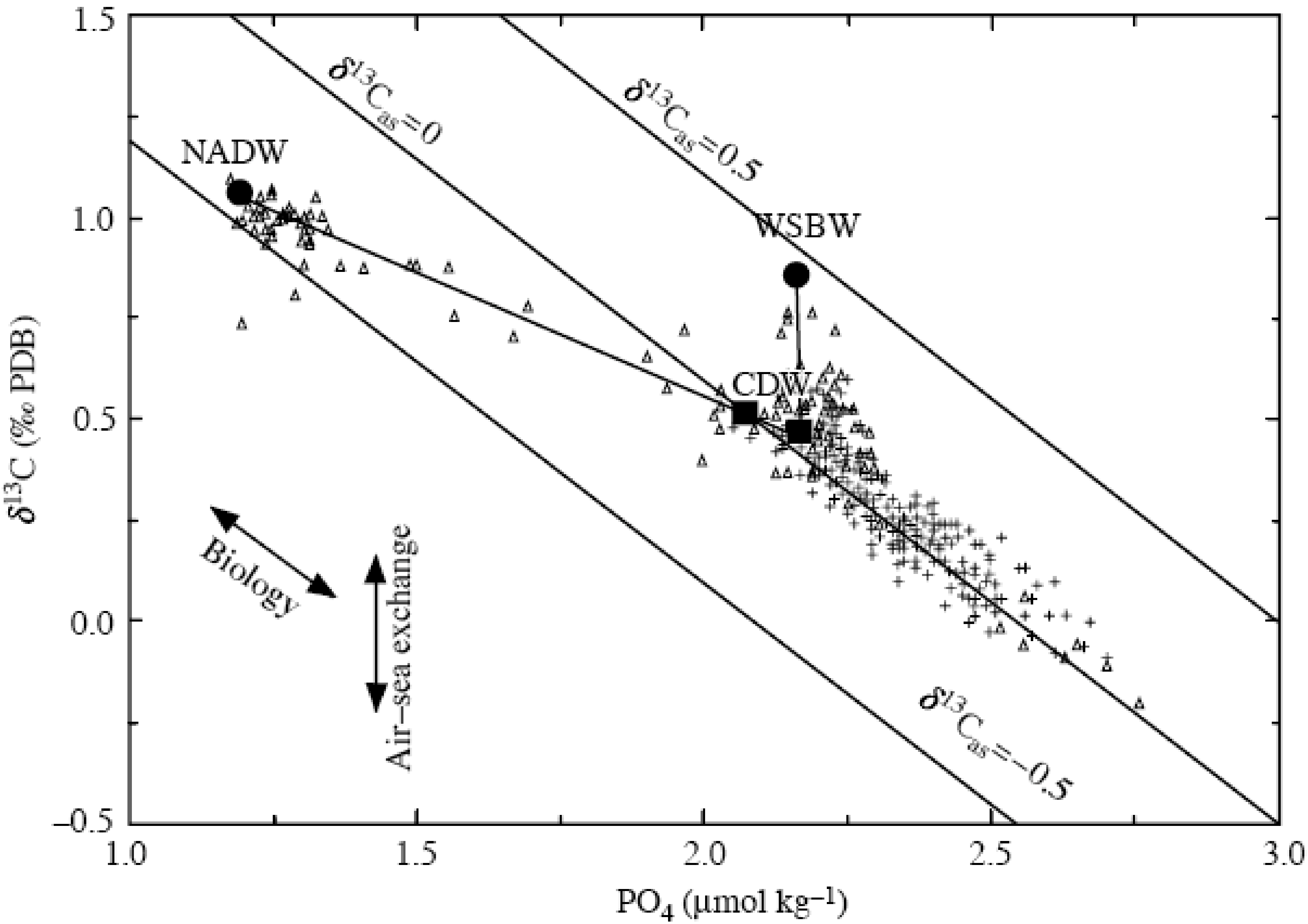
δ18O (‰)
Age (Ma)
Climatic Events
Plt.
Plio.
Miocene
Oligocene
Eocene
Paleocene
N. Hemisphere Ice-sheets
Antarctic Ice-sheets
W. Antarctic ice-sheet
Asian monsoons intensify
E. Antarctic ice-sheet
Mid-Miocene Climatic Optimum
Mi-1 Glaciation
Late Oligocene Warming
Oi-1 Glaciation
Small-ephemeral Ice-sheets appear
E. Eocene Climatic Optimum
Late Paleocene Thermal Maximum
Partial or Ephemeral
Full Scale and Permanent
Temperature (°C)*


Early ice ages
Climatic Events
W. Antarctic ice-sheet
Asian monsoons intensify
E. Antarctic ice-sheet
Mid-Miocene Climatic Optimum
Mi-1 Glaciation
Late Oligocene Warming
Oi-1 Glaciation
Small-ephemeral Ice-sheets appear
E. Eocene Climatic Optimum
Late Paleocene Thermal Maximum
Antarctic Ice-sheets
N. Hemisphere Ice-sheets
Partial or Ephemeral
Full Scale and Permanent
δ18O (‰)
Temperature (°C)*
Age (Ma)
Plt.
Plio.
Miocene
Oligocene
Eocene
Paleocene

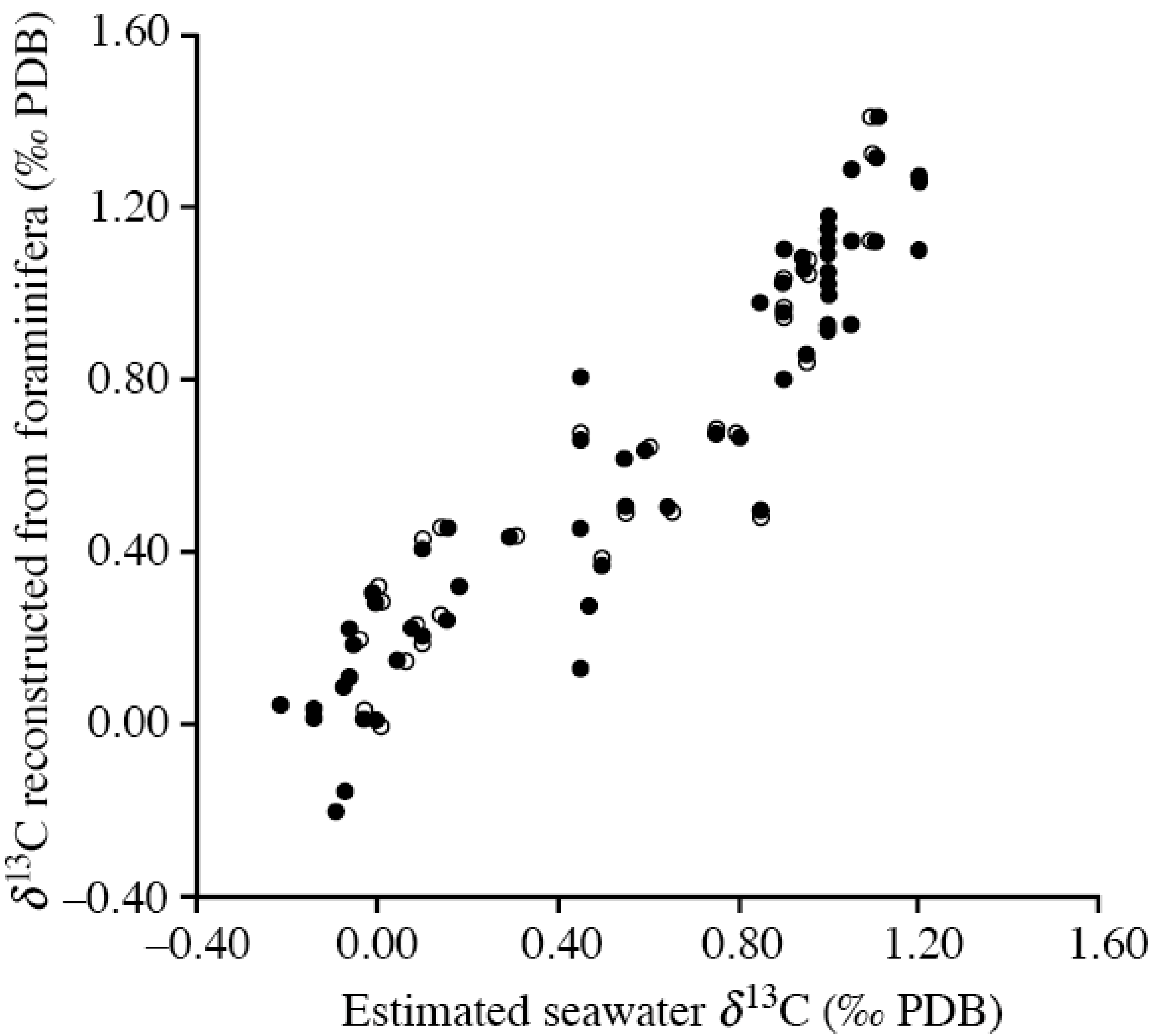

A
B
C
D
δ18OPDB
659
0.0 - 4.0 Ma
588 - Pacific
12.5 - 16.5 Ma
929A
20.5 - 24.5 Ma
Mi-1
Oi-1
522
31.0 - 35.0 Ma


A
Bandwidth for 800 lags on 4999 values at Δt = 1.0
80% level CI
659 δ18O
0.0-4.5 Ma
100
41
Power
B
Bandwidth for 800 lags on 4282 values at Δt = 1.0
80% level CI
929A δ18O
20.5-25.0 Ma
400
126
95
41
Power
Freq
Period (ky)

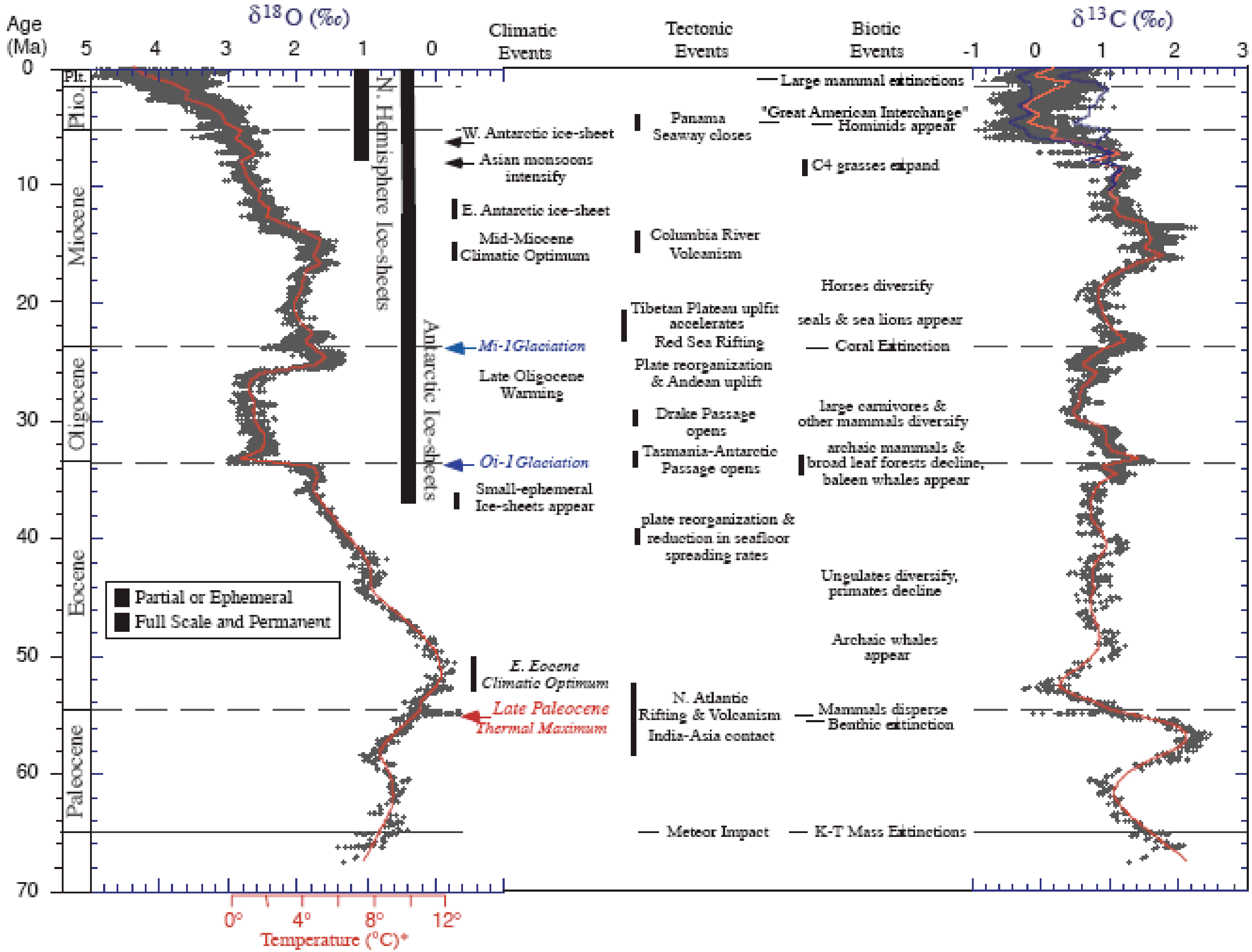

20 µm



1.5
1.0
0.5
0.0
–0.5
1.0
1.5
2.0
2.5
3.0
$\delta^{13}C$ (‰ PDB)
PO_4 (µmol kg^{-1})
$\delta^{13}C_{as}$=0
$\delta^{13}C_{as}$=0.5
$\delta^{13}C_{as}$=–0.5
NADW
WSBW
CDW
Biology
Air–sea exchange

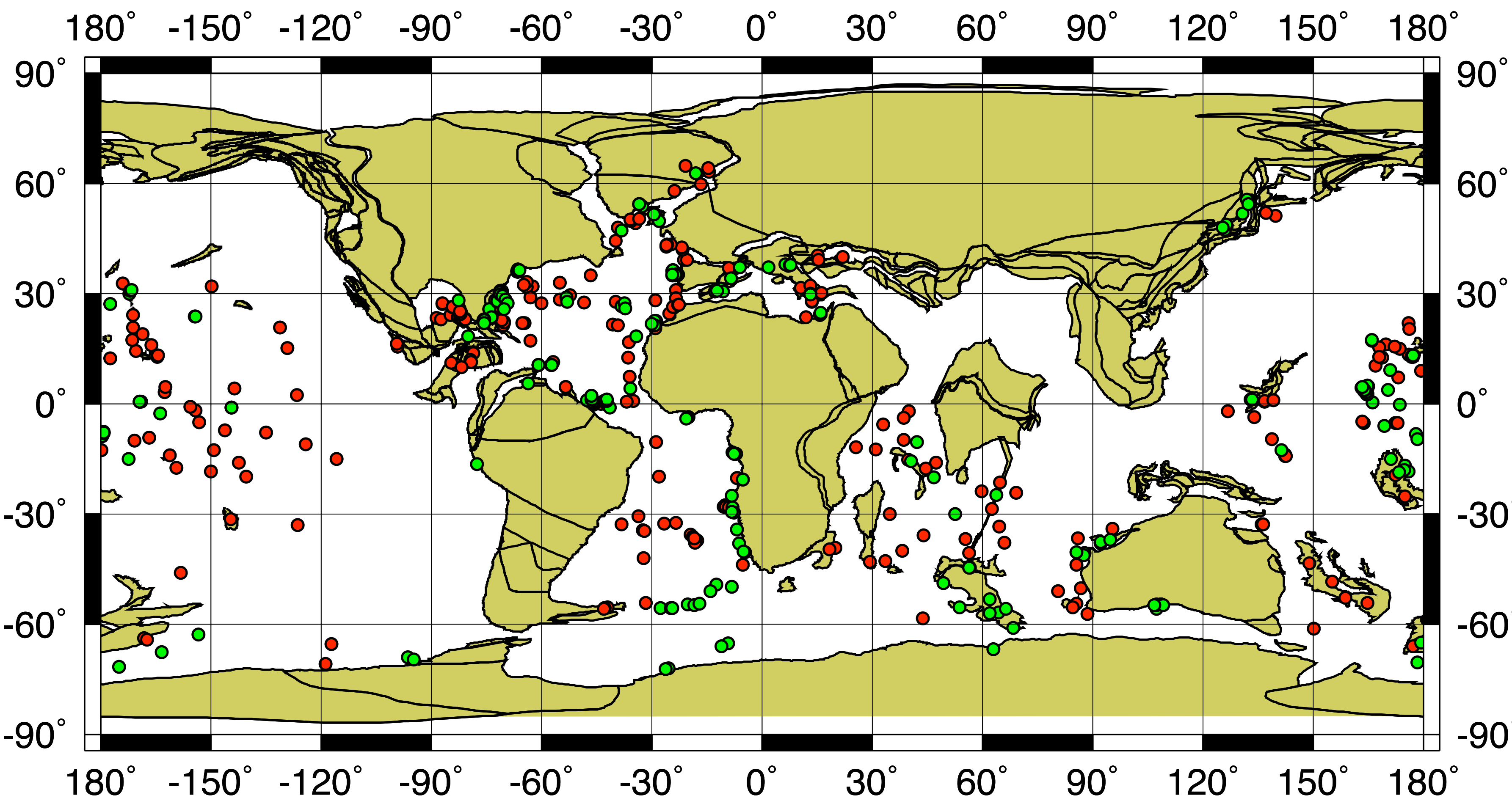


Duplessy 1984

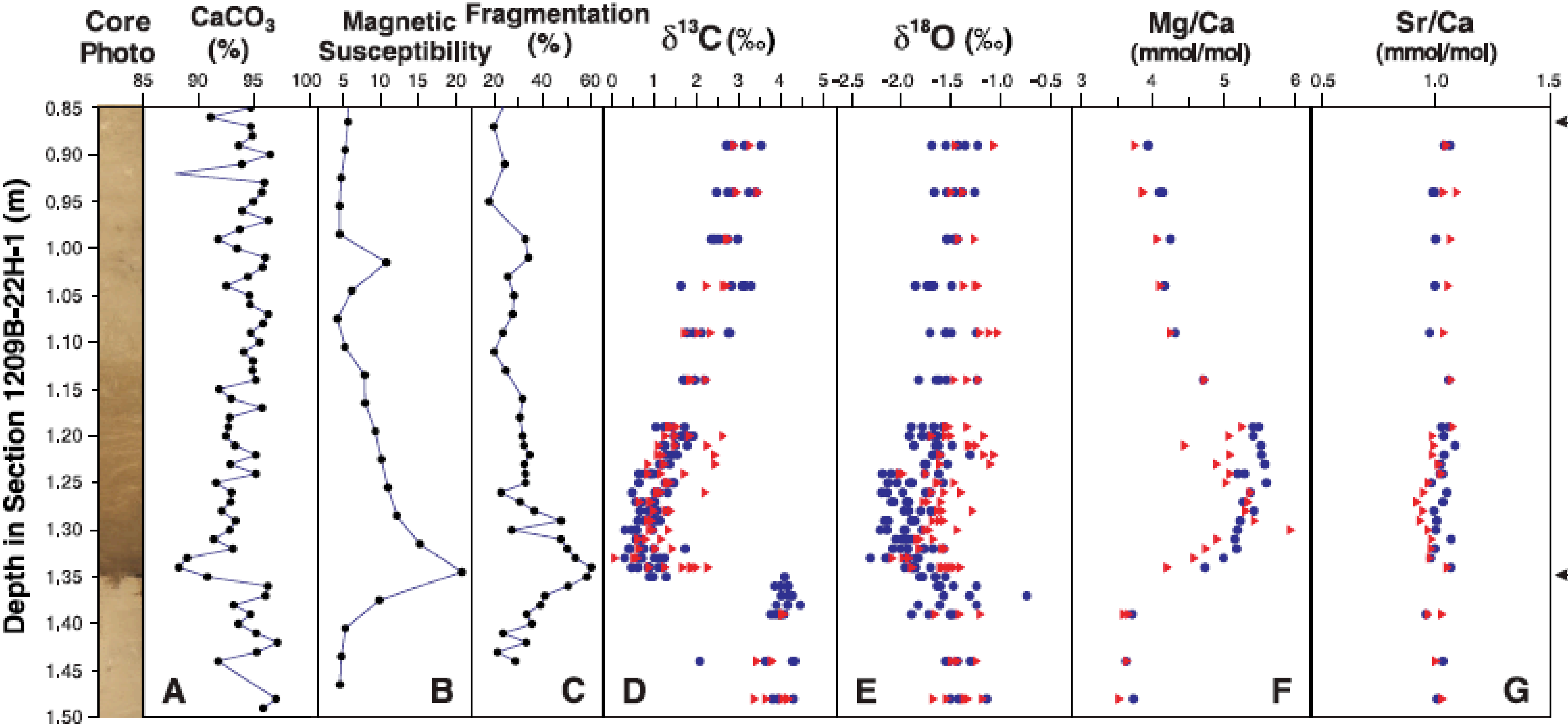


Age (Ma)
δ18O (‰)
Climatic Events
Tectonic Events
Biotic Events
δ13C (‰)
Plt.
Plio.
Miocene
Oligocene
Eocene
Paleocene
N. Hemisphere Ice-sheets
Antarctic Ice-sheets
W. Antarctic ice-sheet
Asian monsoons intensify
E. Antarctic ice-sheet
Mid-Miocene Climatic Optimum
Mi-1Glaciation
Late Oligocene Warming
Oi-1 Glaciation
Small-ephemeral Ice-sheets appear
E. Eocene Climatic Optimum
Late Paleocene Thermal Maximum
Panama Seaway closes
Columbia River Volcanism
Tibetan Plateau uplift accelerates
Red Sea Rifting
Plate reorganization & Andean uplift
Drake Passage opens
Tasmania-Antarctic Passage opens
plate reorganization & reduction in seafloor spreading rates
N. Atlantic Rifting & Volcanism
India-Asia contact
Meteor Impact
Large mammal extinctions
"Great American Interchange"
Hominids appear
C4 grasses expand
Horses diversify
seals & sea lions appear
Coral Extinction
large carnivores & other mammals diversify
archaic mammals & broad leaf forests decline, baleen whales appear
Ungulates diversify, primates decline
Archaic whales appear
Mammals disperse
Benthic extinction
K-T Mass Extinctions
Partial or Ephemeral
Full Scale and Permanent
Temperature (°C)*

PETM

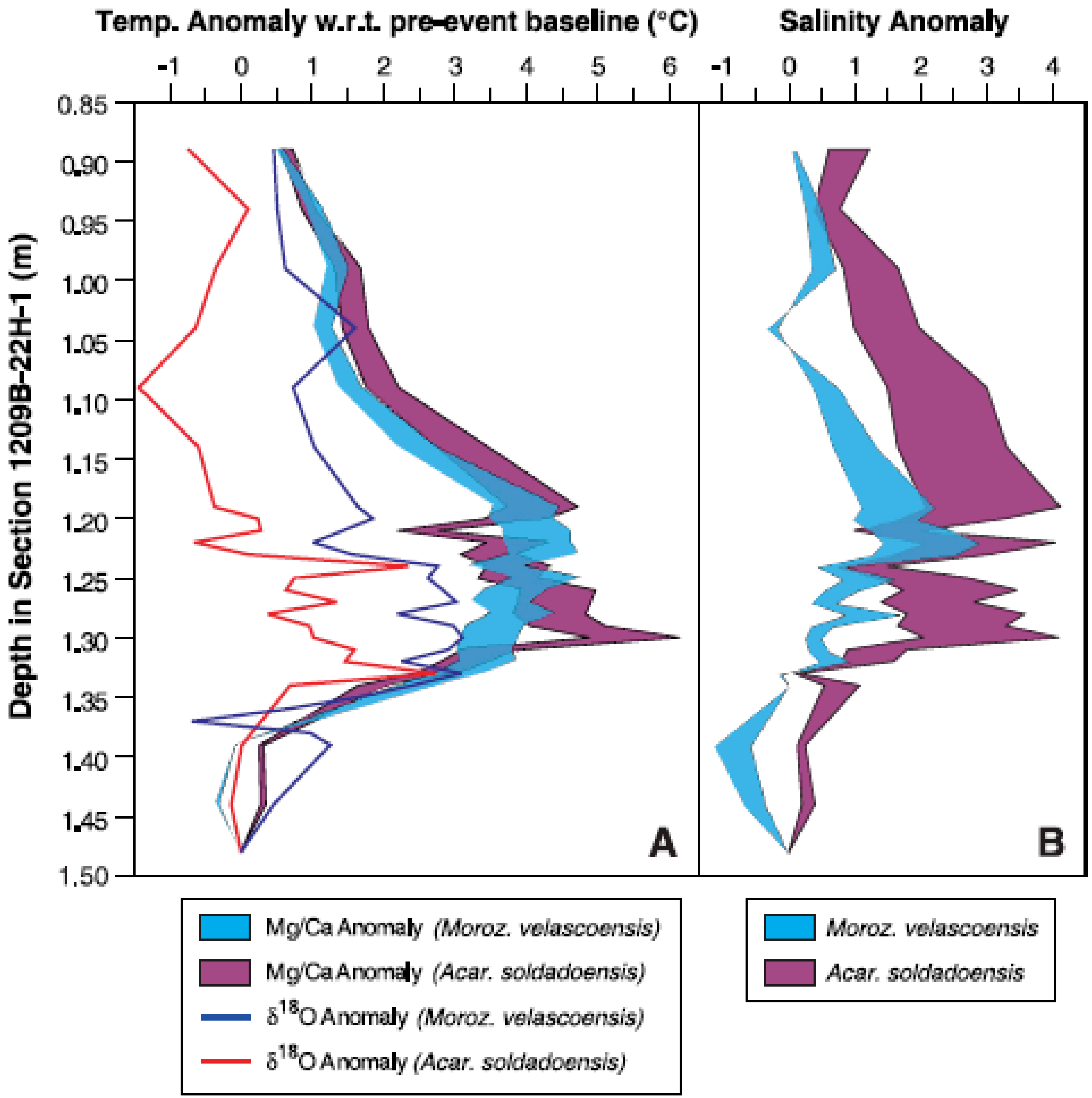


55.0 Ma Reconstruction



Zachos et al Science 2003

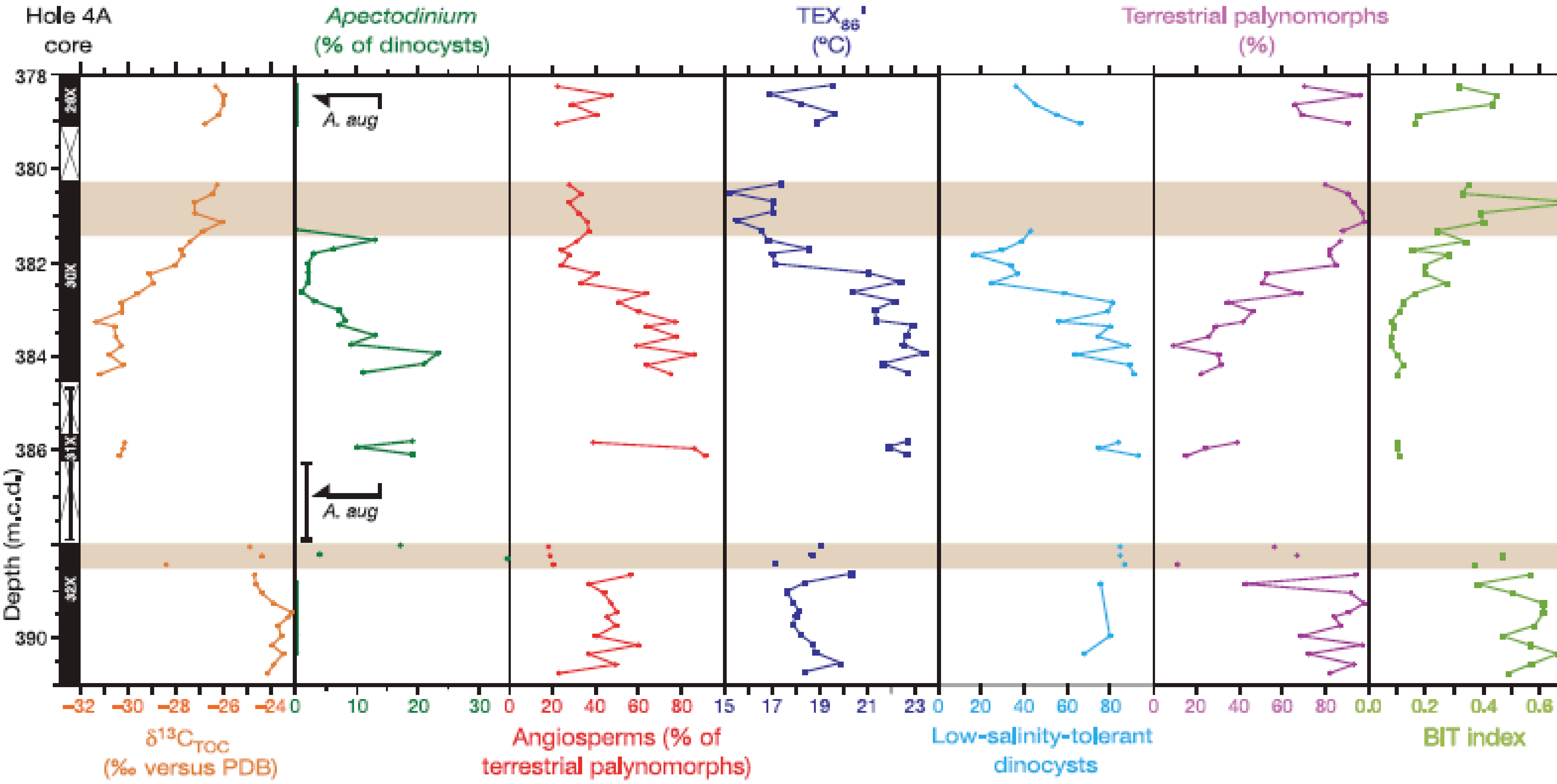
Tropical sea surface



Zachos et al Science 2003

Slujis etal. Nature 2006

PETM Arctic Ocean was warm and fresh



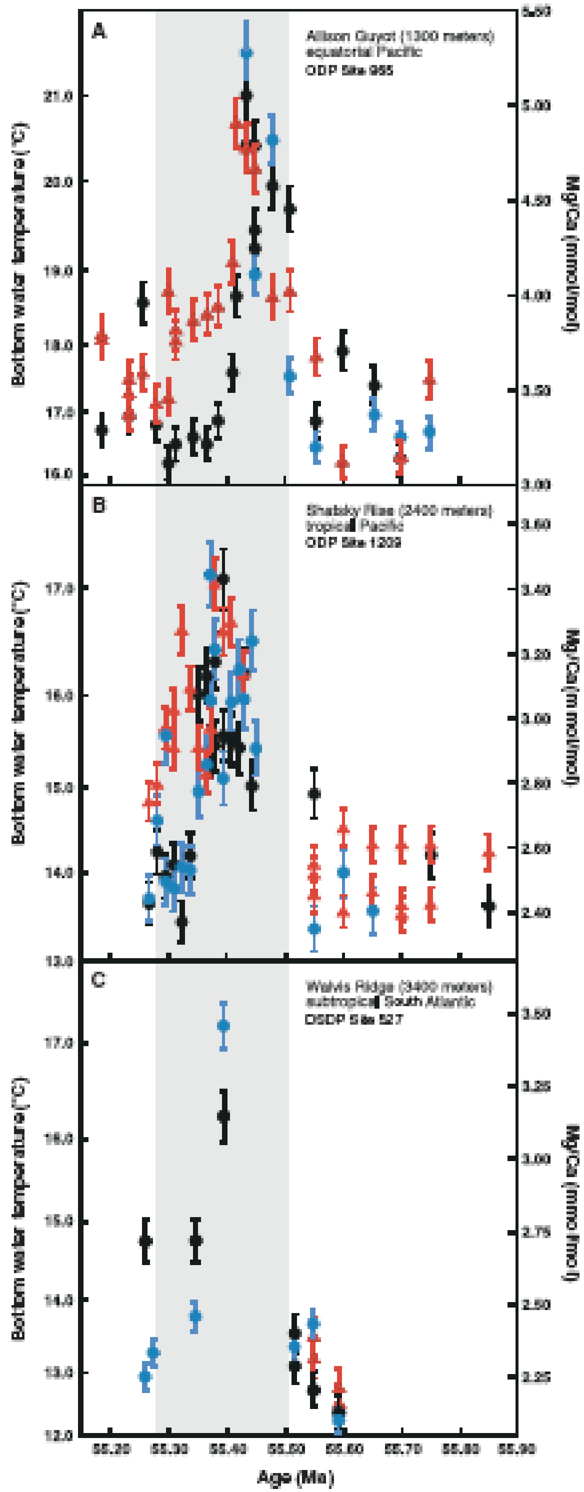


Fig. 1. High-resolution benthic foraminiferal Mg/Ca records across the PETM and corresponding temperature scale (black circles, *Oridorsalis umbonatus*; blue circles, *Nuttallides truempyi*; red triangles, *Cibicidoides* spp.). (A) Allison Guyot, ODP site 865 (equatorial Pacific Ocean, 1300 m in depth). (B) Shatsky Rise, ODP site 1209 (tropical North Pacific Ocean, 2400 m in depth). (C) Walvis Ridge, Deep-Sea Drilling Program (DSDP) site 527 (subtropical South Atlantic Ocean, 3400 m in depth). Mg/Ca ratios are normalized to *O. umbonatus* (30). The PETM interval (55.50 to 55.28 Ma) is highlighted (gray bar). In order to place results on a common age scale, we used reported datum levels for the carbon isotope base, peak, and recovery and also used the reported first occurrence of *Discoaster multiradiatus* and *Fasculithes tympaniform* (table S3). Planktic foraminiferal $\delta^{13}C$ data are shown in fig. S3. Absolute chronologies for the PETM are subject to revision.

Tripati et al Science 2005

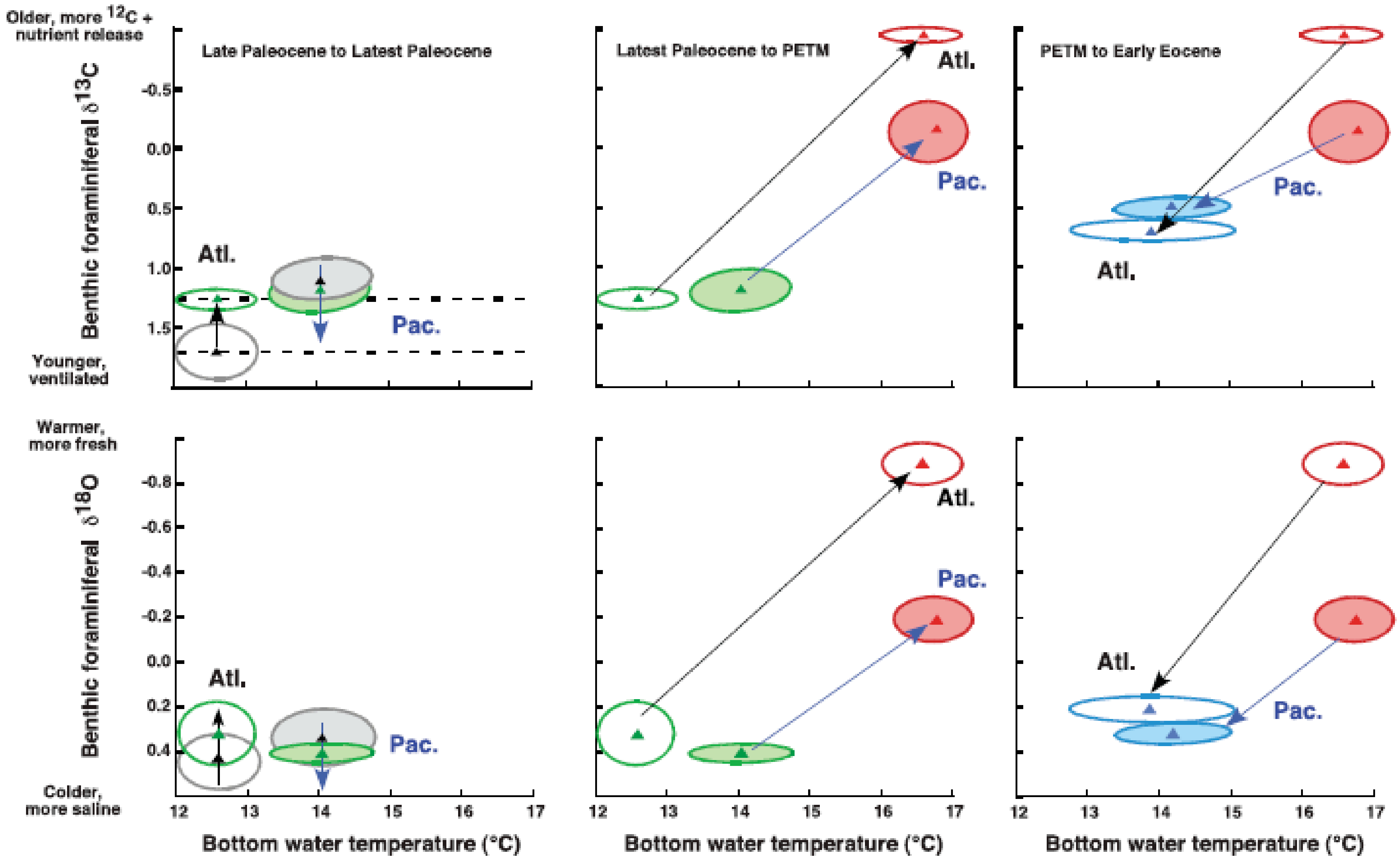


Fig. 4. Cross-plot for T_B versus benthic foraminiferal (top) $\delta^{13}C$ and (bottom) $\delta^{18}O$ across the PETM, illustrating the evolution of deep-water gradients between the North Pacific (Pac., shaded ellipses, Shatsky Rise site) and South Atlantic (Atl., open elipses, Walvis Ridge site). Range (ellipses) and average values (triangles) are shown for specific time slices (gray, Late Paleocene; green, Latest Paleocene; red, PETM; and blue, Earliest Eocene). Dashed lines in the top left panel indicate Atlantic mean $\delta^{13}C$ values. Table S2 shows the change in slope of $\Delta\delta^{18}O/\Delta T_B$ before the PETM (between the Late Paleocene and the Latest Paleocene), indicating a change in the salinity contrast between the South Atlantic and North Pacific.

Tripati et al Science 2005

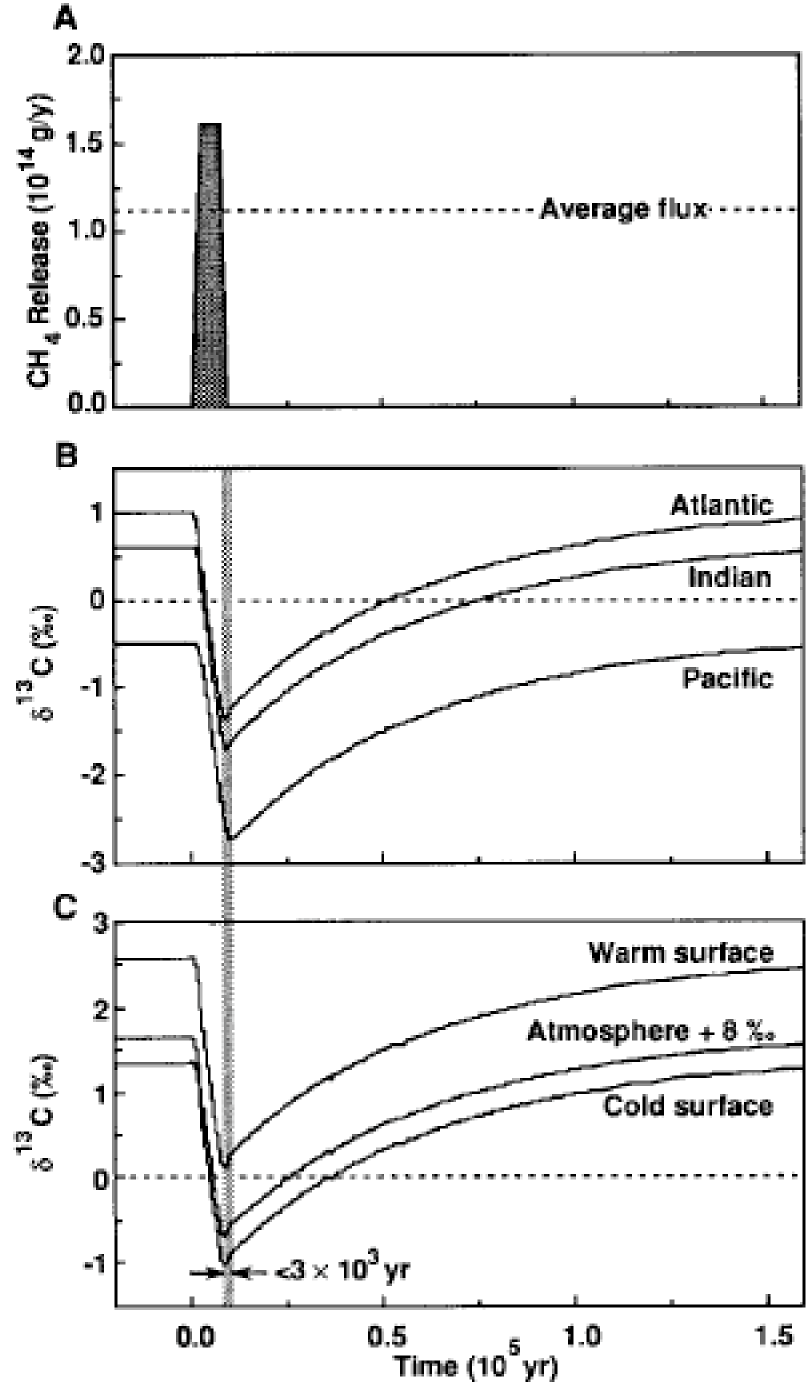


Figure 2. Effect of releasing 1.12×10^{18} g of CH_4 with $\delta^{13}C$ of –60‰ over 10^4 yr on $\delta^{13}C$ value of present-day preindustrial carbon reservoirs. A: Assumed release of CH_4 at average rate of 1.12×10^{14} g of CH_4/yr over 10^4 yr. B: Response of $\delta^{13}C$ in deep water of Atlantic, Indian, and Pacific Oceans. Initial values are 0.996‰, 0.620‰, and –0.508‰, respectively. C: Response of $\delta^{13}C$ in warm surface water, cold surface water, and atmosphere (shifted by +8‰). Initial values are 2.577‰, 1.355‰, and –6.367‰, respectively.

Dickens Geology 1997

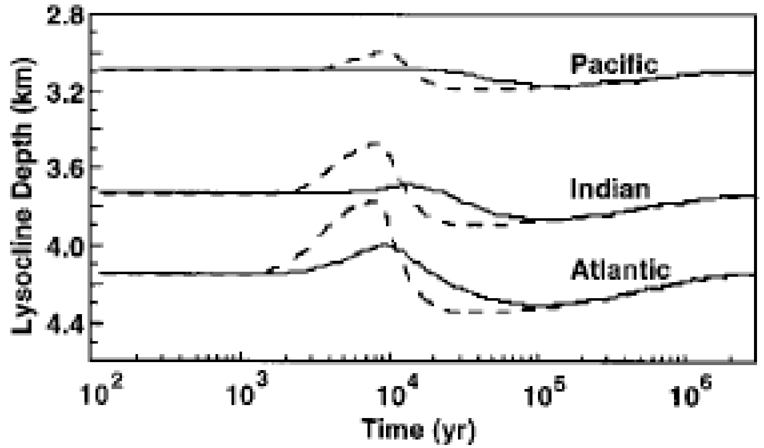


Figure 3. Response of present-day lysocline depths in Atlantic, Indian, and Pacific Oceans to CH_4 release shown in Figure 2A. Dashed curves show response without dissolution of previously deposited $CaCO_3$. Solid curves show response when $CaCO_3$ in upper 30 cm of sediment is dissolved upon addition of CH_4 and introduction of newly corrosive water (Walker and Kasting, 1992). Initial values are 4.14, 3.73, and 3.09 km, respectively. Time scale is logarithmic.

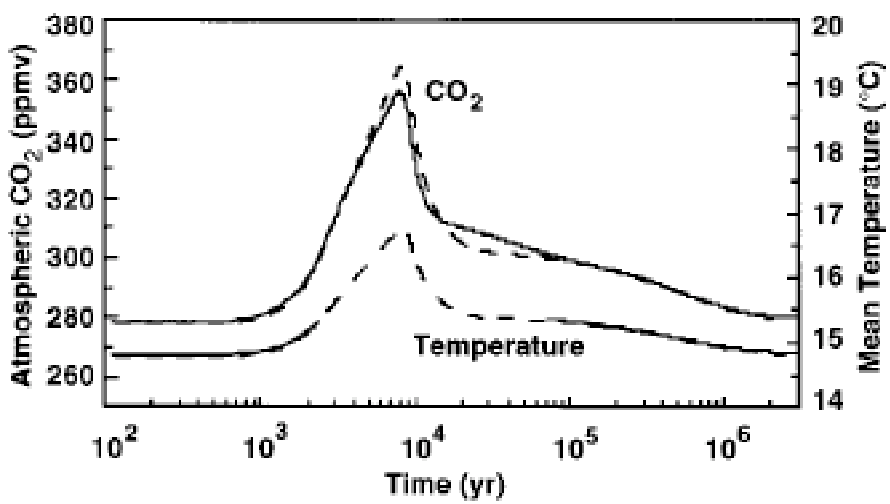
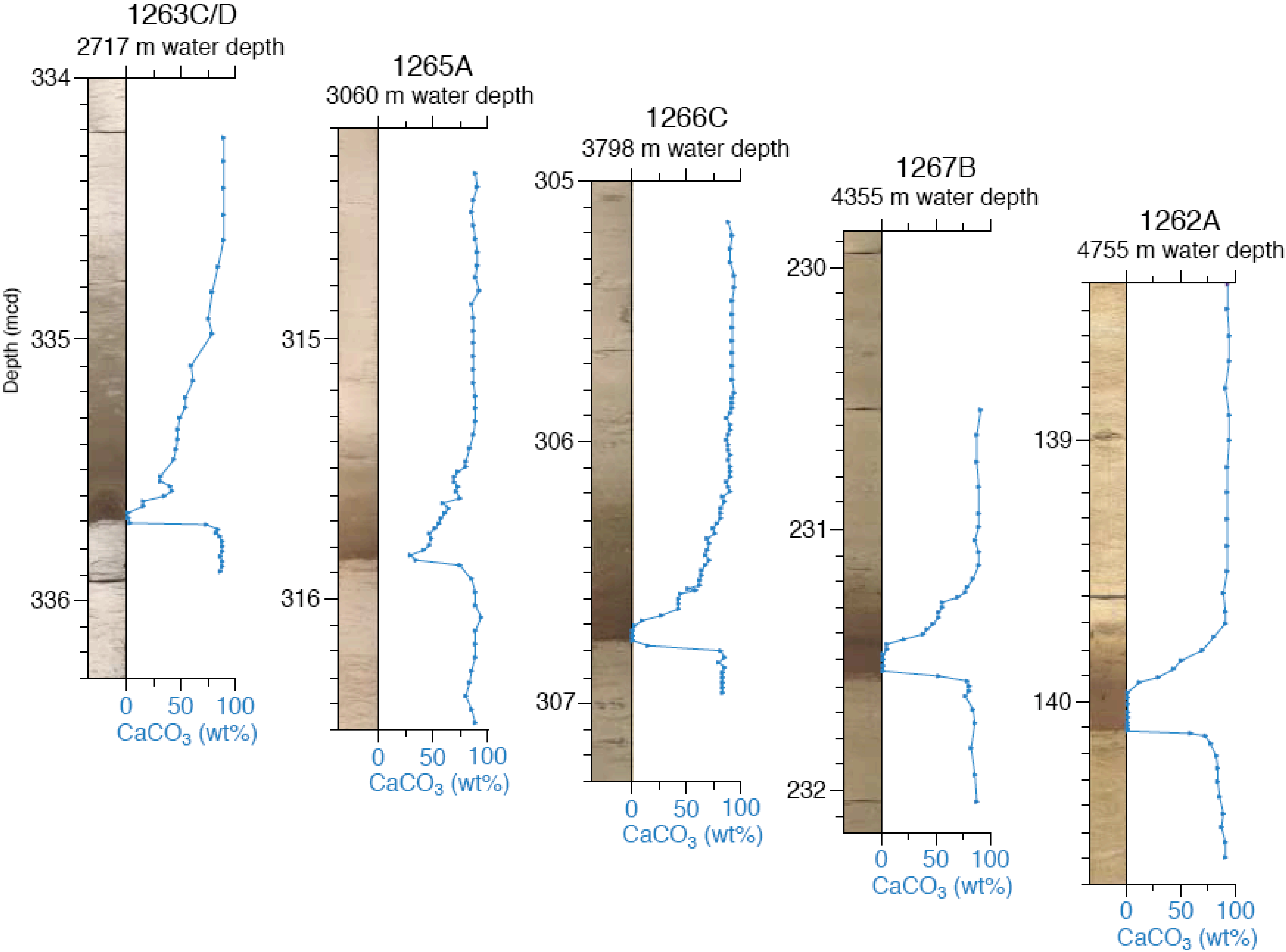
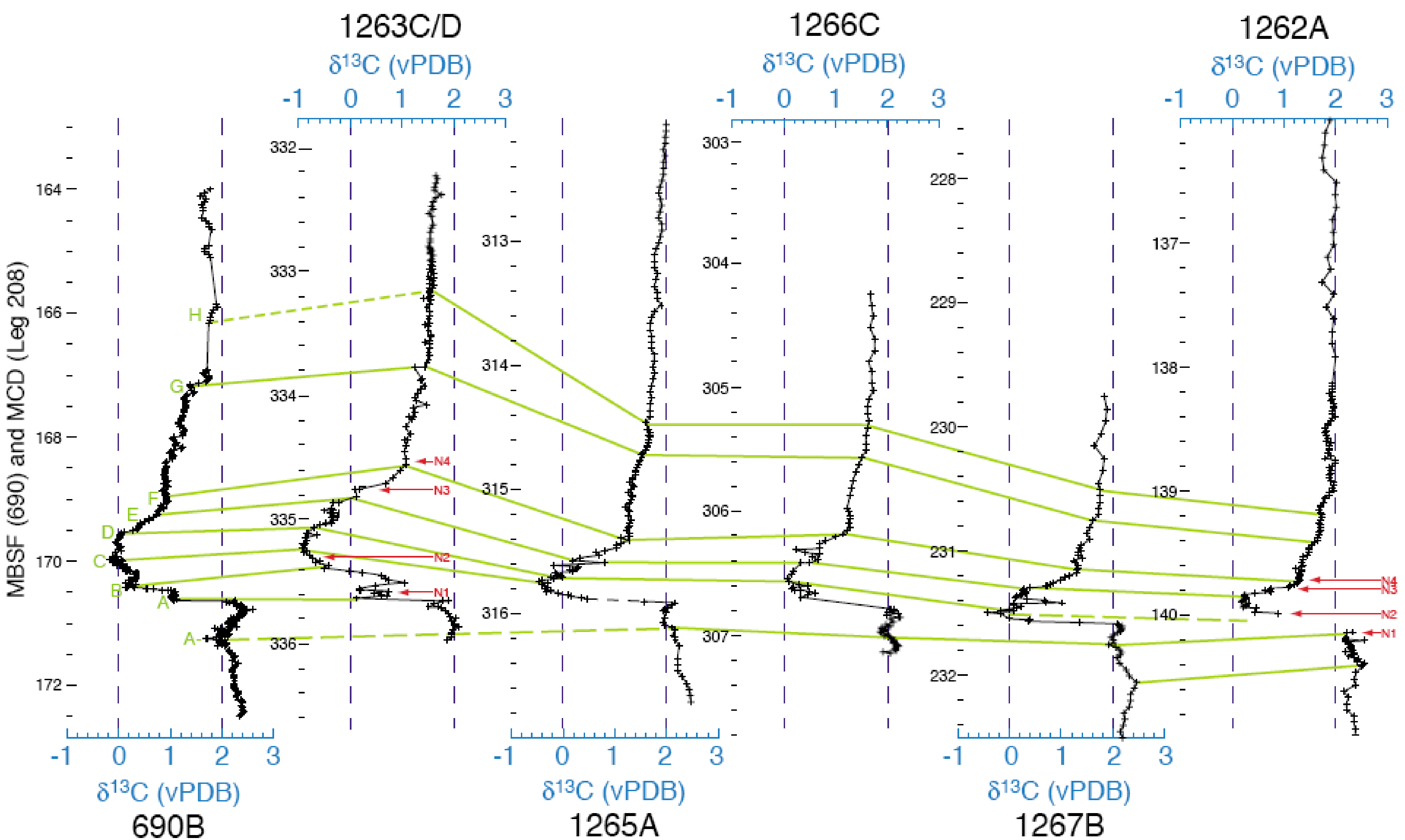
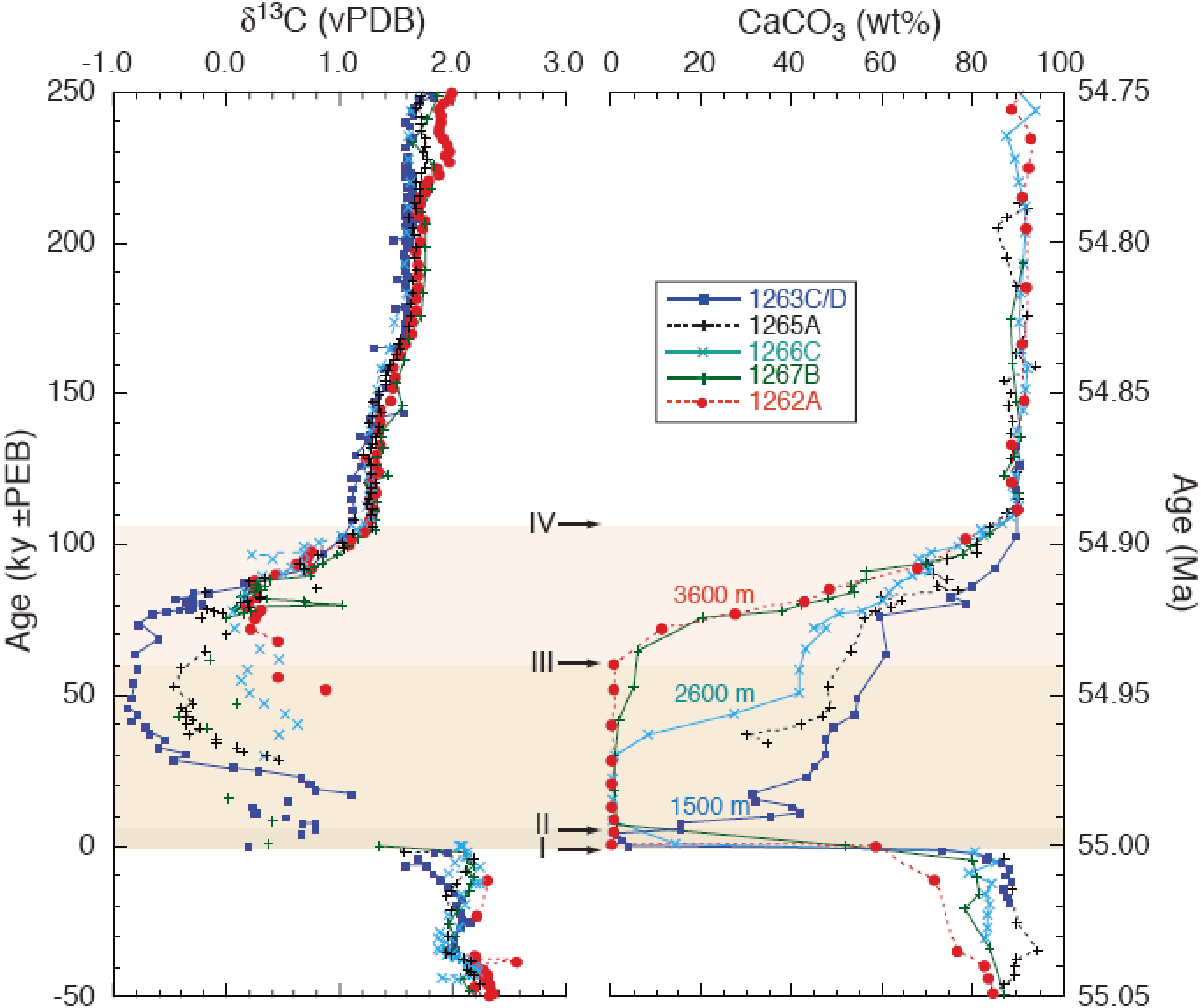


Figure 4. Response of present-day atmospheric pCO_2 and global average surface temperature to CH_4 release shown in Figure 2A. Dashed curves show response without dissolution of previously deposited $CaCO_3$. Solid curves show response when $CaCO_3$ in upper 30 cm of sediment is dissolved upon addition of CH_4 and introduction of newly corrosive water (Walker and Kasting, 1992). Initial values are 279.25 ppmv and 14.84 °C, respectively. Time scale is logarithmic.

Dickens Geology 1997


1263C/D
2717 m water depth
1265A
3060 m water depth
1266C
3798 m water depth
1267B
4355 m water depth
1262A
4755 m water depth
Depth (mcd)
334
335
336
315
316
305
306
307
230
231
232
139
140
0
50
100
$CaCO_3$ (wt%)


1263C/D
1266C
1262A
690B
1265A
1267B
δ13C (vPDB)
MBSF (690) and MCD (Leg 208)
H
G
F
E
D
C
B
A
A-
N4
N3
N2
N1



δ13C (vPDB)
-1.0
0.0
1.0
2.0
3.0
CaCO3 (wt%)
0
20
40
60
80
100
250
200
150
100
50
0
-50
Age (ky ±PEB)
54.75
54.80
54.85
54.90
54.95
55.00
55.05
Age (Ma)
1263C/D
1265A
1266C
1267B
1262A
IV
III
II
I
3600 m
2600 m
1500 m