PARTE III:
Nannoplancton e nannofossili calcarei nelle ricostruzioni paleoclimatiche e paleoambientali

OUTLINE

- Nannoplancton e nannofossili calcarei come *proxies* paleoclimatici

- Evoluzione dei nannofossili calcarei e cambiamenti climatico-ambientali

USO dei **NANNOFOSSILI CALCAREI** come *PROXIES** BIOTICI di CAMBIAMENTI CLIMATICI e PALEOCEANOGRAFICI

Mediante analisi delle:

- distribuzioni dei nannofossili nel record fossile
- composizione delle associazioni
- misurazione di rapporti isotopici di vari elementi

* NOTA:
Proxy (proxies) = contrazione del termine in Inglese *procuracy* (termine dal *Middle English*, forma di *English* diffusa tra il tardo secolo XI e il 1470)

Resti calcarei ascrivibili a Nannoplancton e Nannofossili costituiscono fino al 60% sedimenti carbonatici pelagici del Cenozoico

Mentre solo il 30% dei sedimenti recenti è costituito da elementi prodotti da Coccolithophores (Bramlette,1961)

PALEO-PROXIES GEOCHIMICI BASATI SULLE ALGHE COCCOLITOFORIDI:

MISURAZIONI DI RAPPORTI ISOTOPICI DI VARI ELEMENTI NEI COCCOLITI

- rapporto isotopico del C in *biomarkers* (alkenoni)
- Sr/Ca e Mg/Ca nel carbonato dei coccoliti
- misurazioni degli isotopi stabili di O e C nel bulk (dominato da coccoliti) = usate per ricostruire cambiamenti di T e nel ciclo del C in sedimenti del Mesozoico e Cenozoico

Condizionate dalle piccolissime dimensioni

e dalla presenza di altri elementi (nei minerali argillosi)

USO dei **NANNOFOSSILI CALCAREI**

come *PROXIES** BIOTICI

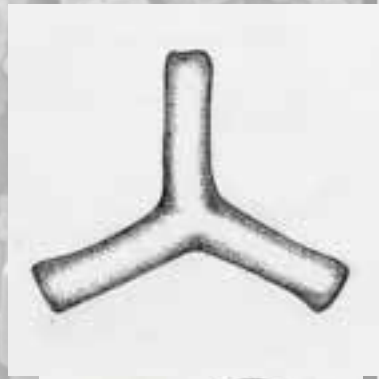
di CAMBIAMENTI CLIMATICI e PALEOCEANOGRAFICI

Mediante analisi delle:

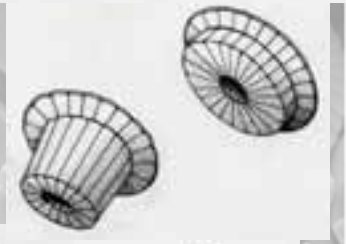
- distribuzioni dei nannofossili nel record fossile
- composizione delle associazioni
- misurazione di rapporti isotopici di vari elementi

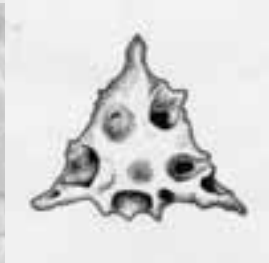
- COCCOLITI (Nannoplancton calcareo)

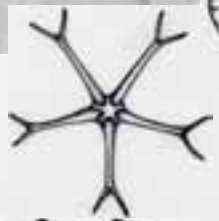
legati alle COCCOLITOFORIDI (alghe unicellurari)

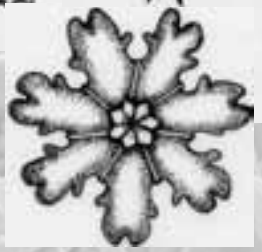


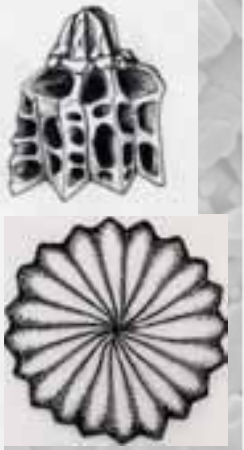
- NANNOLITI (forme differenziate di origine incerta)











Sedimentazione sul fondo

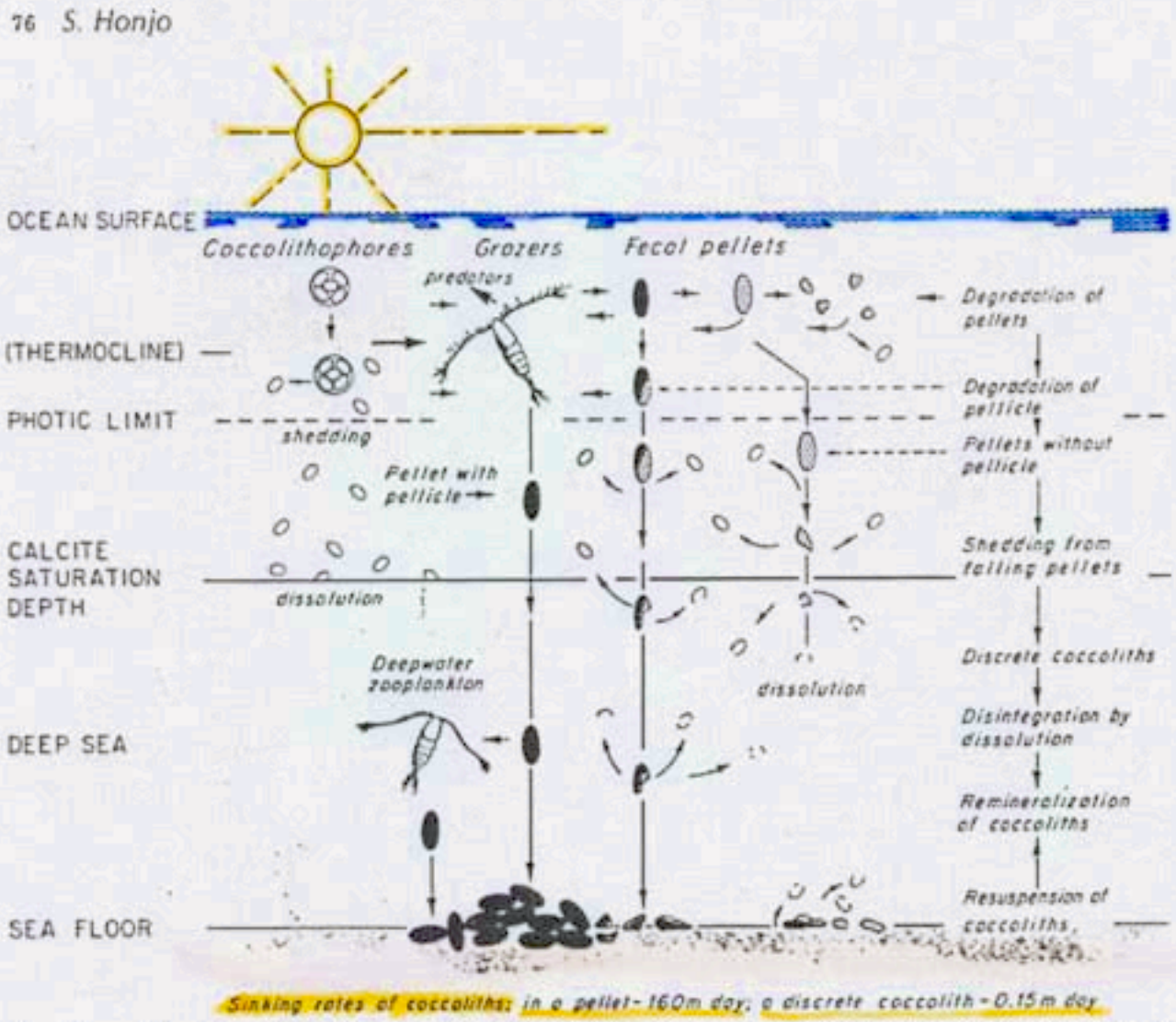


Fig. 2. A model of the relationship between the production, transportation, dissolution and deposition of coccoliths in open, deep ocean. Scales are not in proportion.

Nannofossil assemblages are controlled by

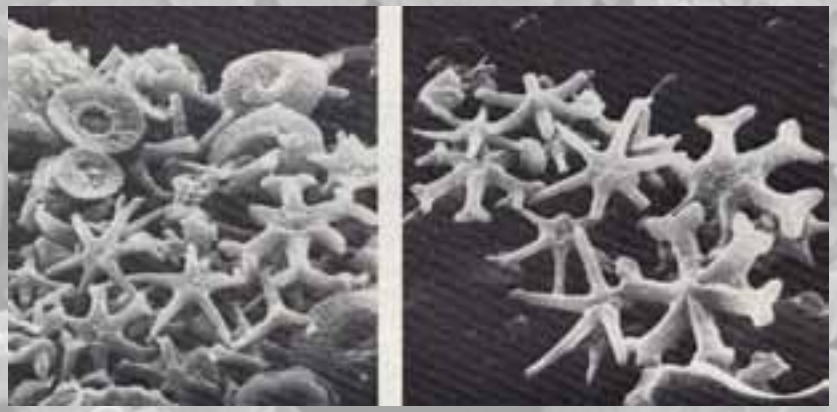
initial plankton production
and
dissolution throughout
the water column and on the seafloor

the number of fossilizable species is considerably lower than the number of living species

fossilizable species can be strongly affected by

DIAGENESIS

Heavily overgrown discoasterids



Heavily etched nannofossil ooze

Gibbs et al. (Paleoceanography, 19, PA1029, 2004)

In absence of obvious qualitative preservation effects dissolution removed ~ 80% of the assemblage in a sub-lysocline Pliocene Site

DIAGENETIC MODIFICATION

influences the data obtained
in ancient pelagic carbonate sediments

DISSOLUTION and/or OVERGROWTH
(during and after sedimentation) alter:

⇩

Assemblages

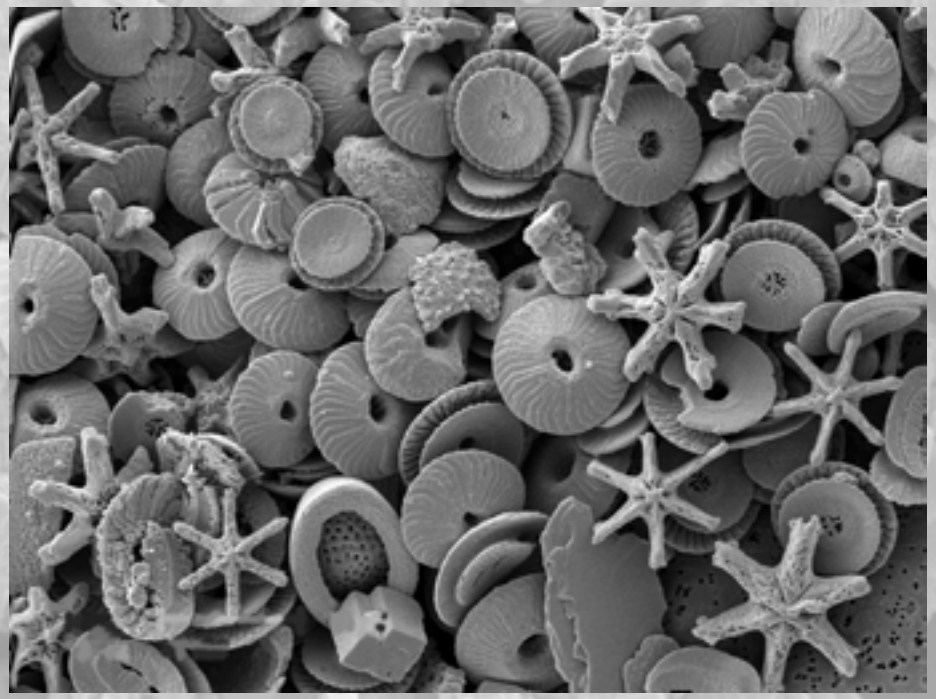
signals preserved in the assemblages

⇩

interpretation and modeling of the processes involved

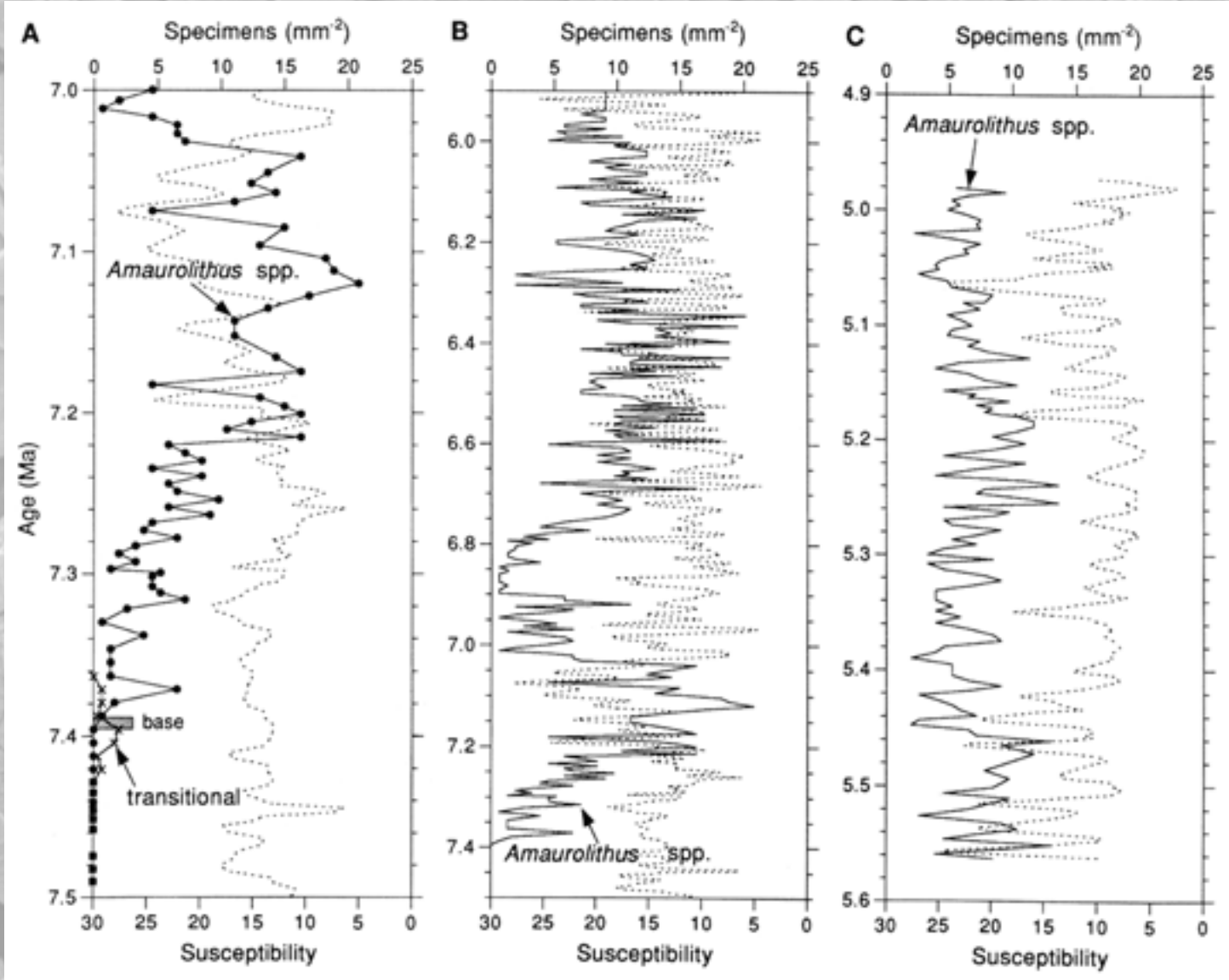
BUT NANNOFOSSILS

- are more resistant to diagenetic change than foraminifers
- are generally abundant and tend to be ubiquitous



Late Miocene at ODP Site 926 - western equatorial Atlantic (Ceara Rise)

from Backman and Raffi (1997)



SIGNALS

- **Sudden appearance or disappearance** - first and last occurrences
- **Abundance fluctuations** - rise or decline in abundance
- **Peak in abundance** (Blooms, Acme interval)

  or ab**sence intervals** (Paracme interval, “crisis”)
- **Reversals** in abundance between taxa
- **Sharp turnovers** in the assemblages with

  extinction of taxa and concomitant appearance of new species

METHODS
for getting a quantitative database

QUANTITATIVE WHOLE ASSEMBLAGE COUNTS

(300 to 500 specimens) to obtain relative and absolute abundance estimates:

- % of single taxa
- n ° per unit area
- absolute abundances of taxa per unit weight - useful in the study of pelagic limestones and hard lithologies

METHODS

NANNOFOSSIL PALEOFLUXES

QUANTIFICATION OF CARBONATE FLUXES OF NANNOFOSSILS

⇩

- **absolute abundance** of most common taxa
- **realistic estimate of nannofossil distribution**

(through calculation of coccolith absolute abundance)

- **volume/mass of individual taxon**
- **unit area** (1 mm^2) and **unit time** (1 year).

INTERPRETATION OF THE SIGNALS
preserved in the ancient nannofossil assemblages

Take into account the data from the modern assemblages

Modern calcareous NANNOPLANKTON communities are controlled by:

- temperature
- nutrient supply
- depth

Characteristics of water masses

With (some) knowledge on the

(PALEO) BIOGEOGRAPHY of NANNOFOSSILS

Assumptions for the fossil record:

• ancient taxa adapted to eutrophic conditions (e.g., upwelling environments) should be common in cold-water assemblages

• taxa adapted to oligotrophic environments are likely to be more common in warm-water assemblages present in a stable water column

Trophic conditions control the assemblage composition:

In waters with relatively high nutrient contents = small coccoliths are dominant, coccoliths of the lower photic zone are rare

In oligotrophic waters, coccolith assemblages are diversified, with “large” specimens

The amount of calcite produced by coccolithophores seems inversely correlated with the trophic levels

heavily calcified coccoliths are typical of oligotrophic stable surface waters

Heterogeneous distributions in living nannoplankton species: influenced by longer-term environmental changes

QUESTION:

WHAT IS THE AMOUNT OF VARIABILITY (CAUSED BY ENVIRONMENTAL CHANGES) TRANSFERRED TO THE GEOLOGICAL RECORD?

Summary:

THE ORIGINAL ASSEMBLAGE COMPOSITION IS ALTERED DURING BURIAL AND LITHIFICATION = nannofossil absolute abundance variations can result from differential dissolution and/or overgrowth of taxa with variable sensitivity to diagenesis

ECOLOGIC AFFINITIES ASSUMED FOR EXTINCT TAXA ARE NOT WELL KNOWN = erroneous interpretations

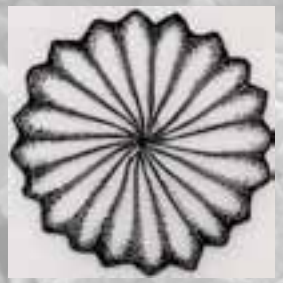
DISCOASTERIDS (ASTEROLITHS)

genus ***Discoaster***

Stratigraphic range: **mid-Paleocene to Pliocene**

Extinction of the genus at the end of Pliocene, concomitantly with the onset of Northern Hemisphere glaciation

In the late Pliocene only “slim” species are present



Appearance of the genus within the Paleocene, with rosette-shaped specimens

Ecologic affinity: Associated with warm waters, adapted to oligotrophic conditions, deep-dweller that expanded its range to high latitudes during warming events

FASCICULITHS

genus ***Fasciculithus***

Fasciculithus richardii

Fasciculithus tympaniformis

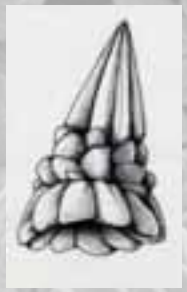
Stratigraphic range:
lower Paleocene to lowermost Eocene

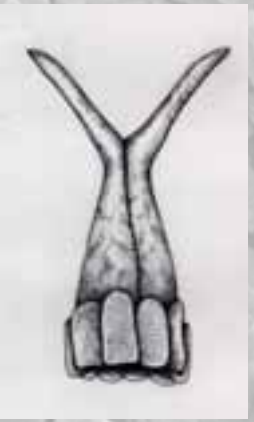
Ecologic affinity (??):
not well known, probably adapted to warmer, more oligotrophic environments

SPHENOLITHS

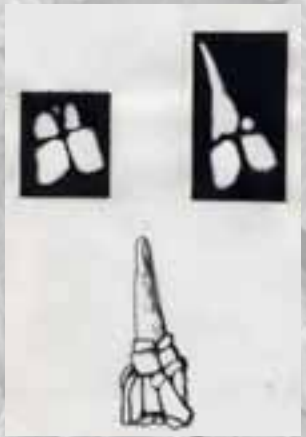
genus ***Sphenolithus***

uncertain taxonomic affinity

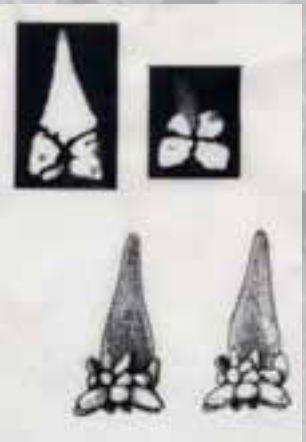




Stratigraphic range:
lower Paleocene to middle Pliocene



Sphenolithus belemnos



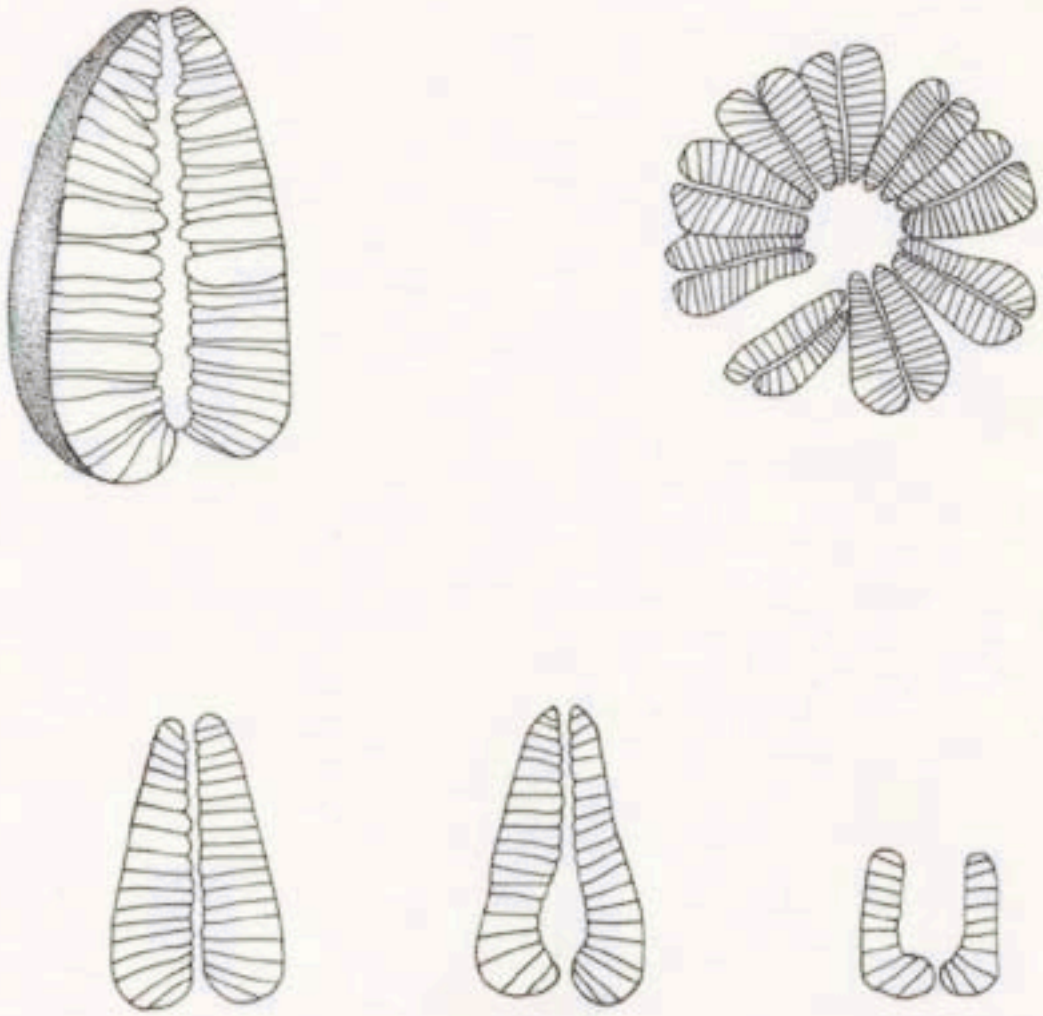
Sphenolithus heteromorphus

Sphenolithus delphix

Sphenolithus dissimilis

Ecologic affinity (?):
Characteristic of low latitudes, warm-water assemblages, perhaps with shallow water preference

NANNOCONIDI (*Nannoconus*)



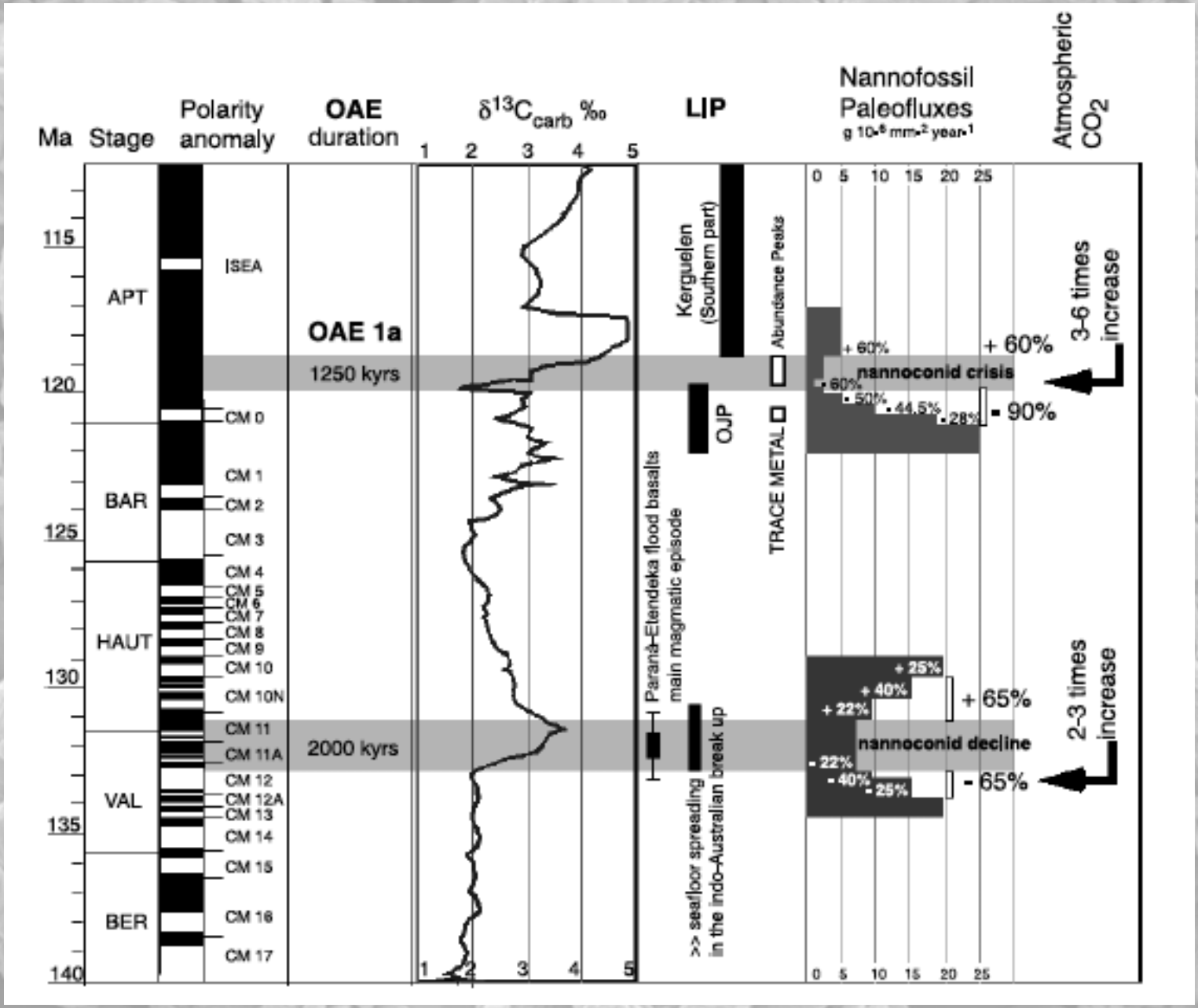
an EXAMPLE from the CRETACEOUS

Nannofossil carbonate fluxes during the Early Cretaceous: Phytoplankton response to nutrification episodes, atmospheric CO_2, and anoxia

Elisabetta Erba and Fabrizio Tremolada
Dipartimento di Scienze Della Terra "A. Desio," Milan, Italy

NANNOFOSSILS and

- ü Greenhouse episodes during Valanginian and Aptian
- ü Major perturbations in the C cycle and in marine ecosystem
- ü Carbonate crises
- ü Widespread deposition of Corg-rich black shales



(Erba and Tremolada, Paleoceanography 19, 2004)

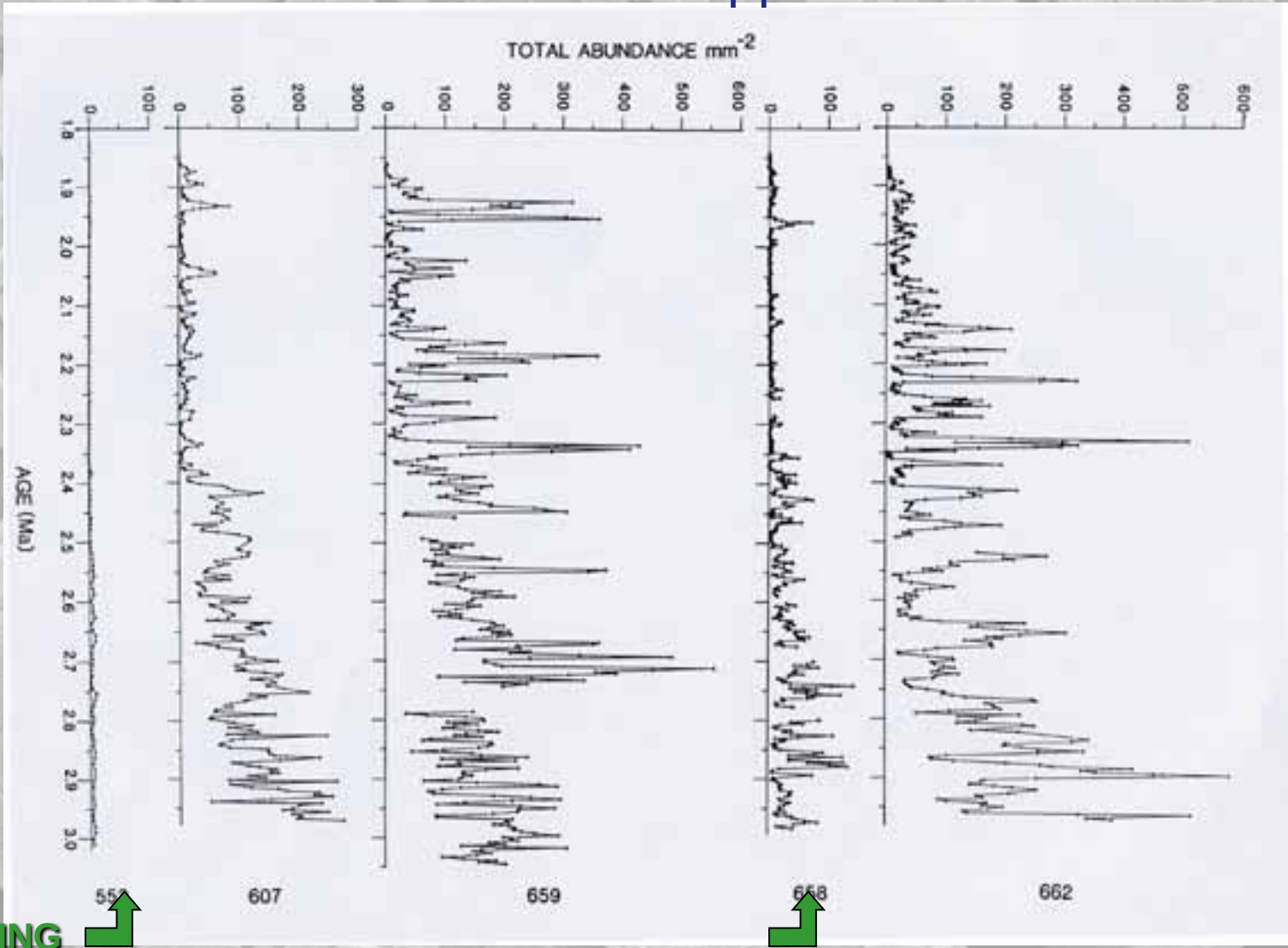
Erba and Tremolada (2004) documented variations in nannofossil abundances and paleofluxes and interpreted them as the response of calcareous phytoplankton to global changes in the ocean-atmosphere system

→ Drastic reduction of calcification
genus *Nannoconus*

- Two major episodes of carbonate crisis documented on global scale in pelagic and shallow water environments

EXAMPLES FROM THE NEOGENE

Late Pliocene *Discoaster* spp. in North Atlantic



UPWELLING

A. Chepstow-Lusty, J. Backman and N.J. Shackleton (1989)

Orbitally forced climate signals in mid-Pliocene nannofossil assemblages

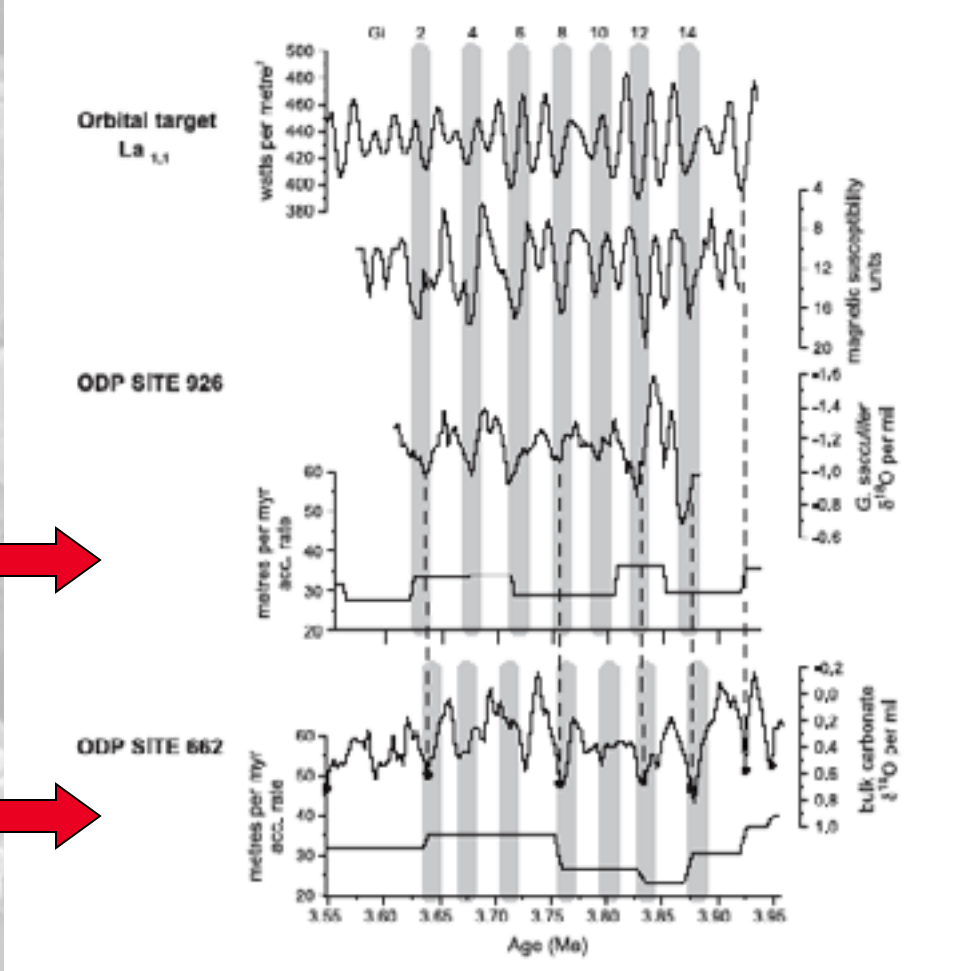
Samantha Gibbs[a,*], Nicholas Shackleton[a], Jeremy Young[b]

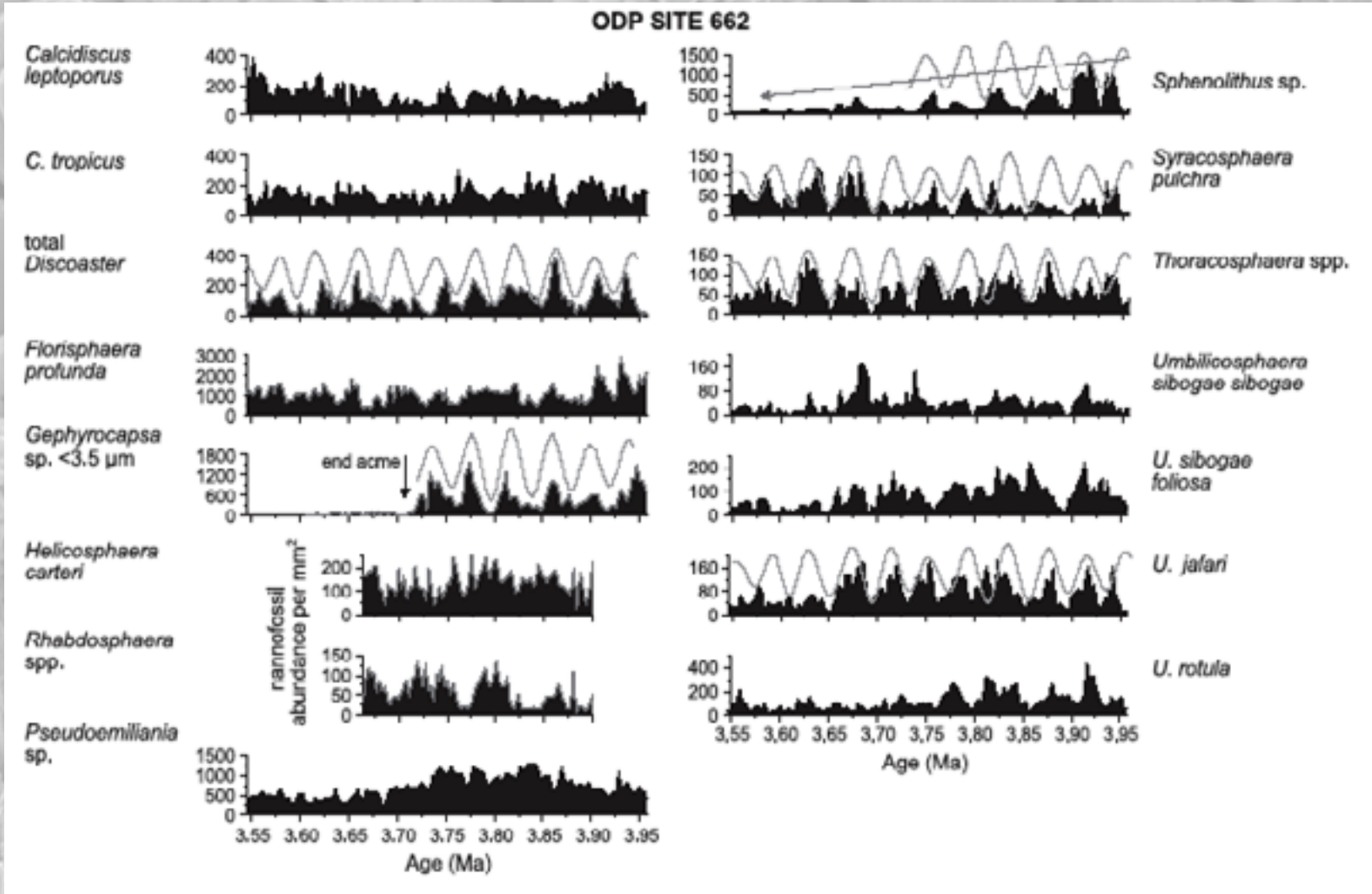
[a]*Godwin Institute for Quaternary Research, University of Cambridge, Pembroke Street, Cambridge CB2 3SA, UK*
[b]*Natural History Museum, South Kensington, London, UK*

Downcore cyclic variations in high-resolution nannofossil abundance records

west tropical Atlantic

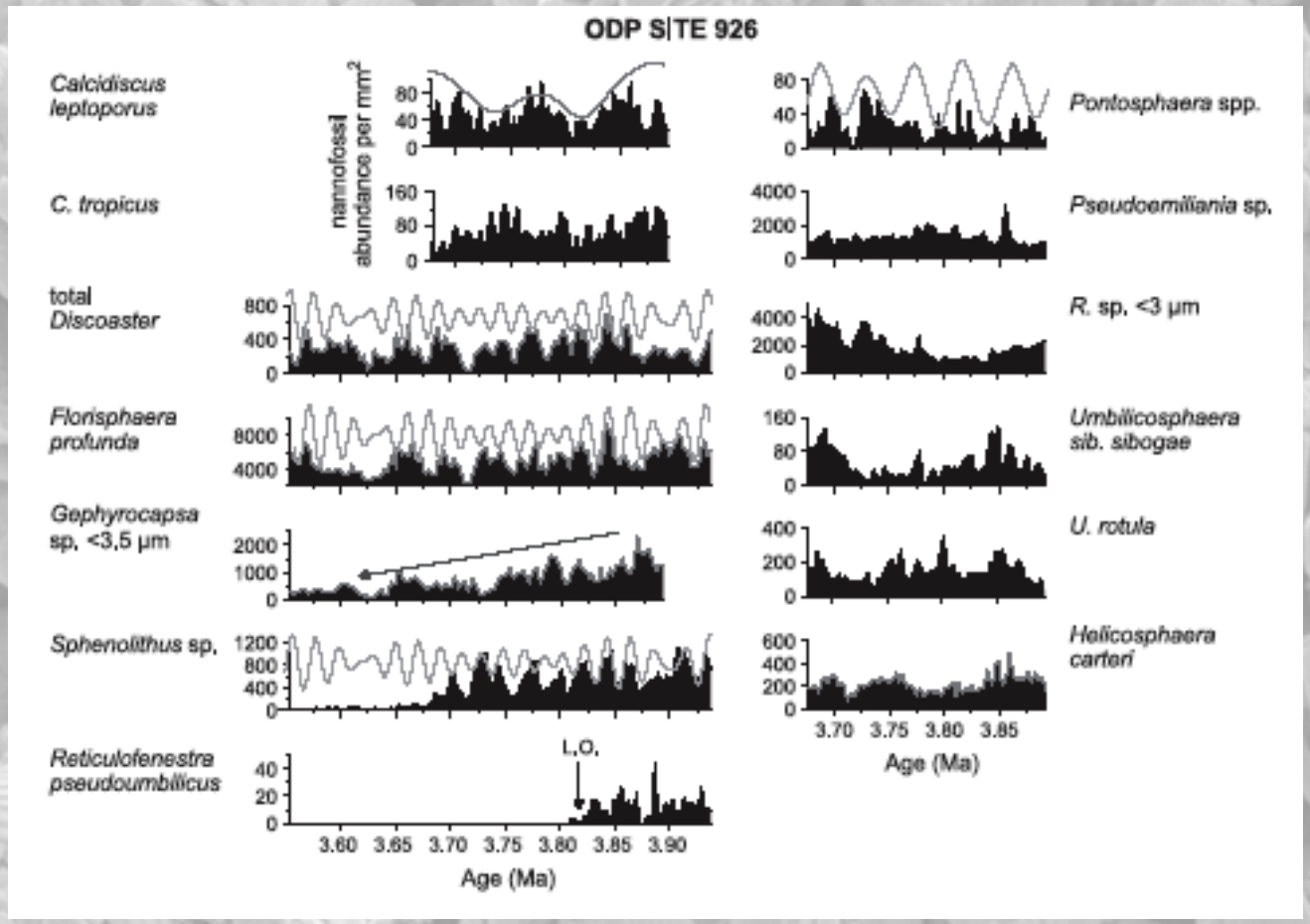
east tropical Atlantic





Selected nannofossil abundance records compared to sequences of Obliquity

(S.Gibbs et al., Marine Micropaleontology, 51, 2004)



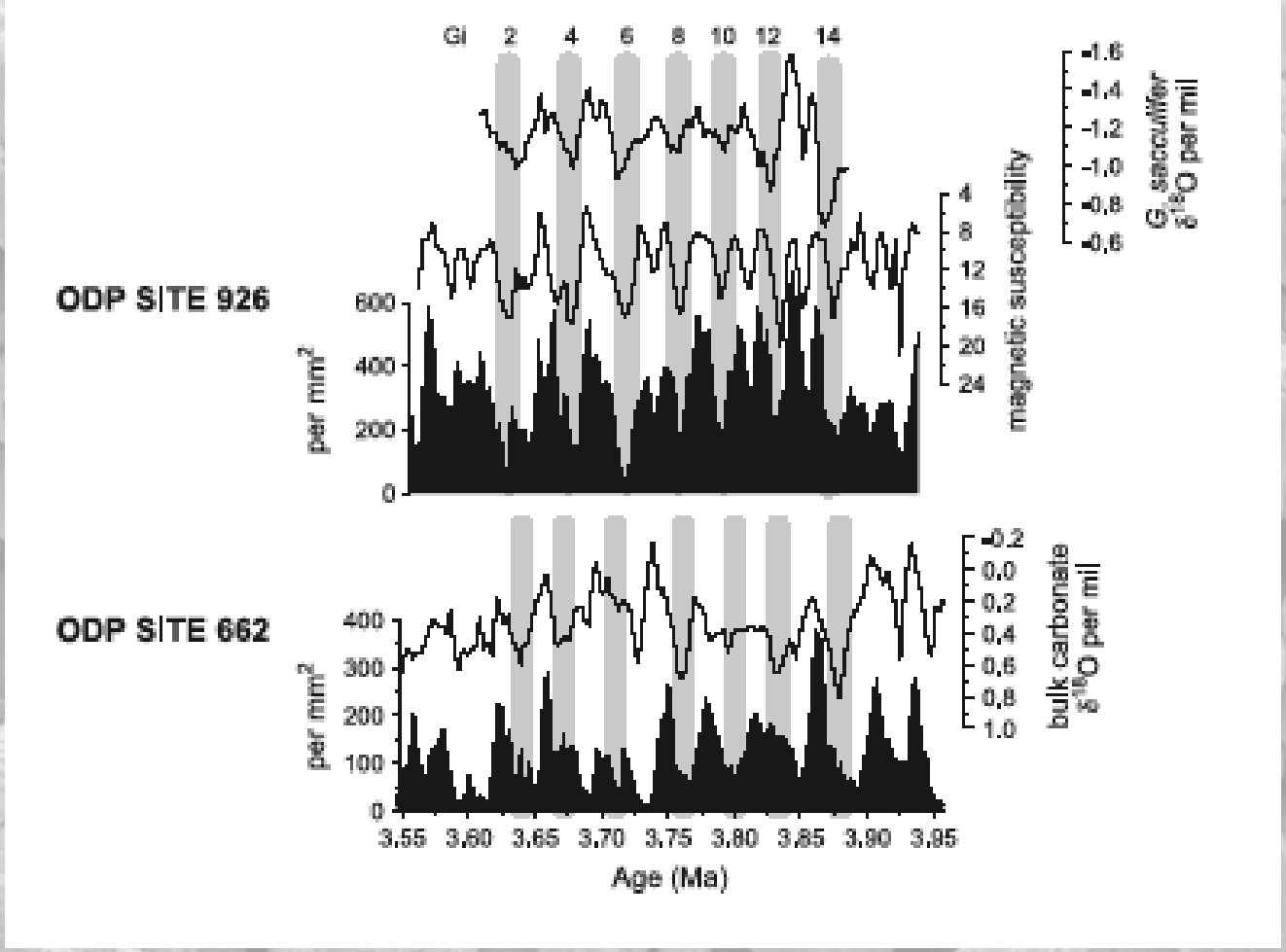
Selected nannofossil abundance records compared to sequences of:

Precession

Obliquity

longer wavelength (100 ky) Eccentricity

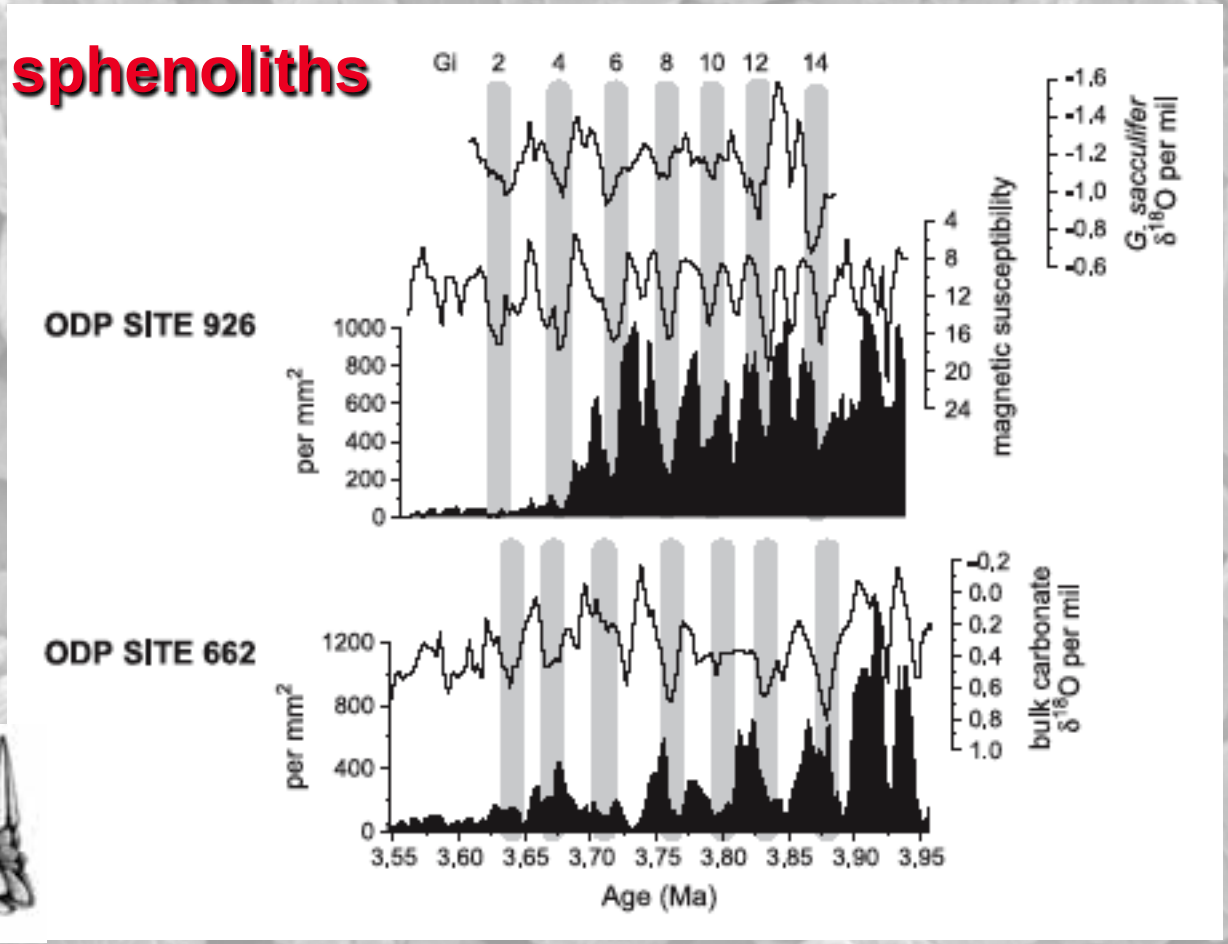
(S.Gibbs et al., Marine Micropaleontology 51, 2004)



-Comparison of total *Discoaster* abundances-
visual assessments of cyclic variations

(S.Gibbs et al., Marine Micropaleontology 51, 2004)

sphenoliths



(S.Gibbs et al., Marine Micropaleontology 51, 2004)

Gibbs et al. (2004) showed that:

- In few nannofossil abundances variance is explained by abiotic processes, because few taxa show correlations with each other or with physical environmental parameters

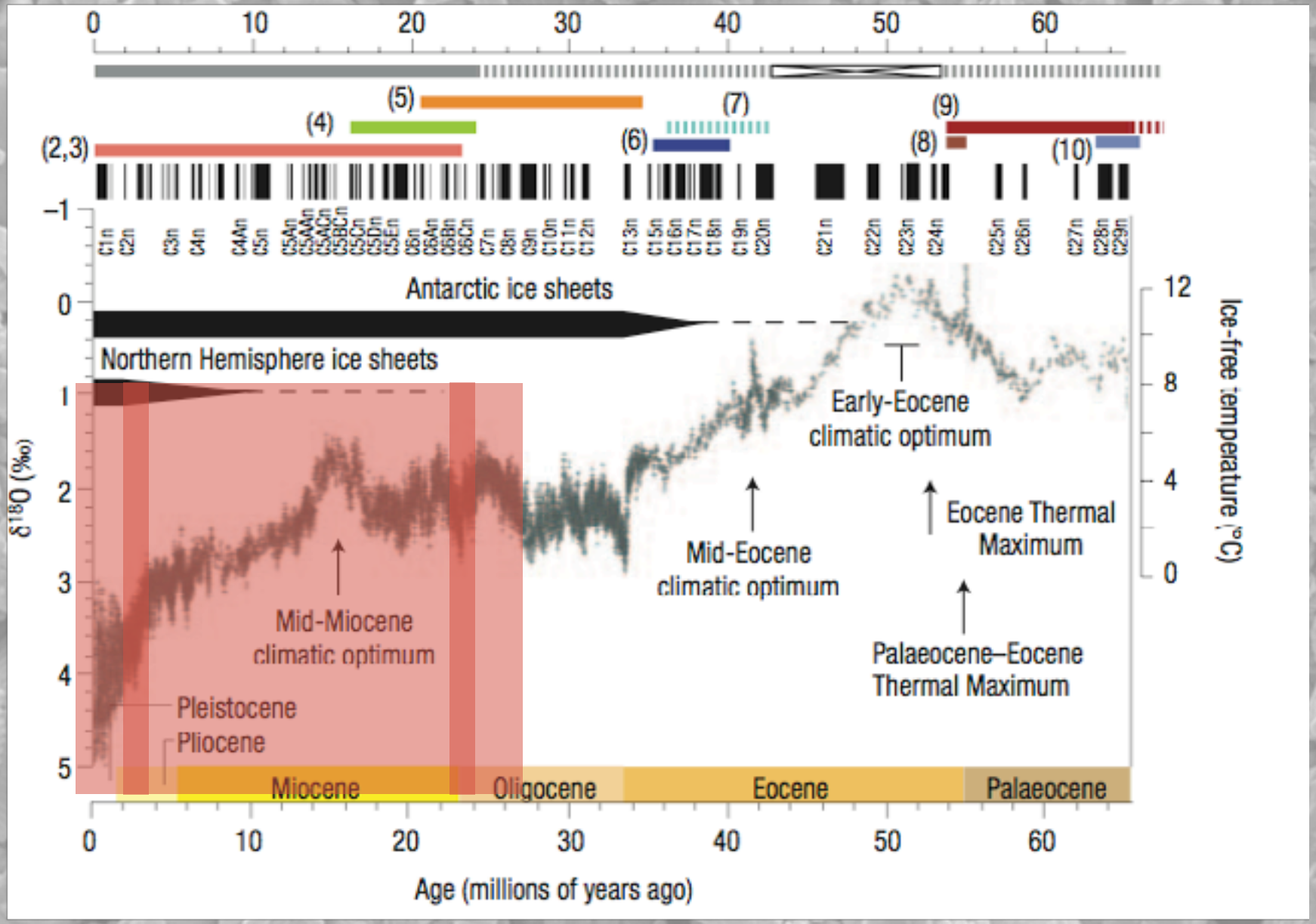
- Some variance can be explained by the primary controls of TEMPERATURE and PRODUCTIVITY

From this case study of the Pliocene:

ü substantial lack of strong and consistent relationship of the nannofossils and the environment

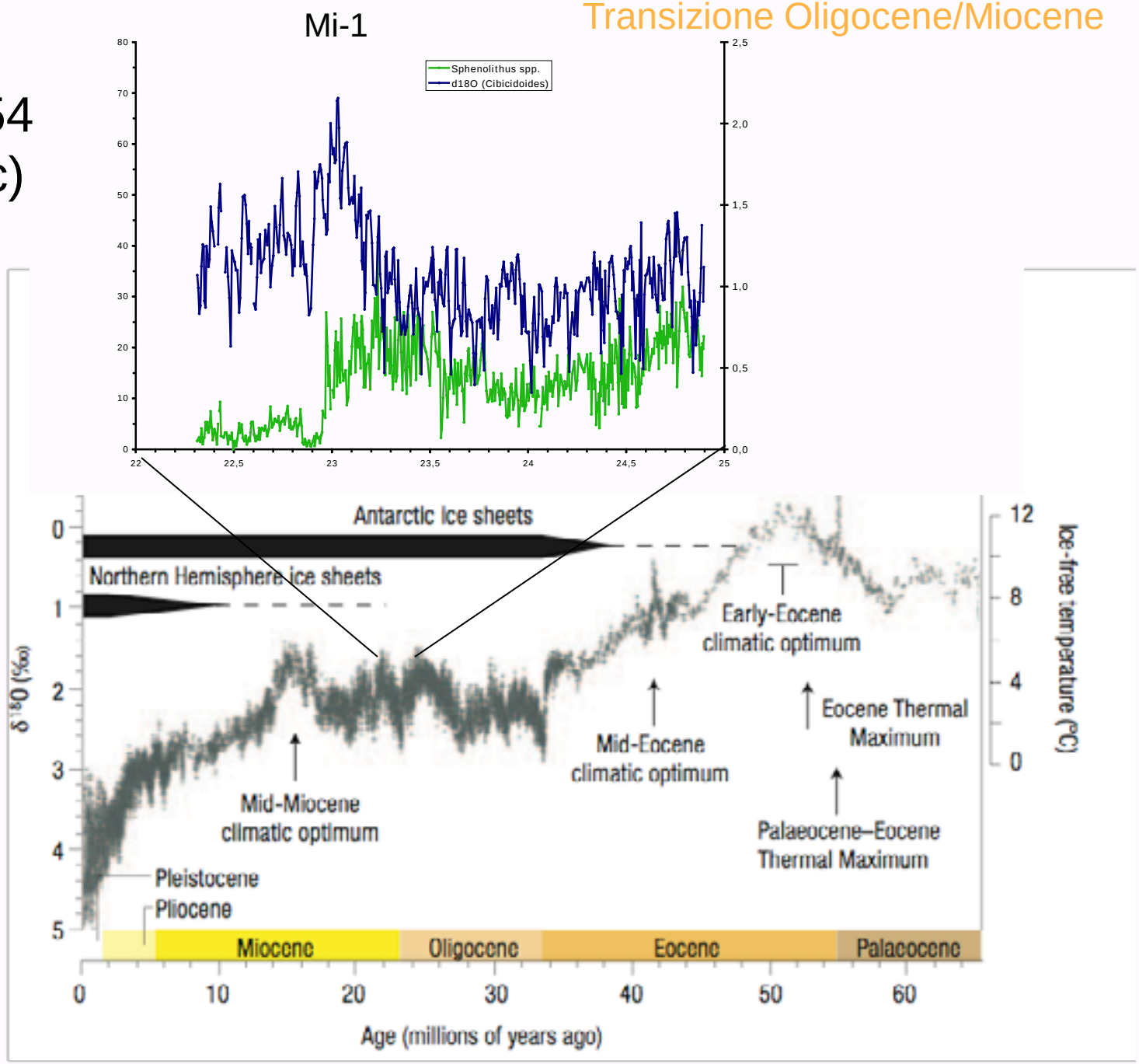
ü non linear response to climatic changes

ü most of the observed variance can be attributed to biotic processes (grazing, predation, viral infection and competition) and/or abiotic factors for which there is no available proxy (e.g. salinity)

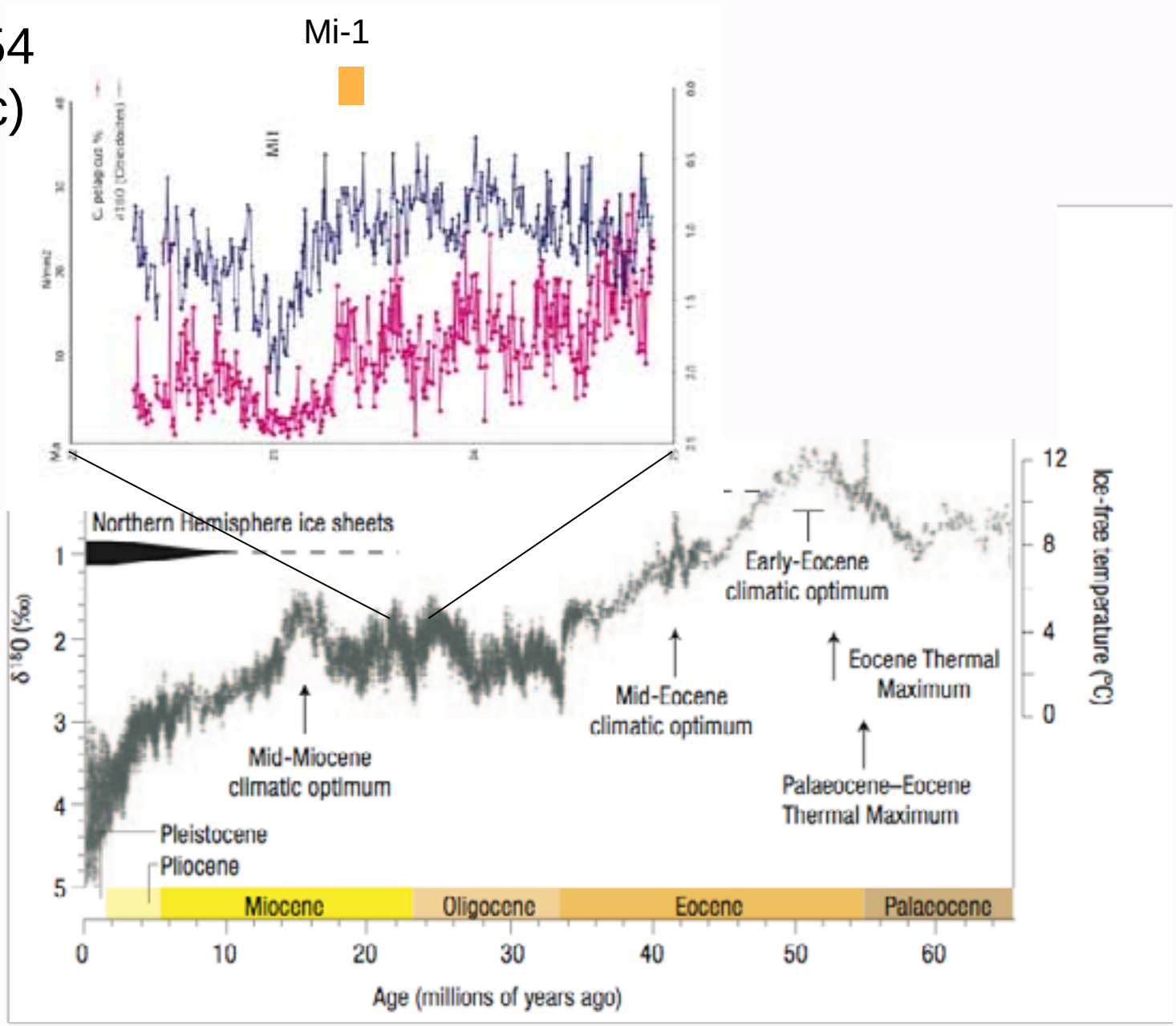

Antarctic ice sheets
Northern Hemisphere ice sheets
Early-Eocene climatic optimum
Mid-Eocene climatic optimum
Eocene Thermal Maximum
Palaeocene–Eocene Thermal Maximum
Mid-Miocene climatic optimum
Pleistocene
Pliocene
Miocene
Oligocene
Eocene
Palaeocene
δ18O (‰)
Ice-free temperature (°C)
Age (millions of years ago)

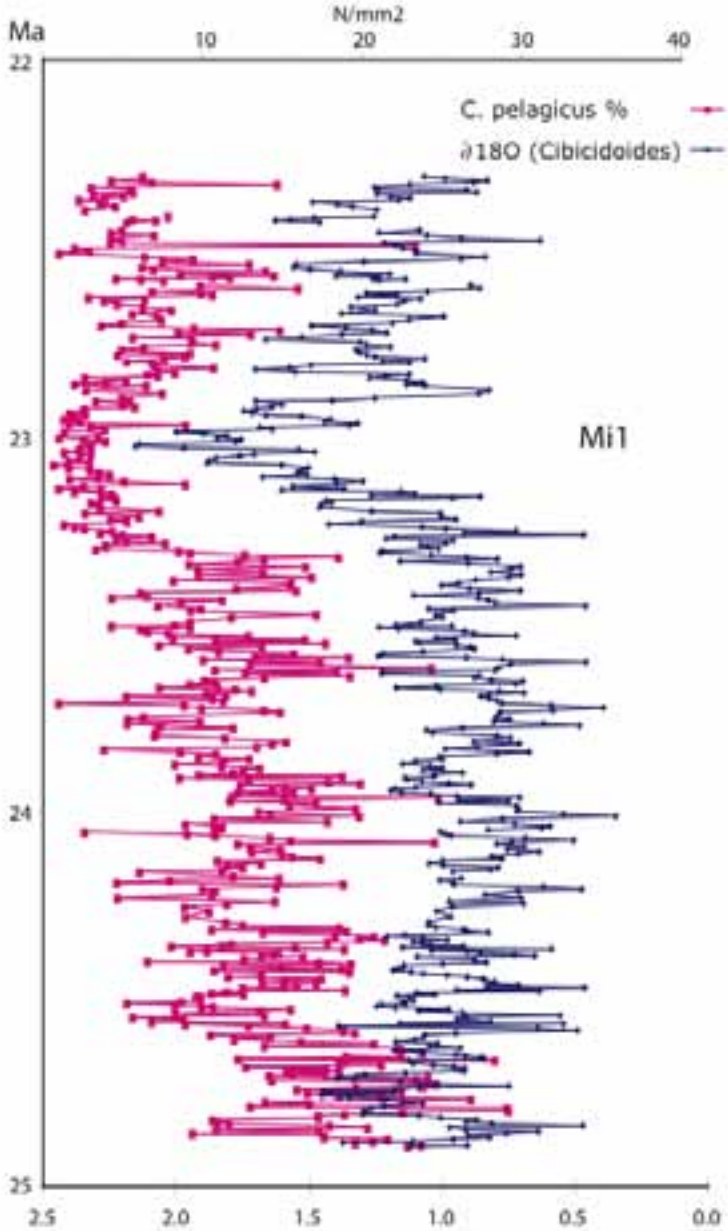
Transizione Oligocene/Miocene

ODP Leg 154
(Eq. Atlantic)
Site 926



ODP Leg 154
(Eq. Atlantic)
Site 926





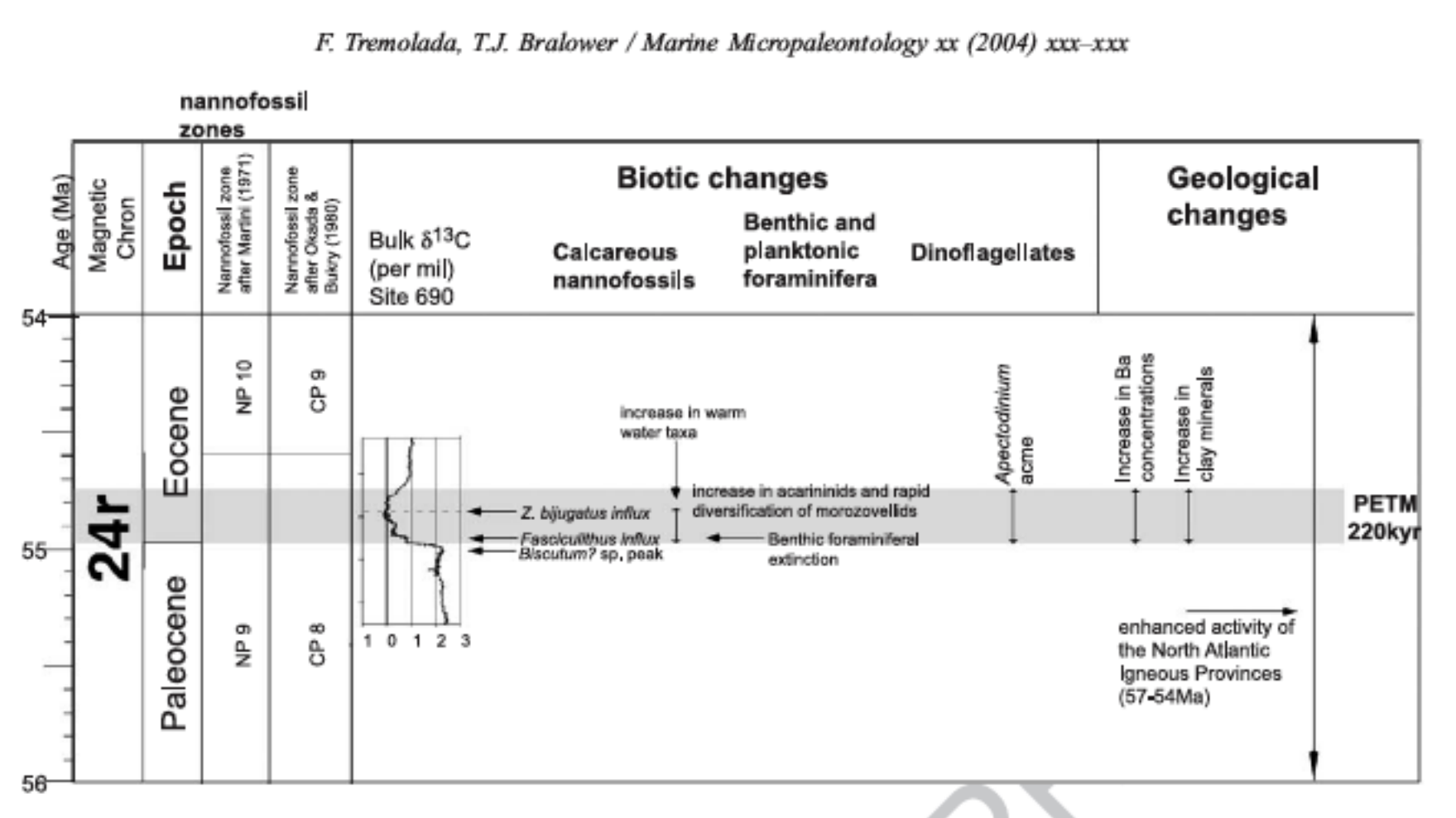
Oligocene/Miocene transition

Coccolithus pelagicus
abundance fluctuations

at ODP Site 929, Ceara Rise,
western equatorial Atlantic
(Isotope curve from J. Zachos and coworkers)

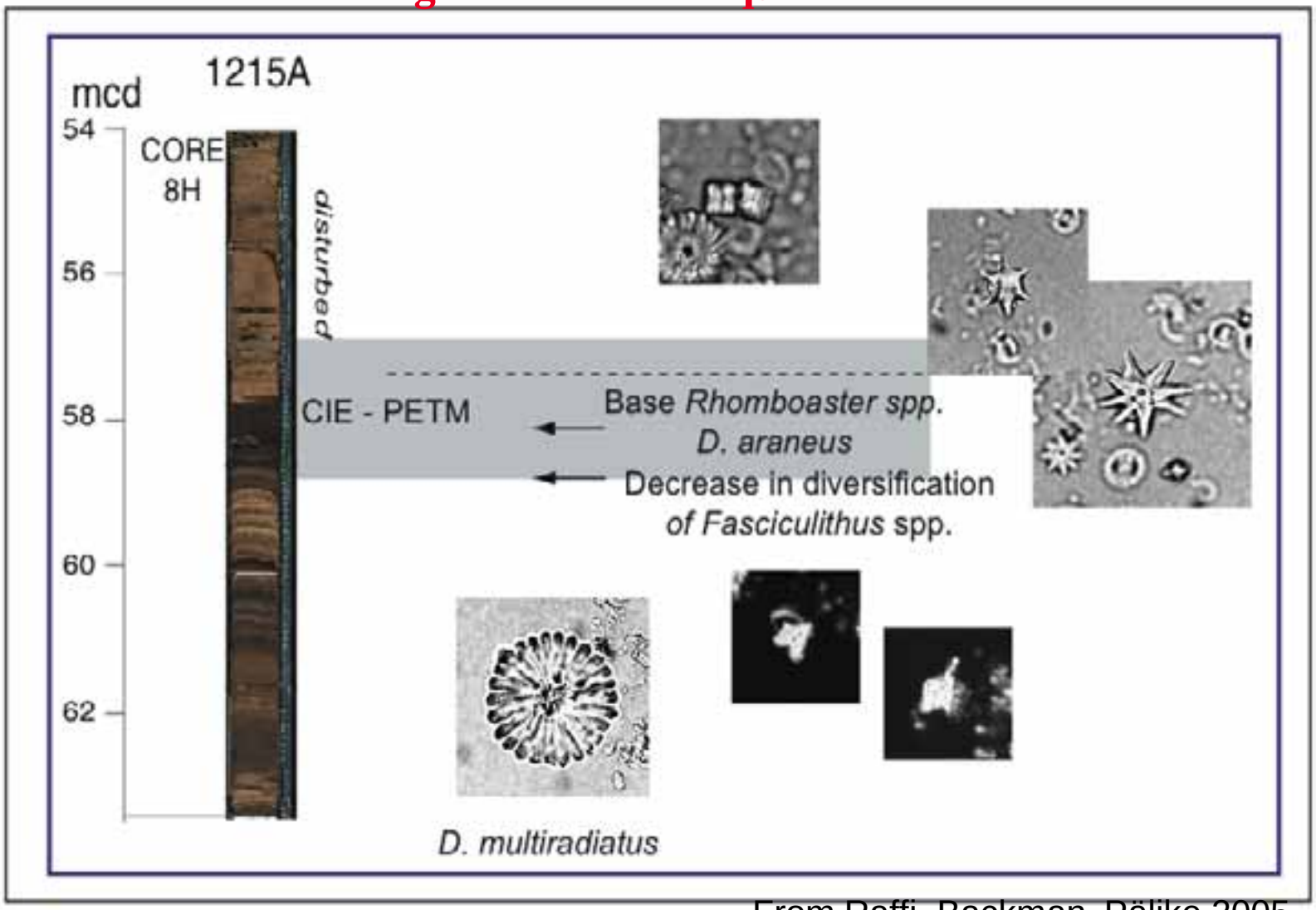
(Raffi and Mozzato, unpublished)

EXAMPLES from the PALEOGENE



The Paleocene/Eocene transition

ODP Leg 199-Site 1215 equatorial Pacific



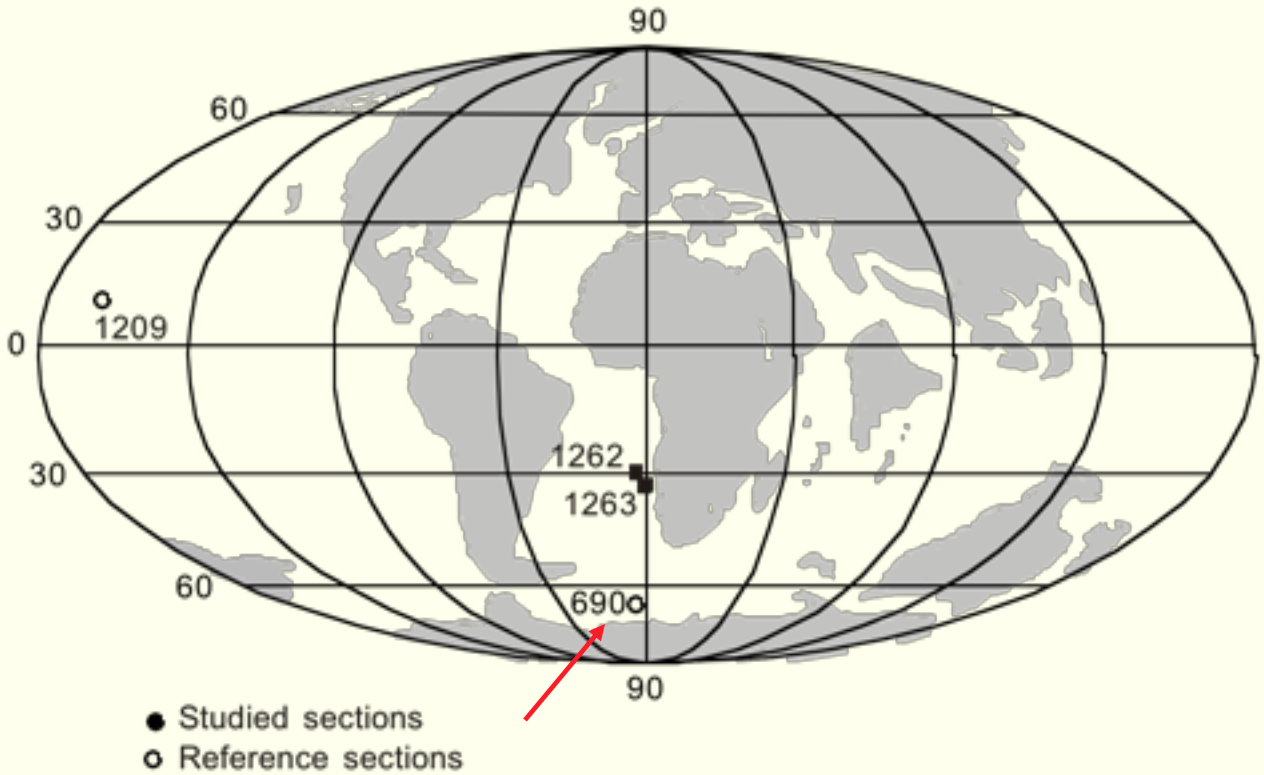
From Raffi, Backman, Pälike,2005

Nannofossils at the Paleocene/Eocene transition

Paleoceanography, vol. 17, 2002

Evidence of surface water oligotrophy during the Paleocene-Eocene thermal maximum: Nannofossil assemblage data from Ocean Drilling Program Site 690, Maud Rise, Weddel Sea

Timothy J. Bralower



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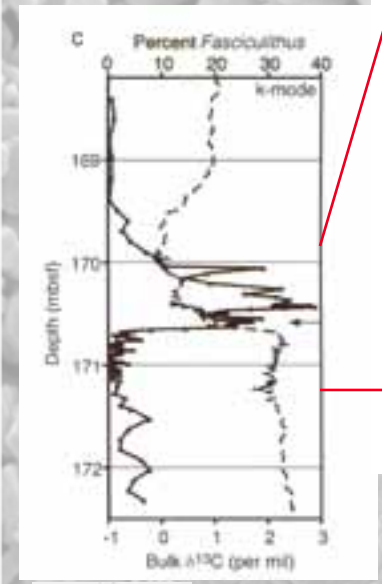
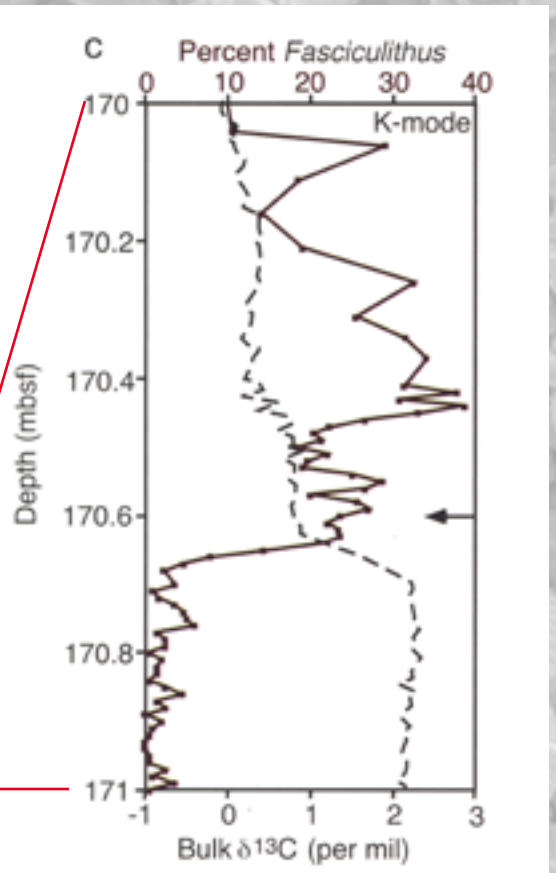
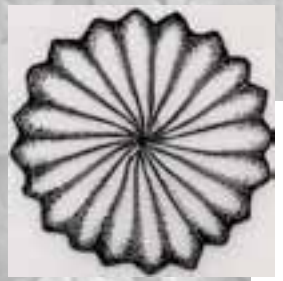
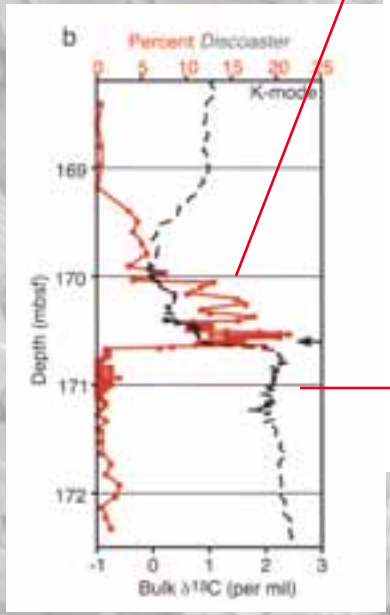
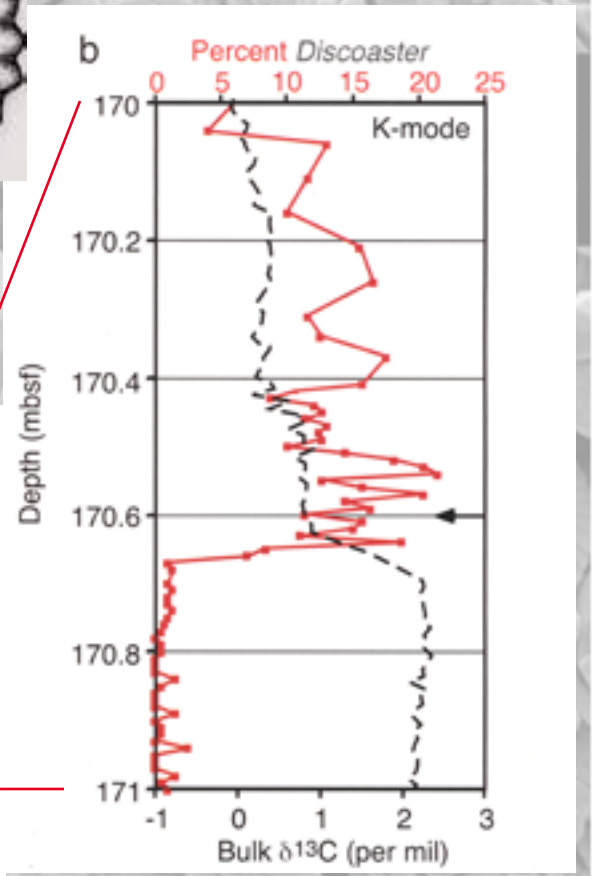




fasciculiths



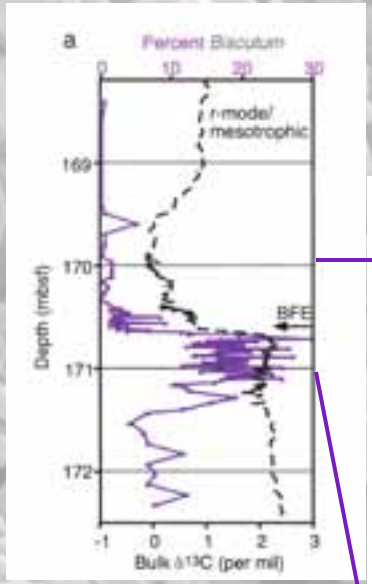


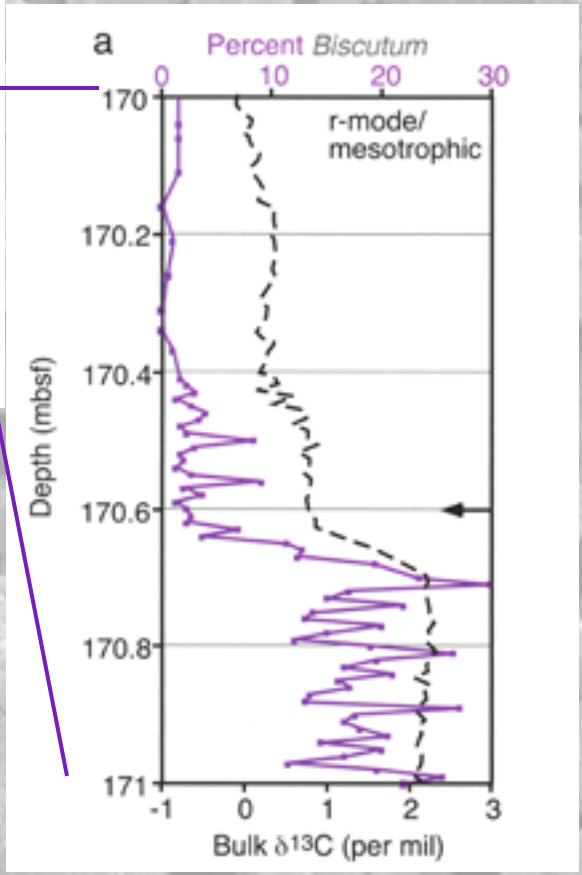


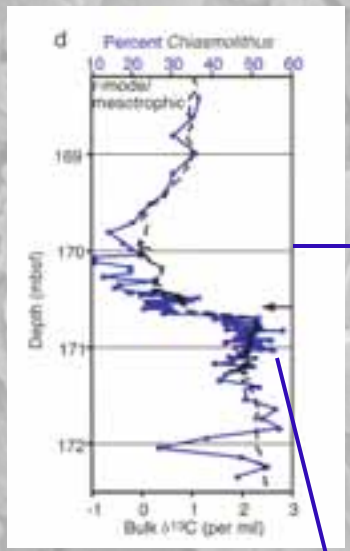
discoasterids

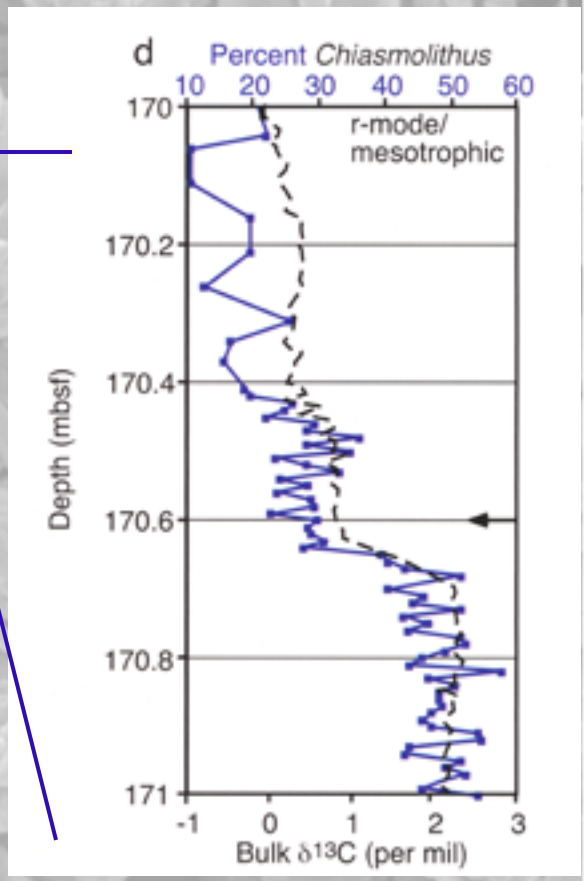
Oligotrophic Taxa

from T. Bralower, Paleoceanography 17 (2002)







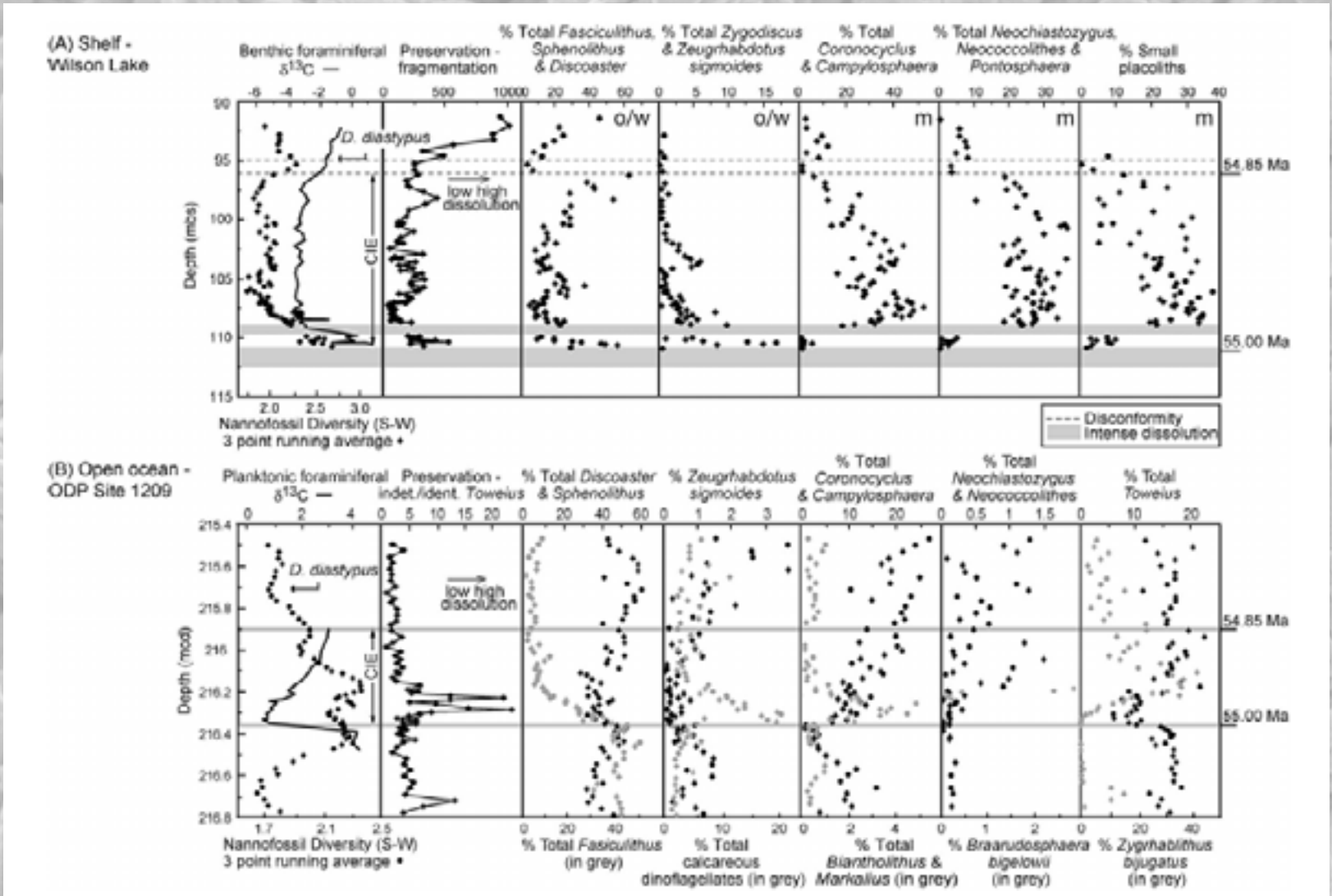


Chiasmolithus

Biscutum

Eutrophic Taxa

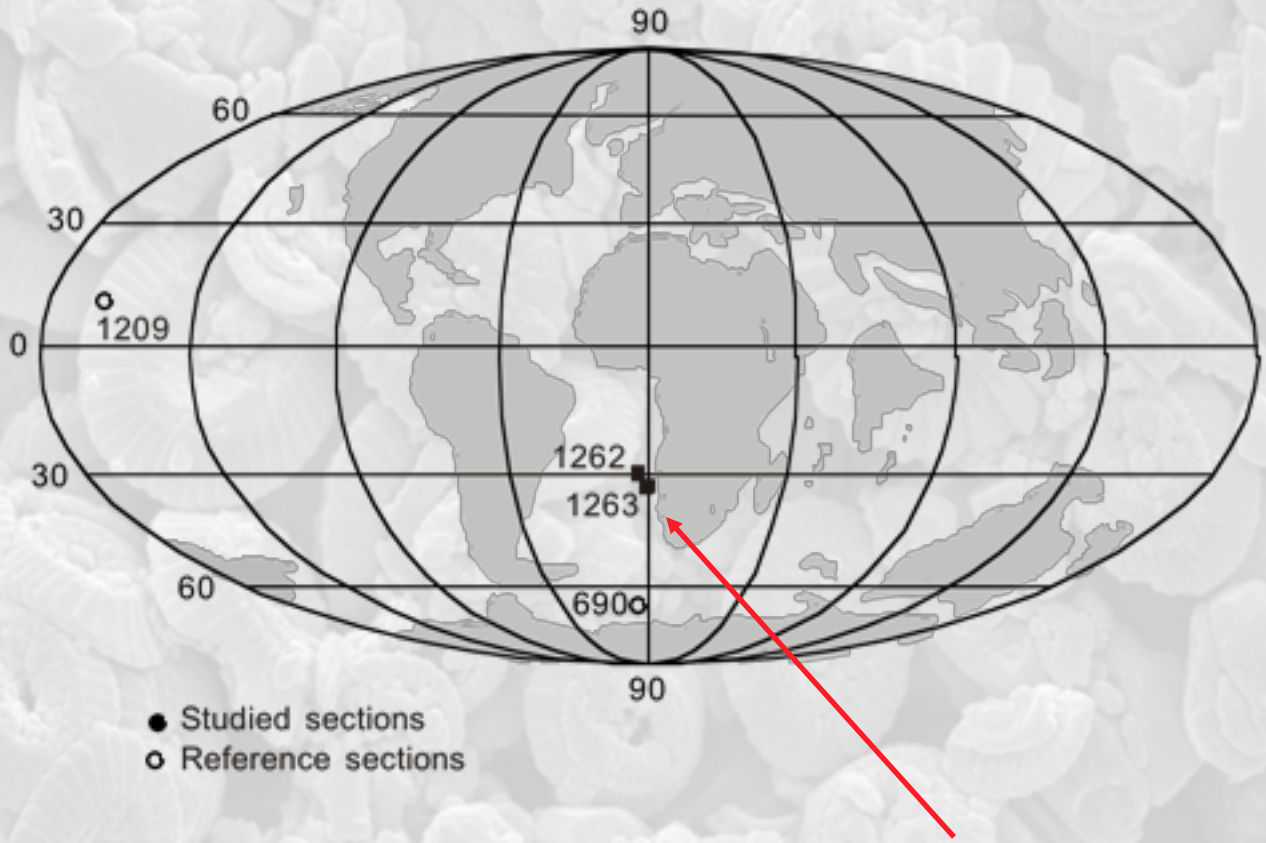
from T. Bralower, Paleoceanography 17 (2002)



- Global but transient increase of oligotrophy in open-ocean sites
- Increased productivity in shelf sites

(Gibbs et al., Geology, 2006)

Nannofossils at the Paleocene/Eocene transition



ODP Leg 208 - southeastern Atlantic

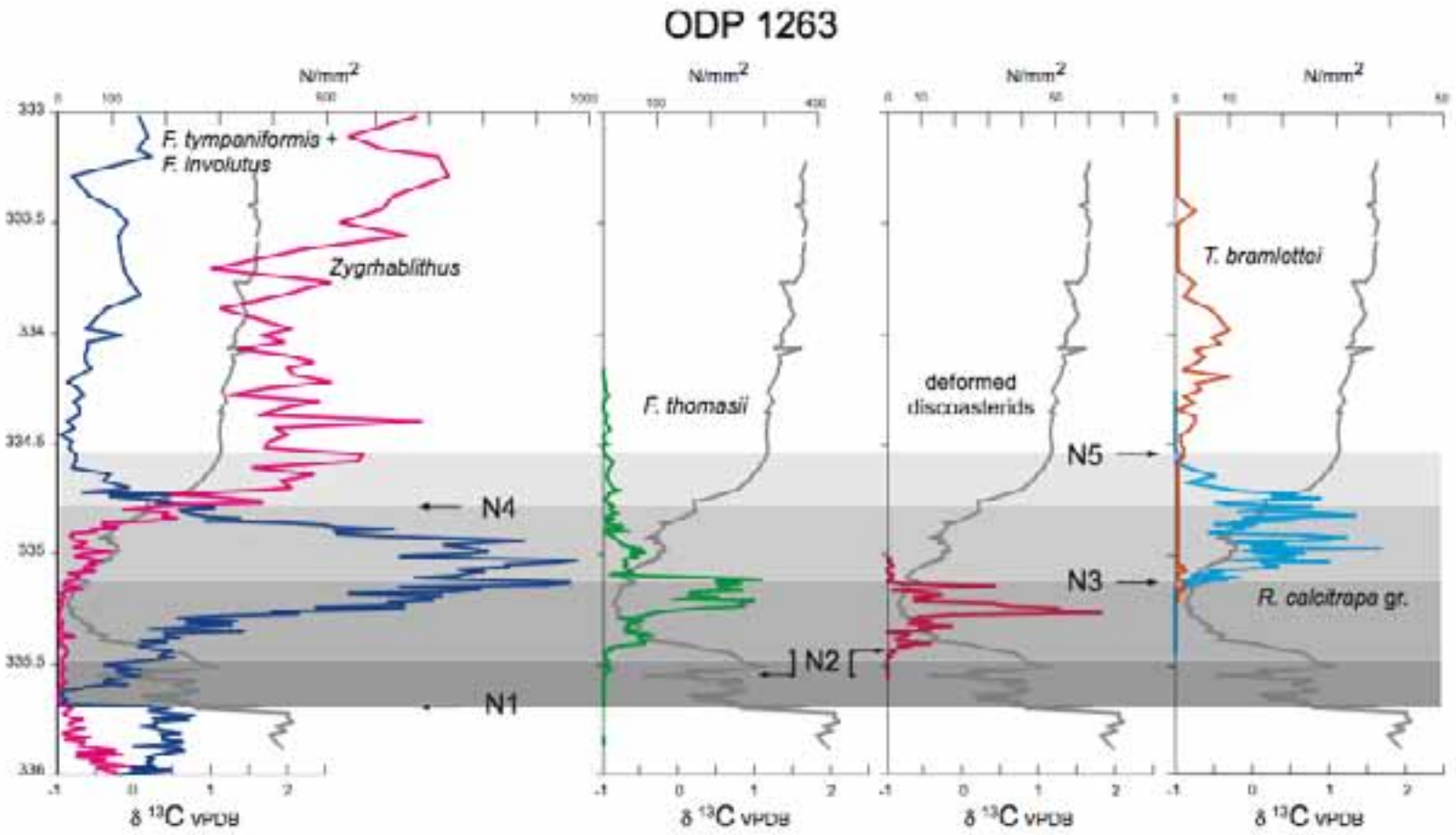
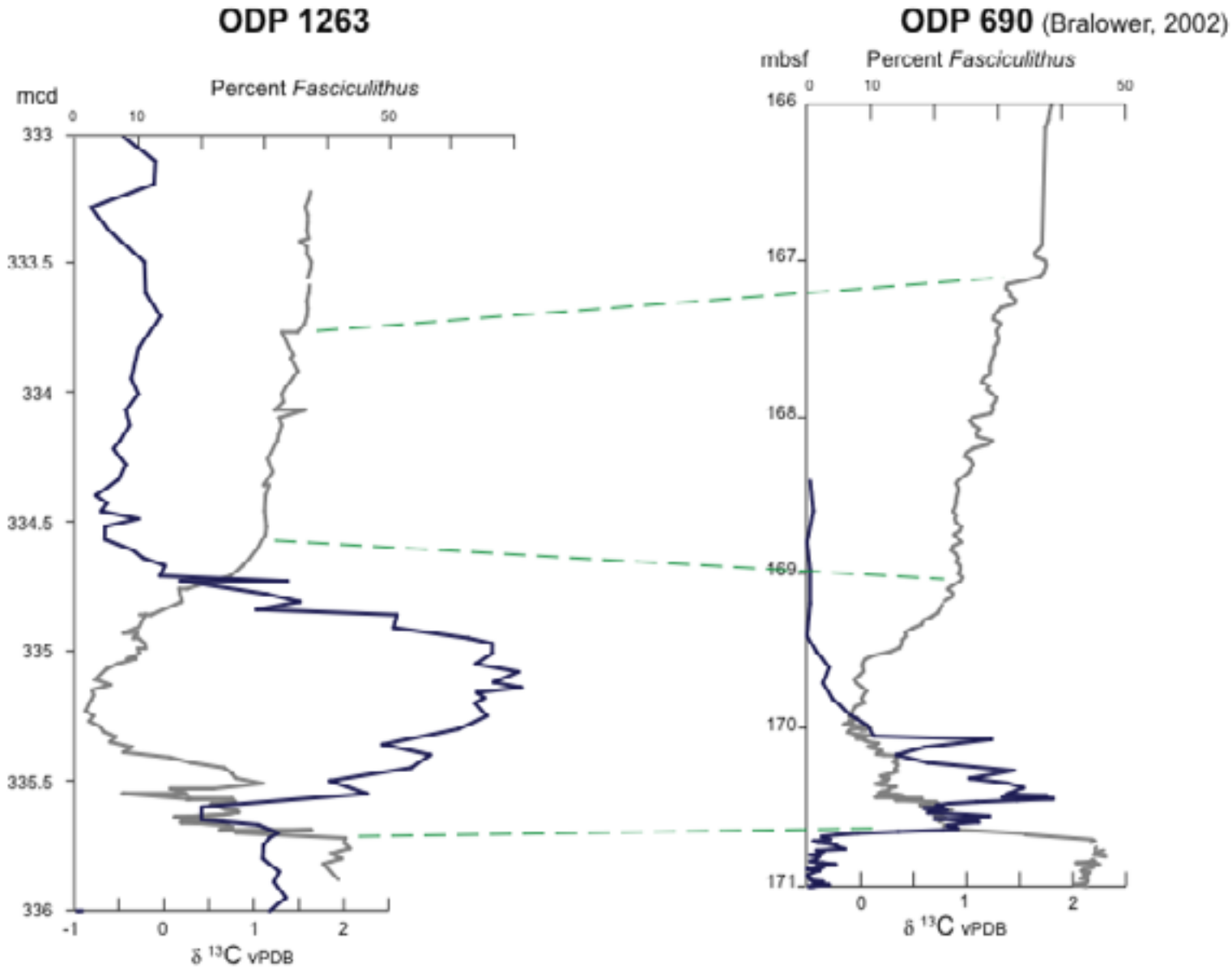


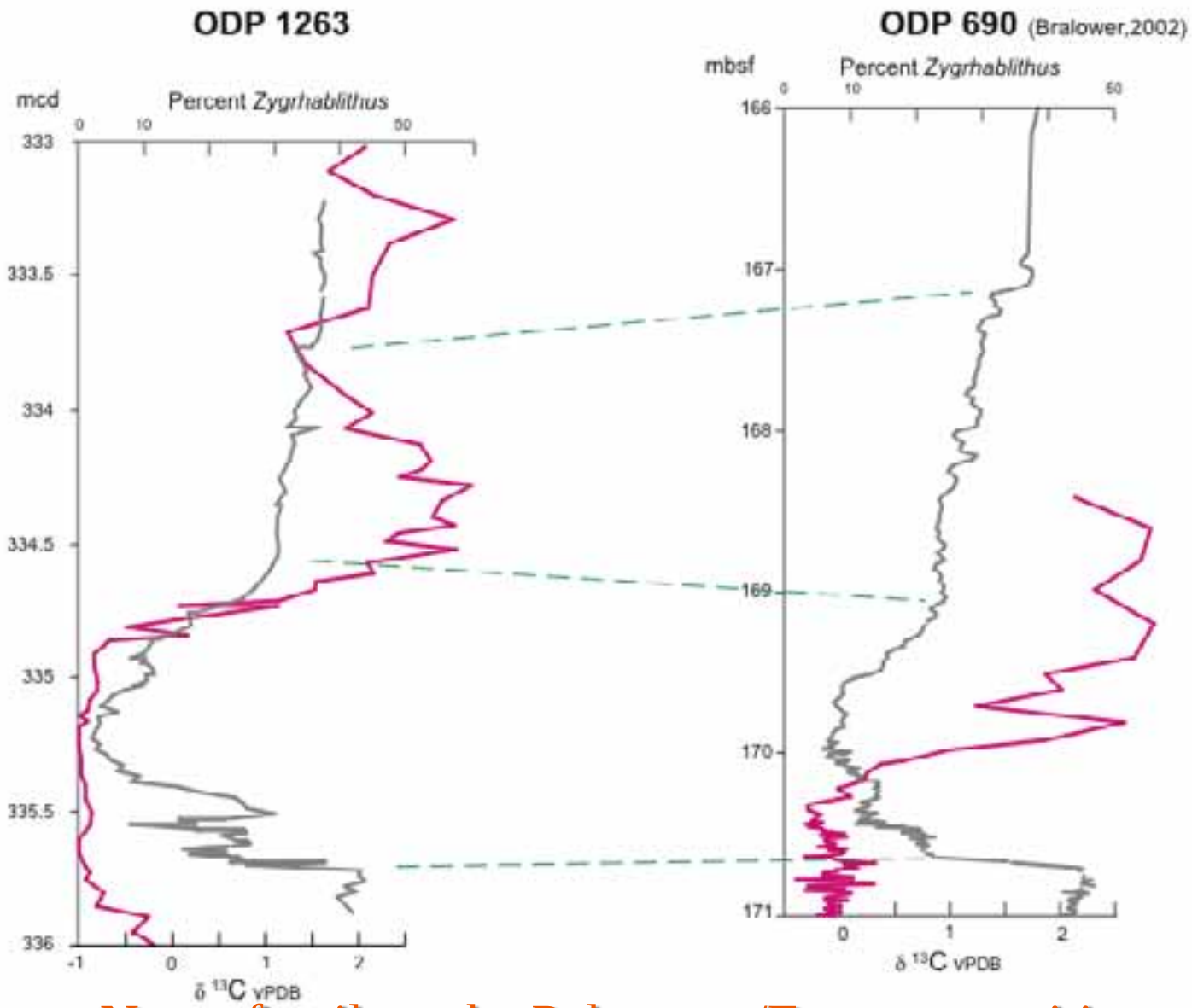
FIGURE 8

(Raffi et al.2008)

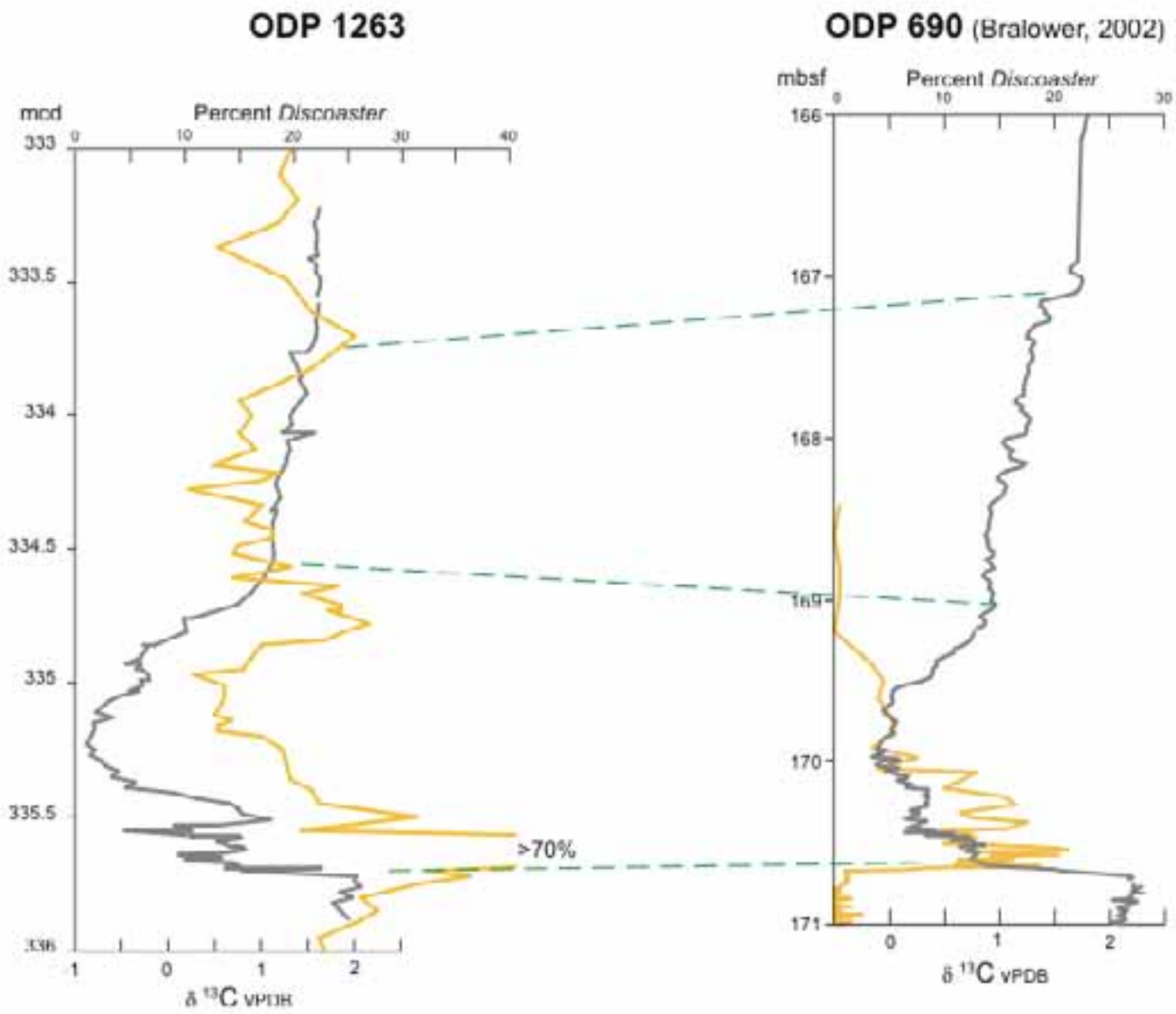


Nannofossils at the Paleocene/Eocene transition

(Raffi et al., 2008)

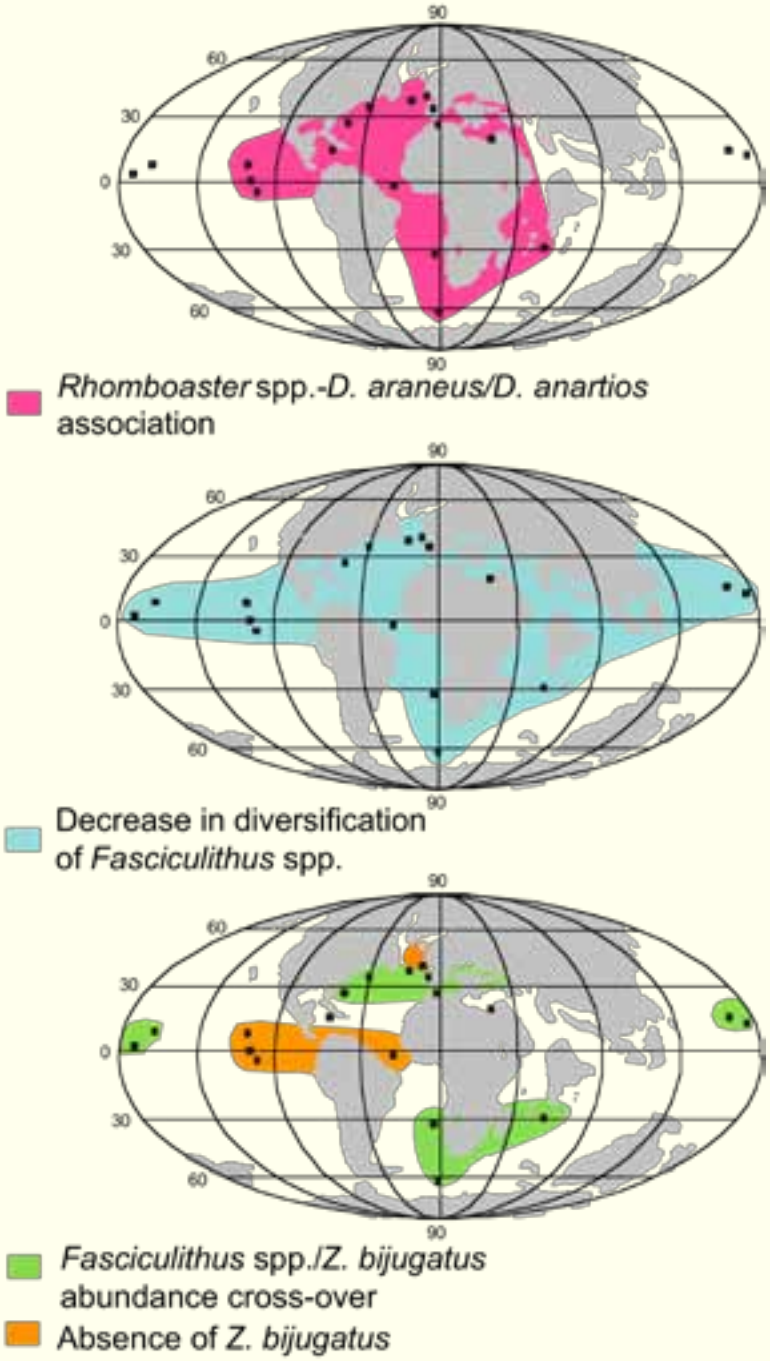


Nannofossils at the Paleocene/Eocene transition



Nannofossils at the Paleocene/Eocene transition

(Raffi, Zachos, Sluijs, in preparation)



Paleobiogeography of nannofossil taxa at the Paleocene-Eocene transition

From I. Raffi, J. Backman and H. Pälike (2005)

I NANNOFOSSILI CALCAREI (Nannoflora) rappresentano

una comunità differenziata e complessa dal punto di vista ecologico, che fornisce segnali complessi, trasmessi e conservati nel record fossile

PARTE III:
Nannoplancton e nannofossili calcarei nelle ricostruzioni paleoclimatiche e paleoambientali

OUTLINE

- Nannoplancton e nannofossili calcarei come *proxie* paleoclimatici

- **Evoluzione dei nannofossili calcarei e cambiamenti climatico-ambientali**

MOMENTI di MAGGIORE DIVERSIFICAZIONE nell'ambito delle ASSOCIAZIONI a NANNOFOSSILI

TARDO GIURASSICO	OXFORDIANO
CRETACICO	APTIANO- ALBIANO
CRETACICO superiore	MAASTRICHTIANO *

PALEOCENE superiore - EOCENE inferiore *

MIOCENE inferiore - MIOCENE medio

Trend verso **DECRESCENTE DIVERSITA'**

fino al PLEISTOCENE

CURVE della DIVERSITA' delle COCCOLITOFORIDI e dei NANNOFOSSILI

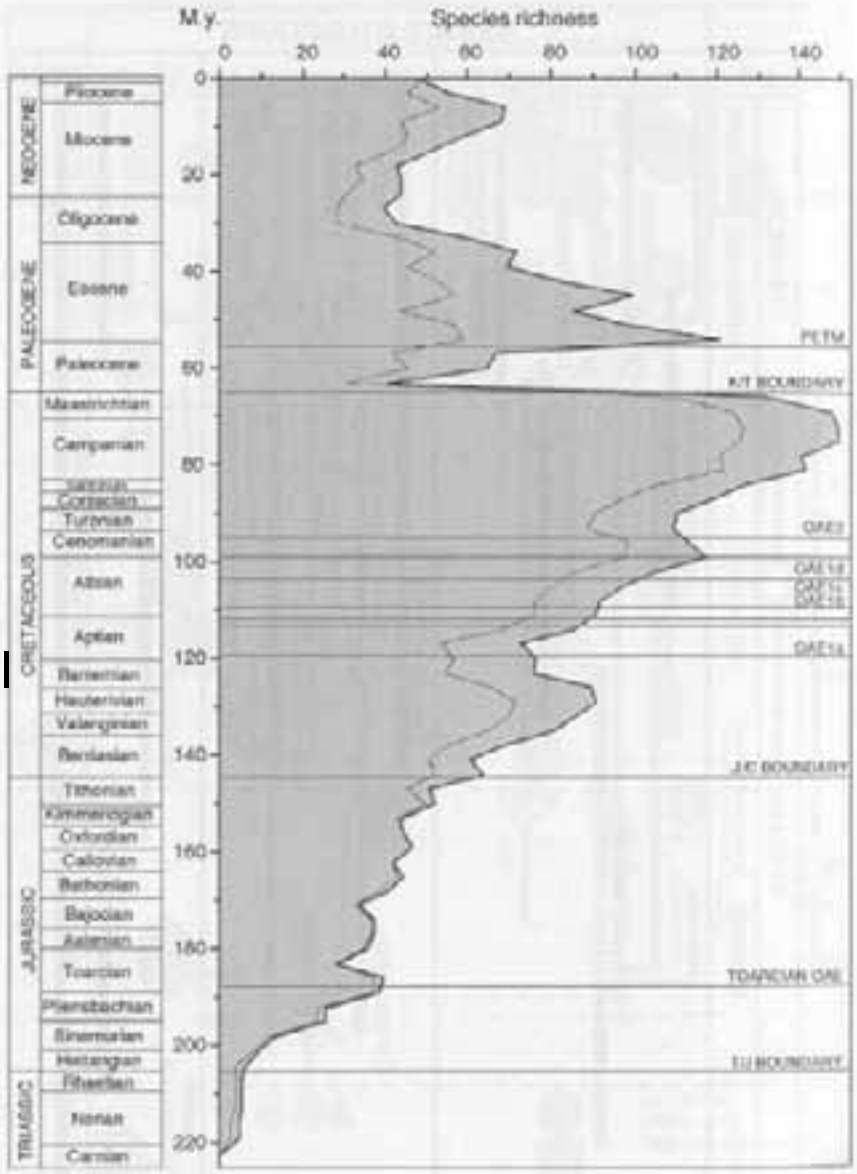
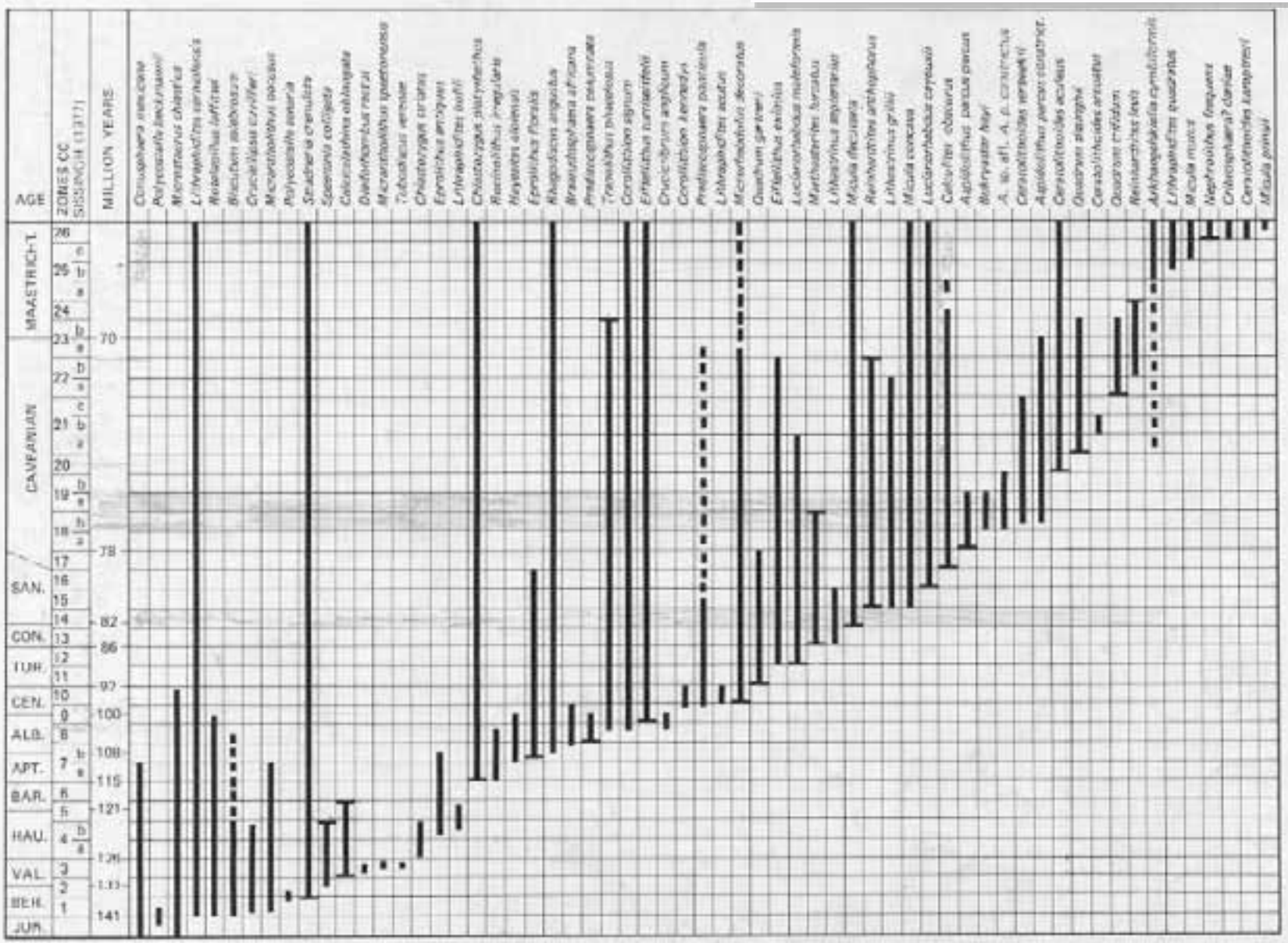
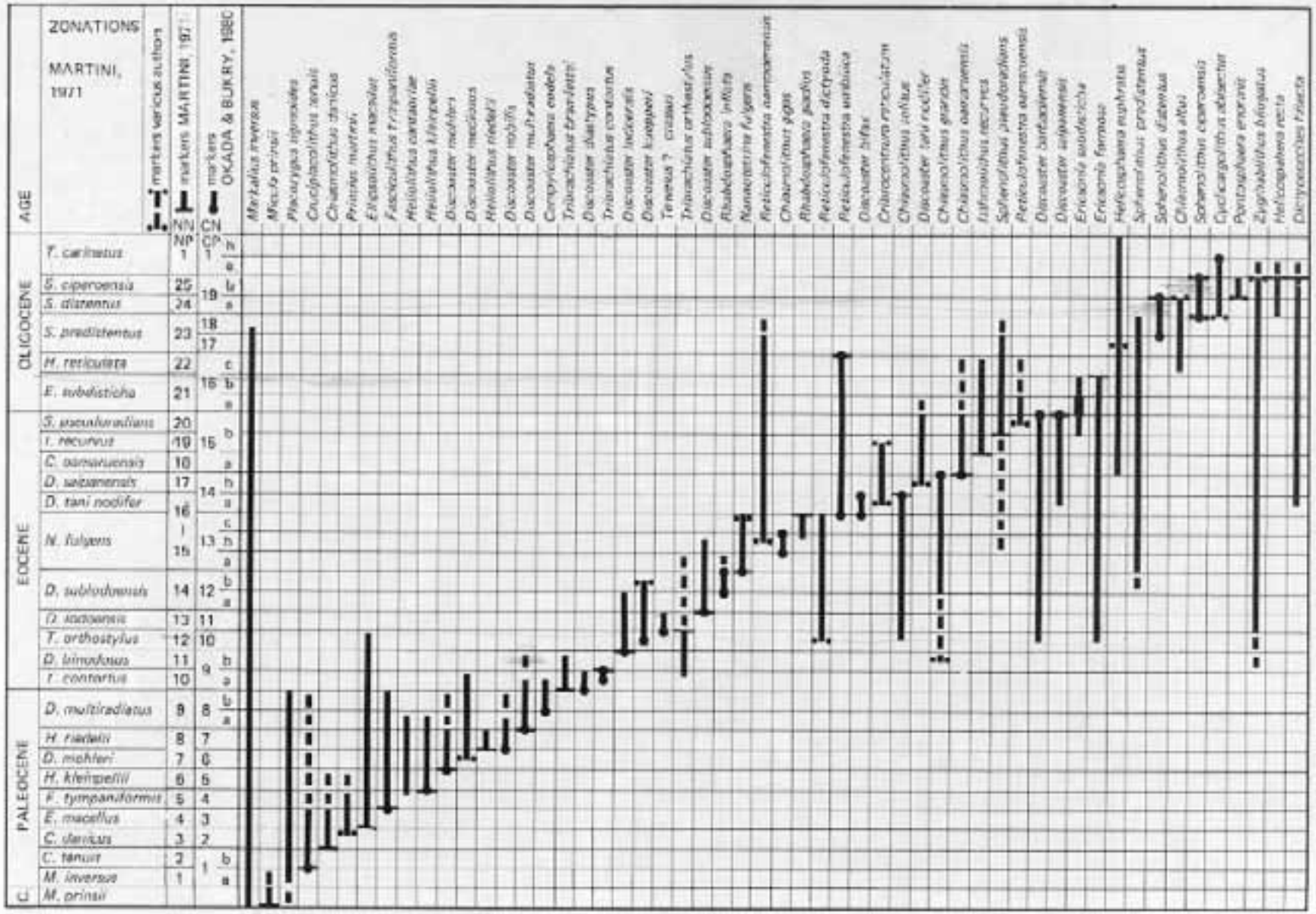


Fig. 2. Coccolithophore (light line) and total nannofossil (dark line) diversity. Data represents species richness for a three million-year interval, plotted at the mid-point. The timescales are from Berggren et al. (1995) and Gradstein et al. (1995). OAE: oceanic anoxic event. PETM: Paleocene/Eocene thermal maximum.

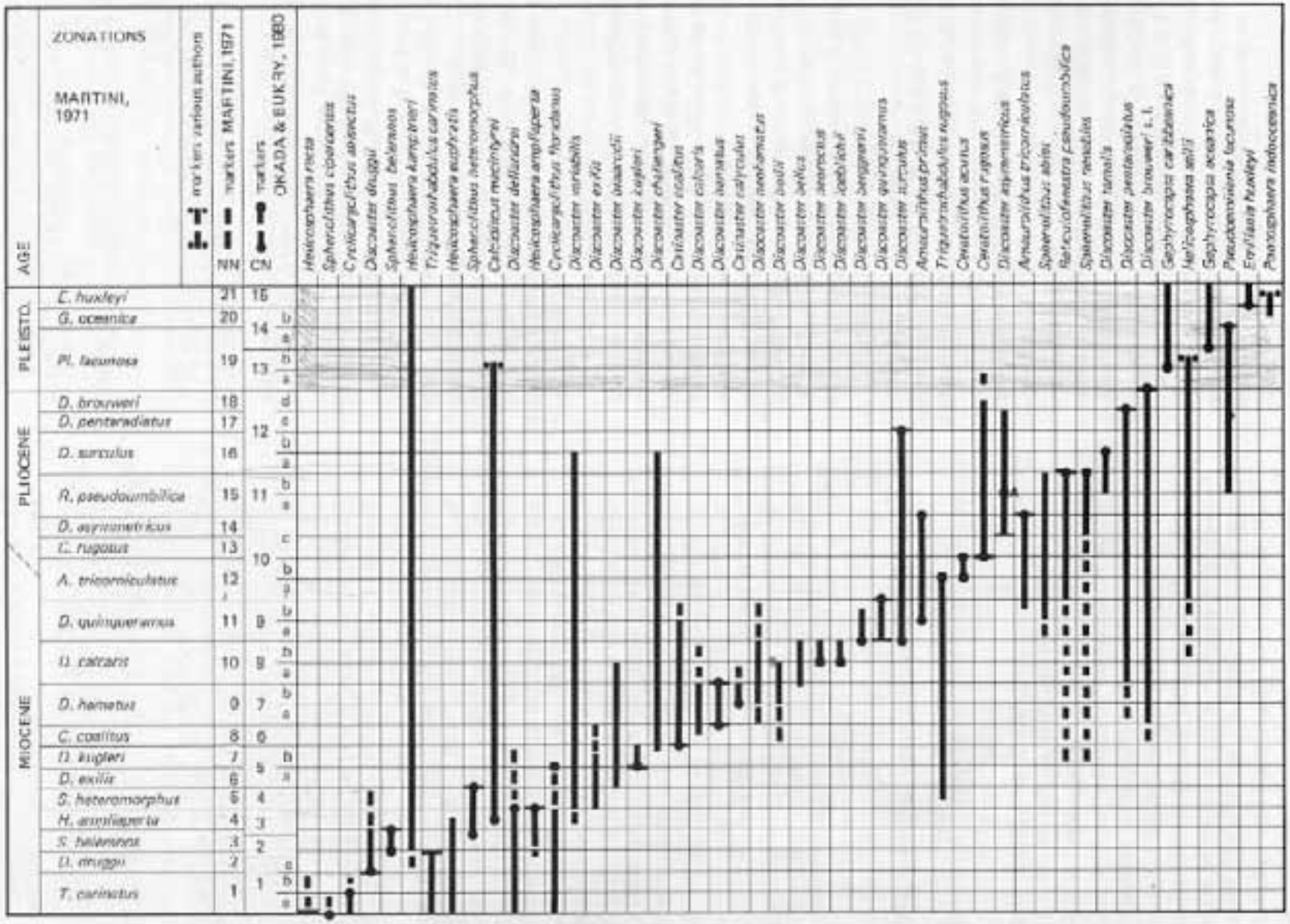
CRETACICO


AGE
ZONES CC
SISSINGH (1977)
MILLION YEARS
MAASTRICHT.
CAMPANIAN
SAN.
CON.
TUR.
CEN.
ALB.
APT.
BAR.
HAU.
VAL.
BER.
JUR.
70
78
82
86
97
100
108
115
121
126
133
141
Conusphaera mexicana
Polycostella beckmanni
Microstaurus chiastius
Lithraphidites carniolensis
Retecapsa ellipsoidea
Biscutum ellipticum
Cretarhabdus crenulatus
Microrhabdulus decorus
Polycostella senaria
Seribiscutum granulatum
Speetonia colligata
Calcicalathina oblongata
Quadrum sissinghii
Micrantholithus hoborsii
Tubodiscus verenae
Chiastozygus litterarius
Eprolithus floralis
Lithraphidites bollii
Chiastozygus platyrhethus
Rucinolithus irregularis
Nannoconus steinmanni
Eprolithus floralis
Rhagodiscus asperus
Braarudosphaera africana
Predinosphaera cretacea
Transhelicopontosphaera polyhedra
Corollithion signum
Eiffellithus turriseiffelii
Cretarhabdus angustiforatus
Cretarhabdus conicus
Prediscosphaera cretacea
Lithraphidites acutus
Microrhabdulus decorus
Quadrum gartneri
Eiffellithus eximius
Lucianorhabdus maleformis
Marthasterites furcatus
Lithastrinus septenarius
Micula decussata
Reinhardtites anthophorus
Lithastrinus grilli
Micula concava
Lucianorhabdus cayeuxii
Calculites obscurus
Aspidolithus parcus parcus
Watznaueria barnesae
A. cf. A. parcus constrictus
Ceratolithoides verbeekii
Aspidolithus parcus expansus
Ceratolithoides aculeus
Quadrum sissinghii
Ceratolithoides arkhangelskiei
Quadrum trifidum
Reinhardtites levis
Arkhangelskiella cymbiformis
Lithraphidites quadratus
Micula murus
Nephrolithus frequens
Cribrosphaerella ehrenbergii
Ceratolithoides kamptneri
Micula prinsii

PALEOGENE


AGE
ZONATIONS
MARTINI, 1971
markers various authors
markers MARTINI, 1971
markers OKADA & BUKRY, 1980
NN
CN
OLIGOCENE
EOCENE
PALEOCENE
T. carinatus
S. ciperoensis
S. distentus
S. praedistentus
H. reticulata
E. subdistichia
S. moniliformis
I. recurvus
C. oamaruensis
D. sugaiensis
D. tani nodifer
N. fulgens
D. sublodoensis
D. lodoensis
T. orthostylus
D. binodosus
T. contortus
D. multiradiatus
H. riedelii
D. mohleri
H. kleinpellii
F. tympaniformis
E. macellus
C. danicus
C. tenuis
M. inversus
M. prinsii
Markalius inversus
Micula prinsii
Placozygus sigmoides
Cruciplacolithus tenuis
Chiasmolithus danicus
Prinsius martini
Ellipsolithus macellus
Fasciculithus tympaniformis
Heliolithus cantabriae
Heliolithus kleinpellii
Discoaster mohleri
Discoaster mediosus
Heliolithus riedelii
Discoaster nobilis
Discoaster multiradiatus
Campylosphaera dela
Tribrachiatus bramlettei
Discoaster skaiterus
Tribrachiatus contortus
Discoaster lodoensis
Discoaster kuepperi
Tribrachiatus orthostylus
Discoaster sublodoensis
Rhabdosphaera inflata
Nannotetrina fulgens
Reticulofenestra samodurovii
Chiasmolithus grandis
Rhabdosphaera gladius
Reticulofenestra dictyoda
Reticulofenestra umbilica
Discoaster barbadiensis
Cribrocentrum reticulatum
Chiasmolithus solitus
Discoaster tani nodifer
Chiasmolithus grandis
Chiasmolithus oamaruensis
Isthmolithus recurvus
Sphenolithus pseudoradians
Reticulofenestra umbilica
Discoaster barbadiensis
Discoaster deflandrei
Ericsonia subdisticha
Ericsonia formosa
Helicosphaera euphratis
Sphenolithus moriformis
Sphenolithus distentus
Chiasmolithus altus
Sphenolithus ciperoensis
Cyclicargolithus abisectus
Pontosphaera enormis
Zygrhablithus bijugatus
Helicosphaera recta
Dictyococcites bisectus

NEOGENE


AGE
ZONATIONS
MARTINI, 1971
markers various authors
markers MARTINI, 1971
markers OKADA & EUKRY, 1980
NN
CN
PLEISTO.
PLIOCENE
MIOCENE
E. huxleyi
G. oceanica
Pl. lacunosa
D. brouweri
D. pentaradiatus
D. surculus
R. pseudoumbilica
D. asymmetricus
C. rugosus
A. tricorniculatus
D. quinqueramus
D. calcaris
D. hamatus
C. coalitus
D. kugleri
D. exilis
S. heteromorphus
H. amplaperta
S. belemnos
D. druggi
T. carinatus
Helicosphaera recta
Sphenolithus moriformis
Cyclicargolithus floridanus
Discoaster druggii
Sphenolithus belemnos
Helicosphaera kamptneri
Triquetrorhabdulus carinatus
Helicosphaera euphratis
Sphenolithus heteromorphus
Calcidiscus macintyrei
Discoaster deflandrei
Helicosphaera ampliaperta
Cyclicargolithus floridanus
Discoaster variabilis
Discoaster exilis
Discoaster braarudii
Discoaster kugleri
Discoaster challengeri
Catinaster coalitus
Discoaster calcaris
Discoaster hamatus
Catinaster calyculus
Discoaster neohamatus
Discoaster bellus
Discoaster berggrenii
Discoaster loeblichii
Discoaster berggrenii
Discoaster quinqueramus
Discoaster surculus
Amaurolithus primus
Triquetrorhabdulus rugosus
Cestrolithus acutus
Cestrolithus rugosus
Discoaster asymmetricus
Amaurolithus tricorniculatus
Sphenolithus abies
Reticulofenestra pseudoumbilica
Sphenolithus neoabies
Discoaster tamalis
Discoaster pentaradiatus
Discoaster brouweri s. l.
Gephyrocapsa caribbeanica
Helicosphaera sellii
Gephyrocapsa oceanica
Pseudoemiliania lacunosa
Emiliania huxleyi
Pontosphaera indonesica

CURVE della DIVERSITA' delle COCCOLITOFORIDI e dei NANNOFOSSILI

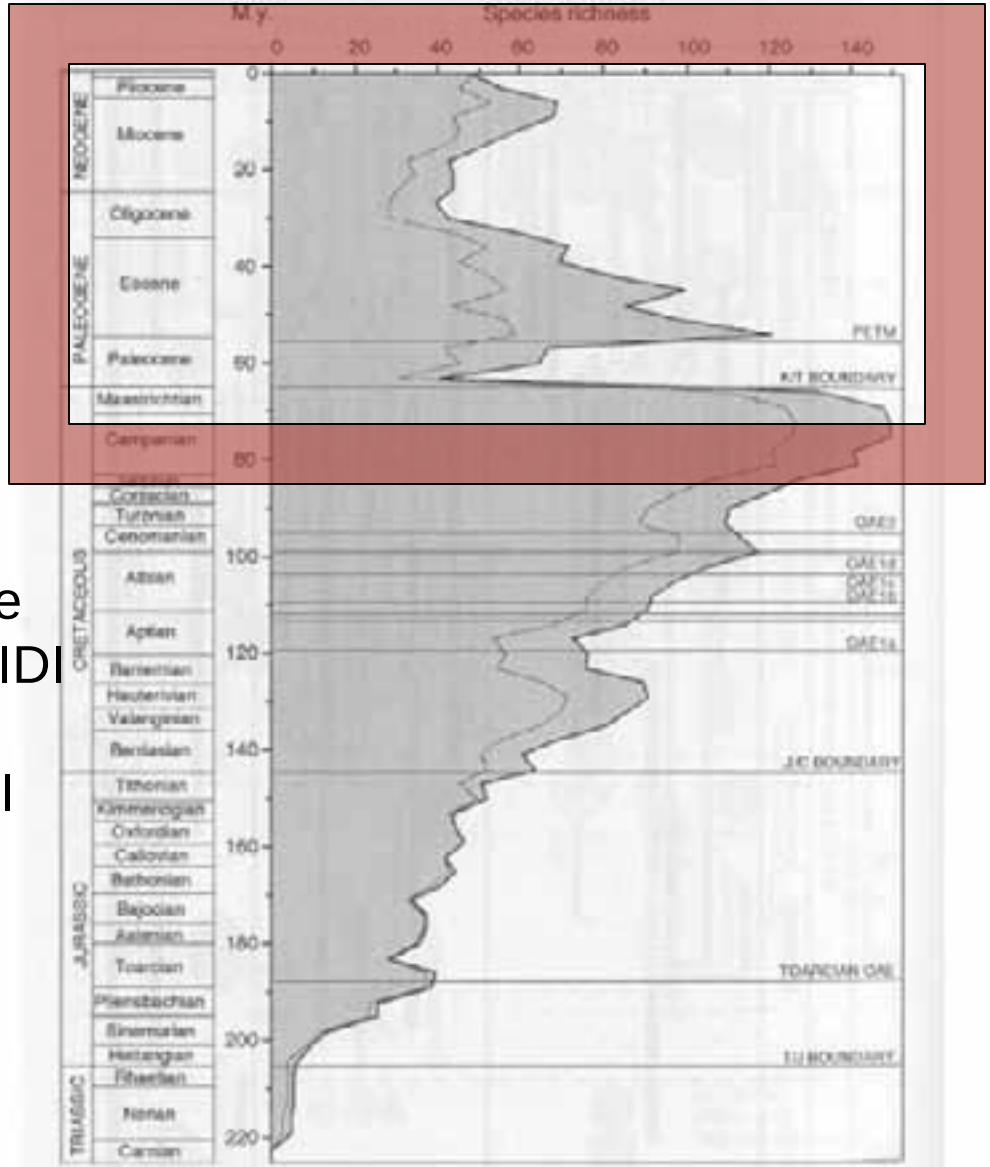
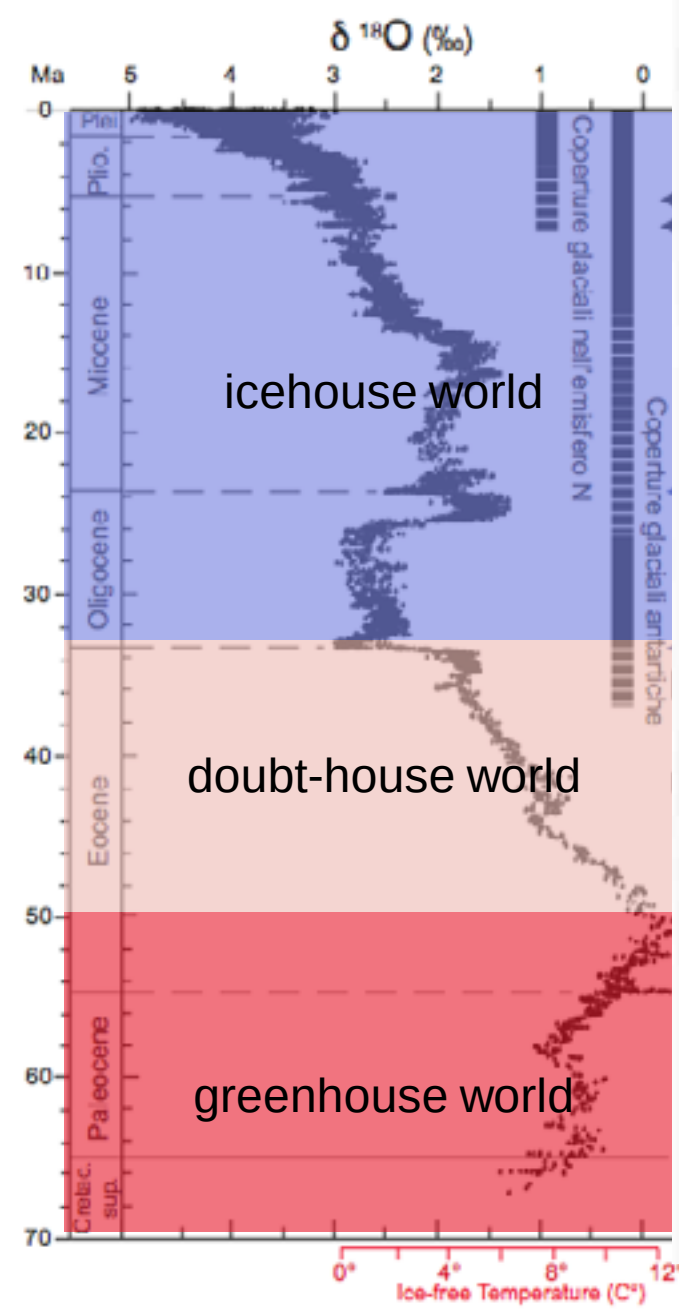
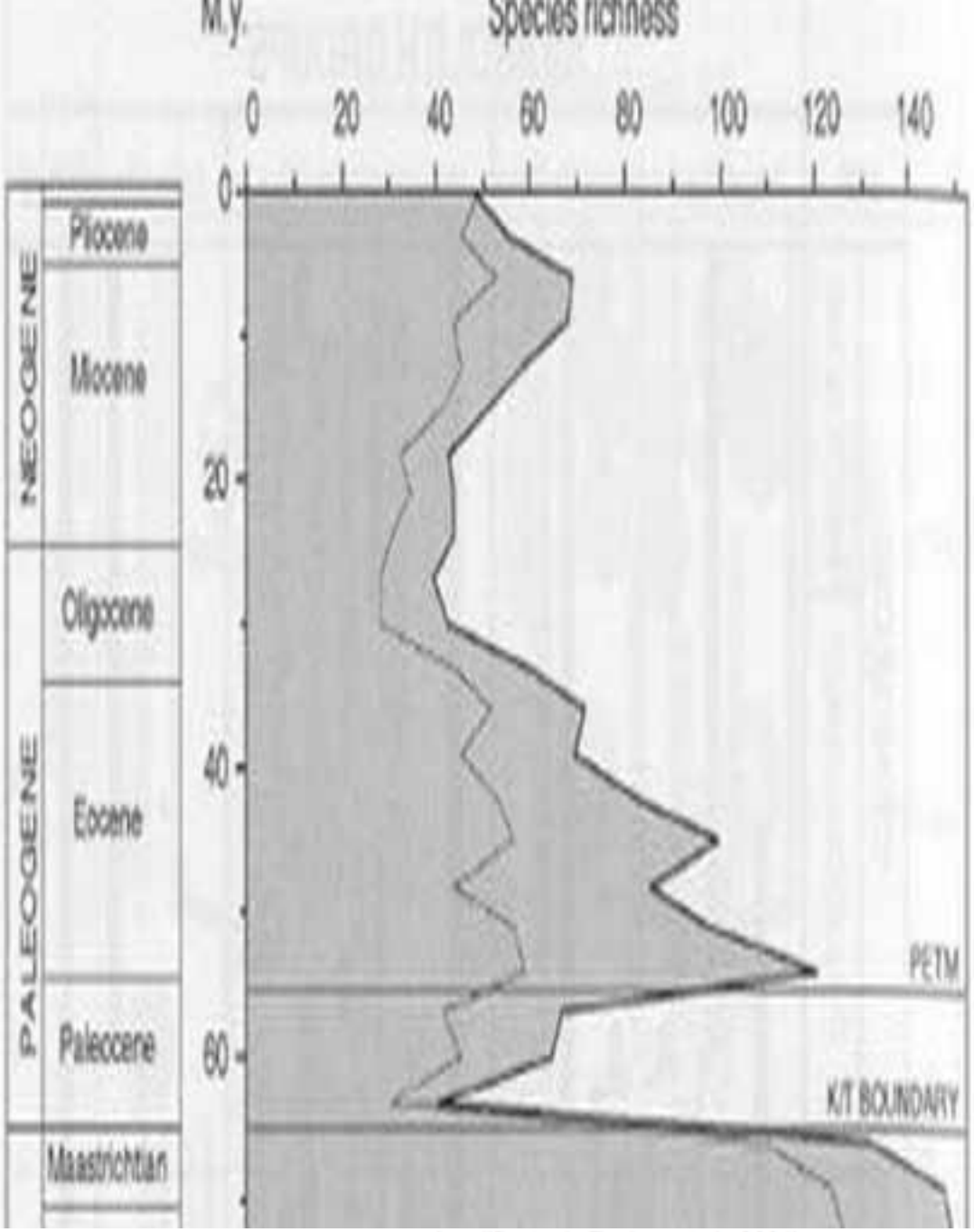


Fig. 2. Coccolithophore (light line) and total nannofossil (dark line) diversity. Data represents species richness for a three million-year interval, plotted at the mid-point. The timescales are from Berggren et al. (1995) and Gradstein et al. (1995). OAE: oceanic anoxic event. PETM: Paleocene/Eocene thermal maximum.

Il clima nel Cen





(modificato da Zachos et al., 2001)

CURVE della DIVERSITA' delle COCCOLITOFORIDI e dei NANNOFOSSILI

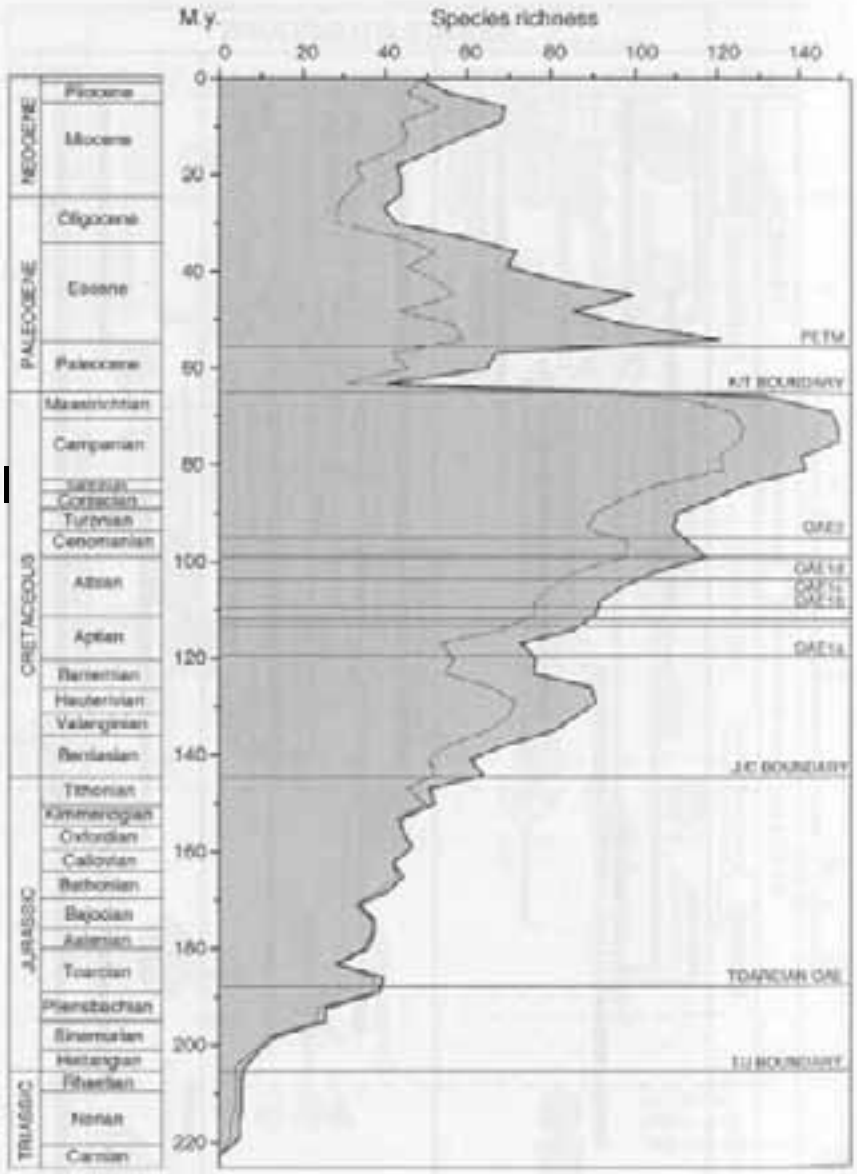
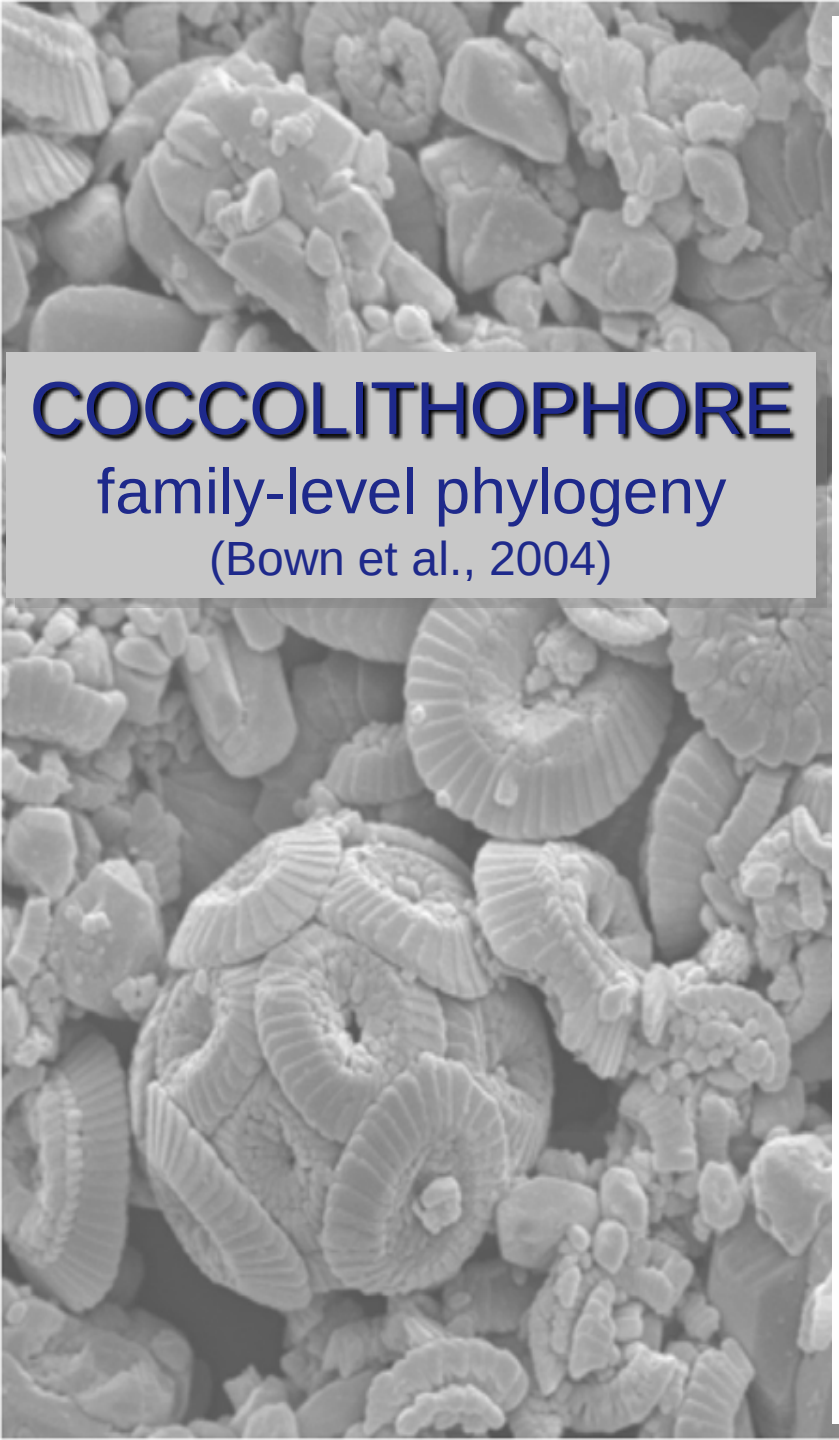


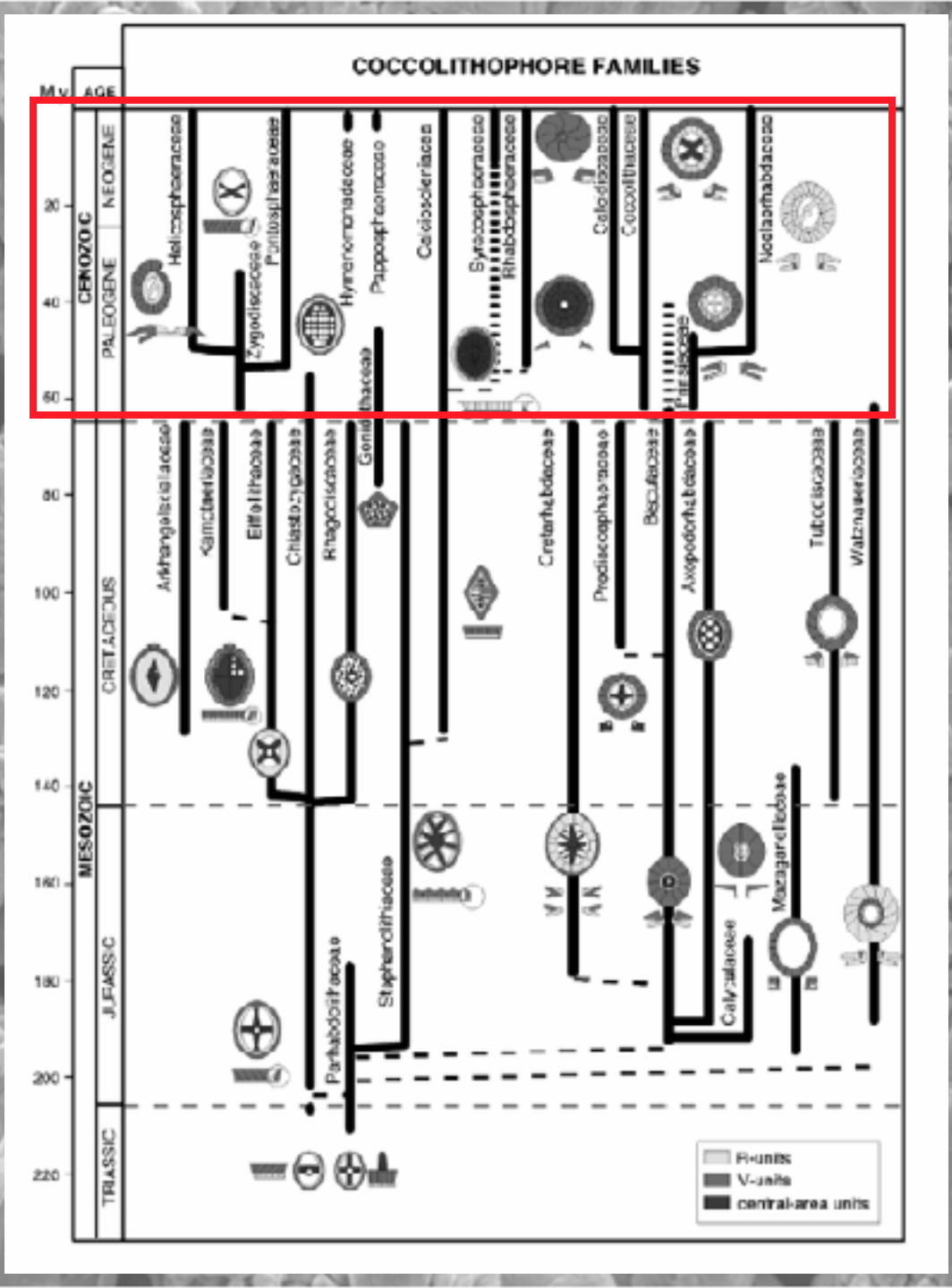
Fig. 2. Coccolithophore (light line) and total nannofossil (dark line) diversity. Data represents species richness for a three million-year interval, plotted at the mid-point. The timescales are from Berggren et al. (1995) and Gradstein et al. (1995). OAE: oceanic anoxic event. PETM: Paleocene/Eocene thermal maximum.

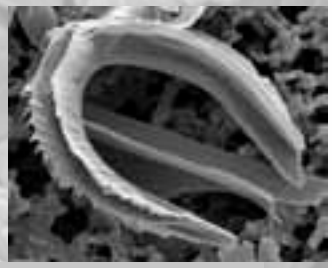
COCCOLITHOPHORE

family-level phylogeny

(Bown et al., 2004)



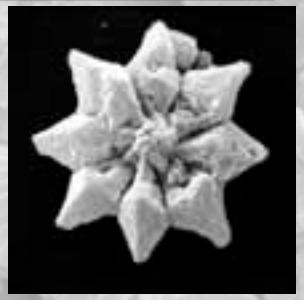


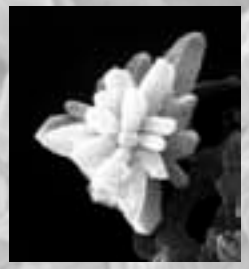


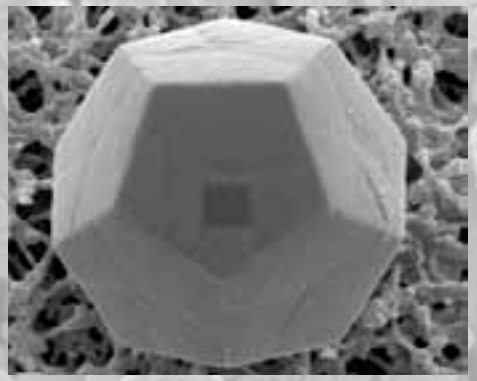
NANNOLITHS

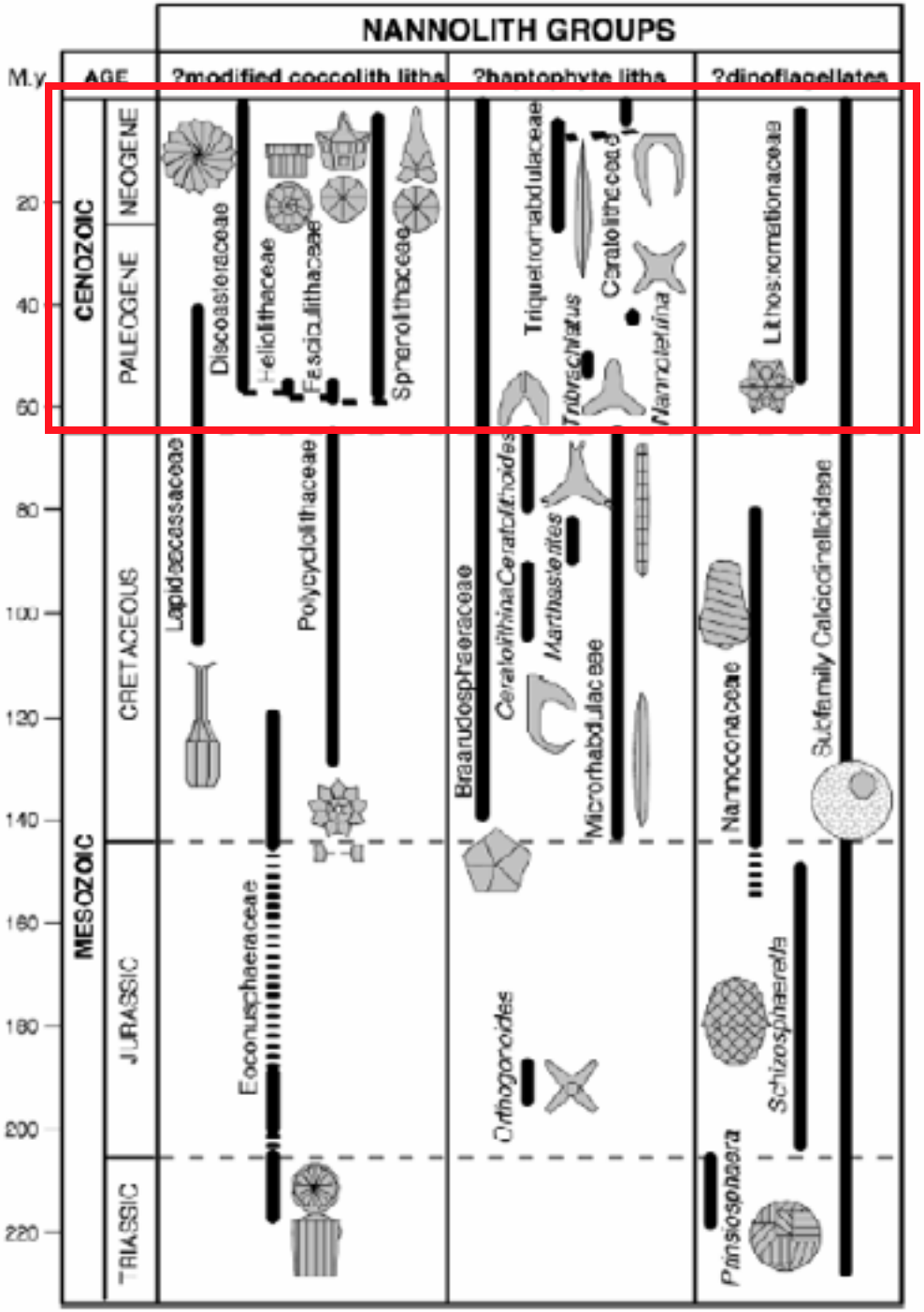
family-level phylogeny

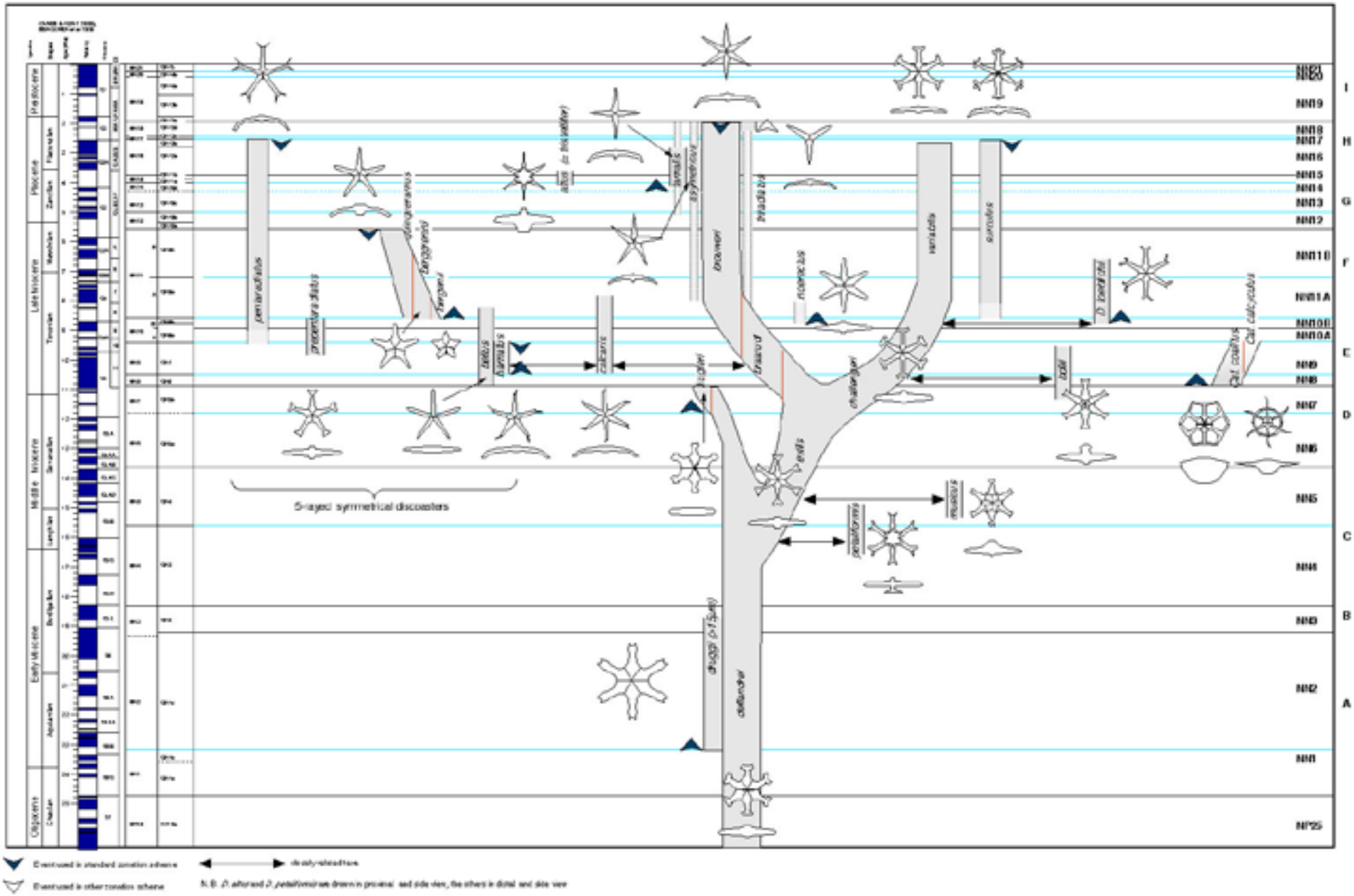
(Bown et al., 2004)



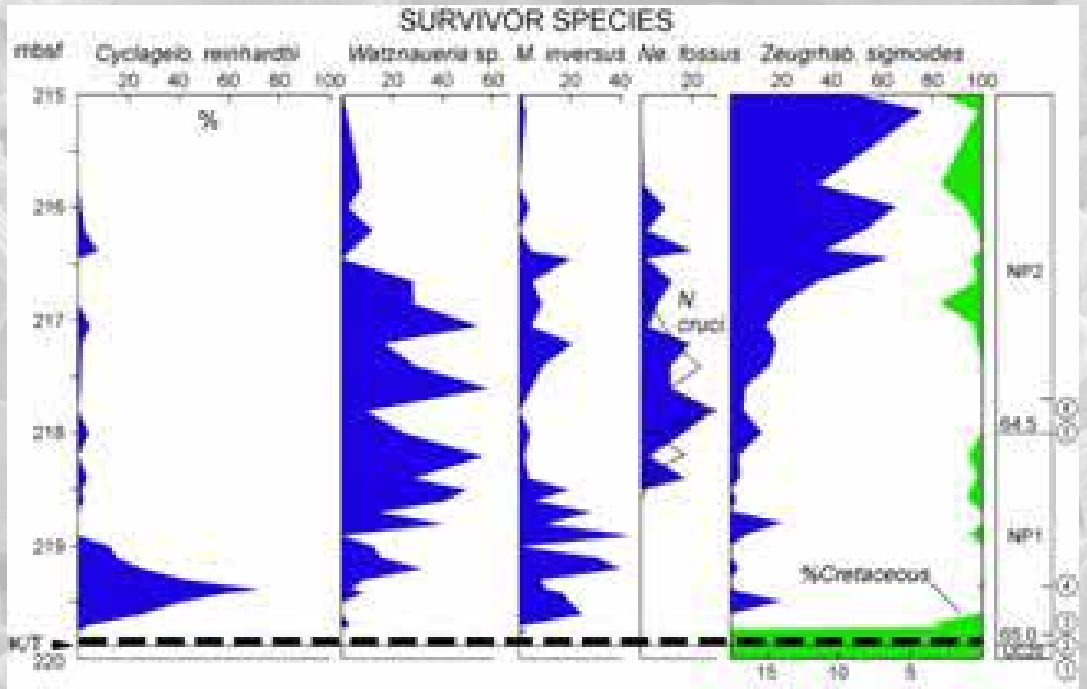


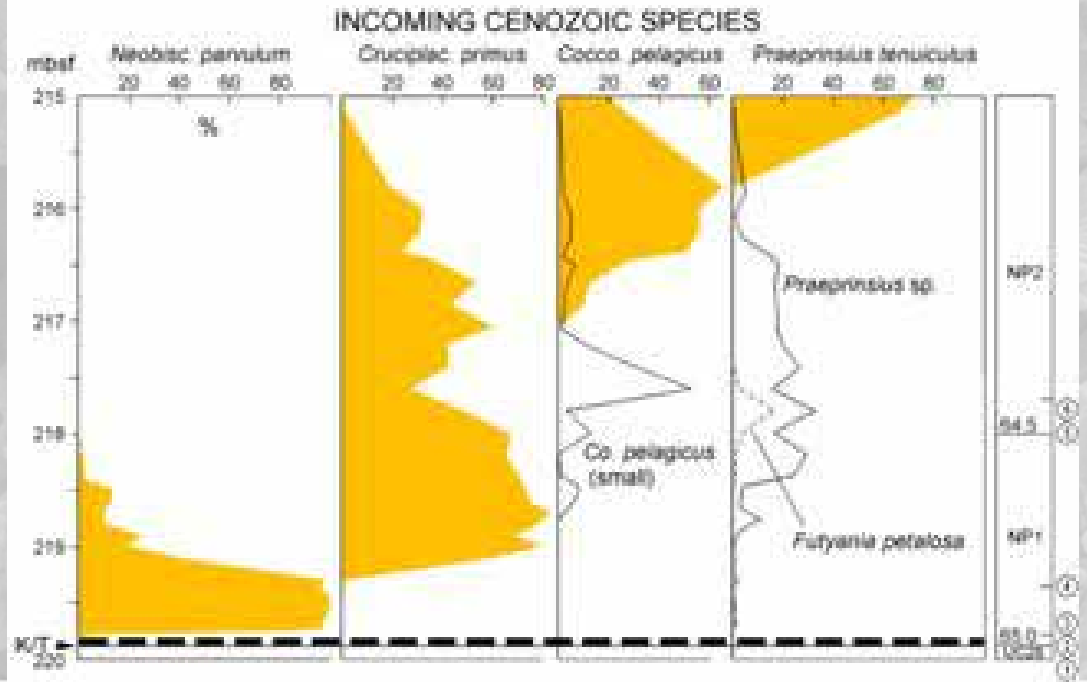






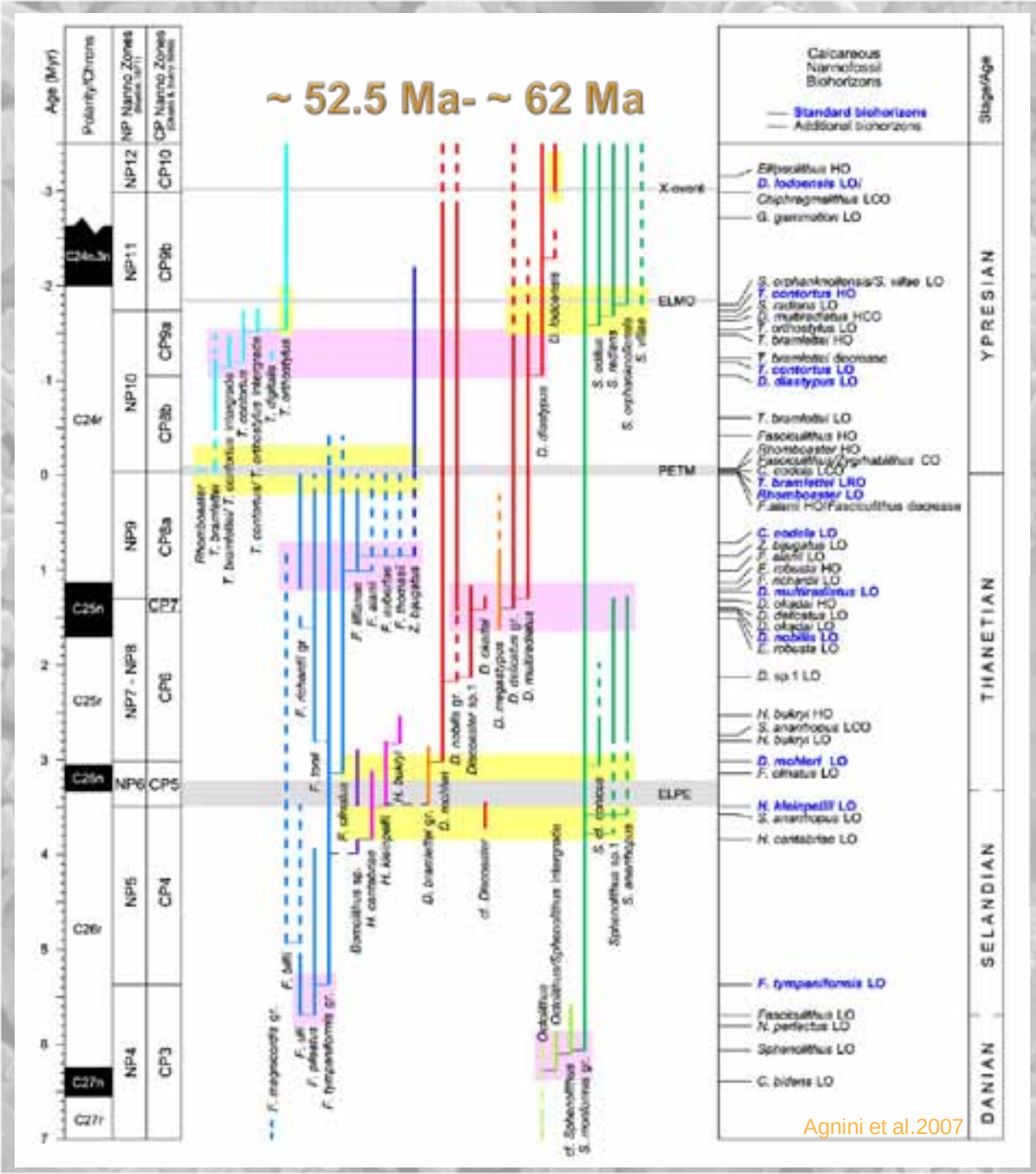
(J. Young,1998. In: http://www.nhm.ac.uk/hosted_sites/ina/)



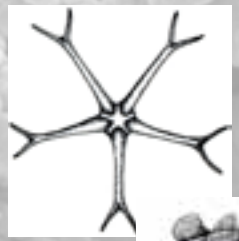


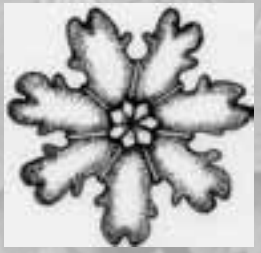
EVENTI EVOLUTIVI dopo il K/pg

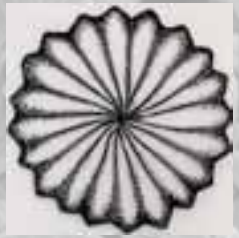
ODP Site 1262 (Walvis Ridge)

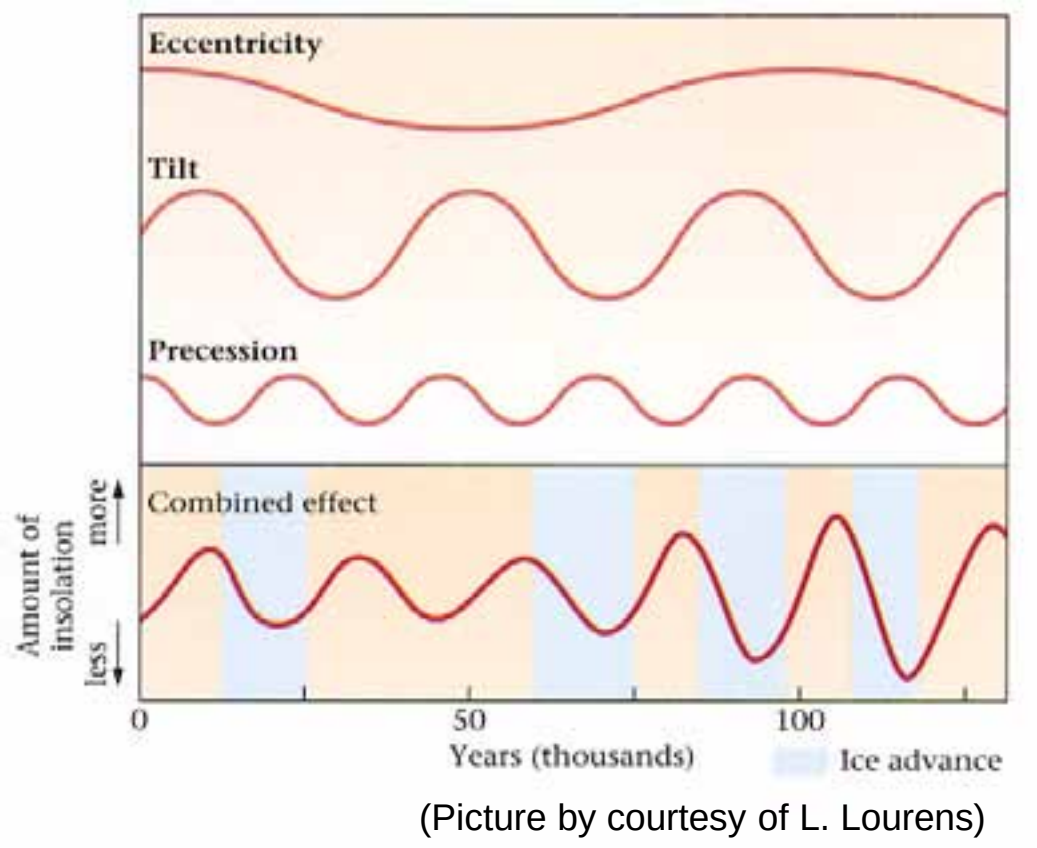


Distribuzione stratigrafica e linee evolutive di nannofossili nel Paleogene Inferiore









(Picture by courtesy of L. Lourens)

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