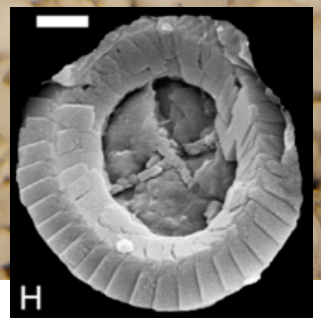
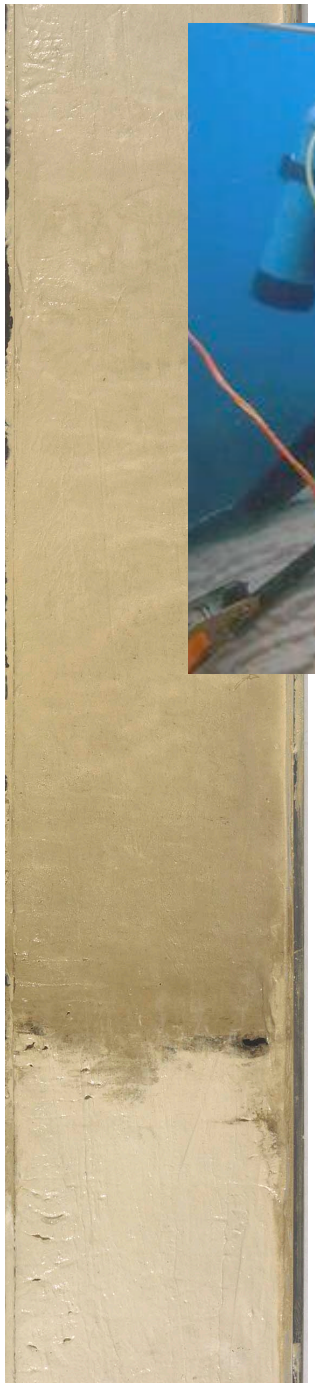
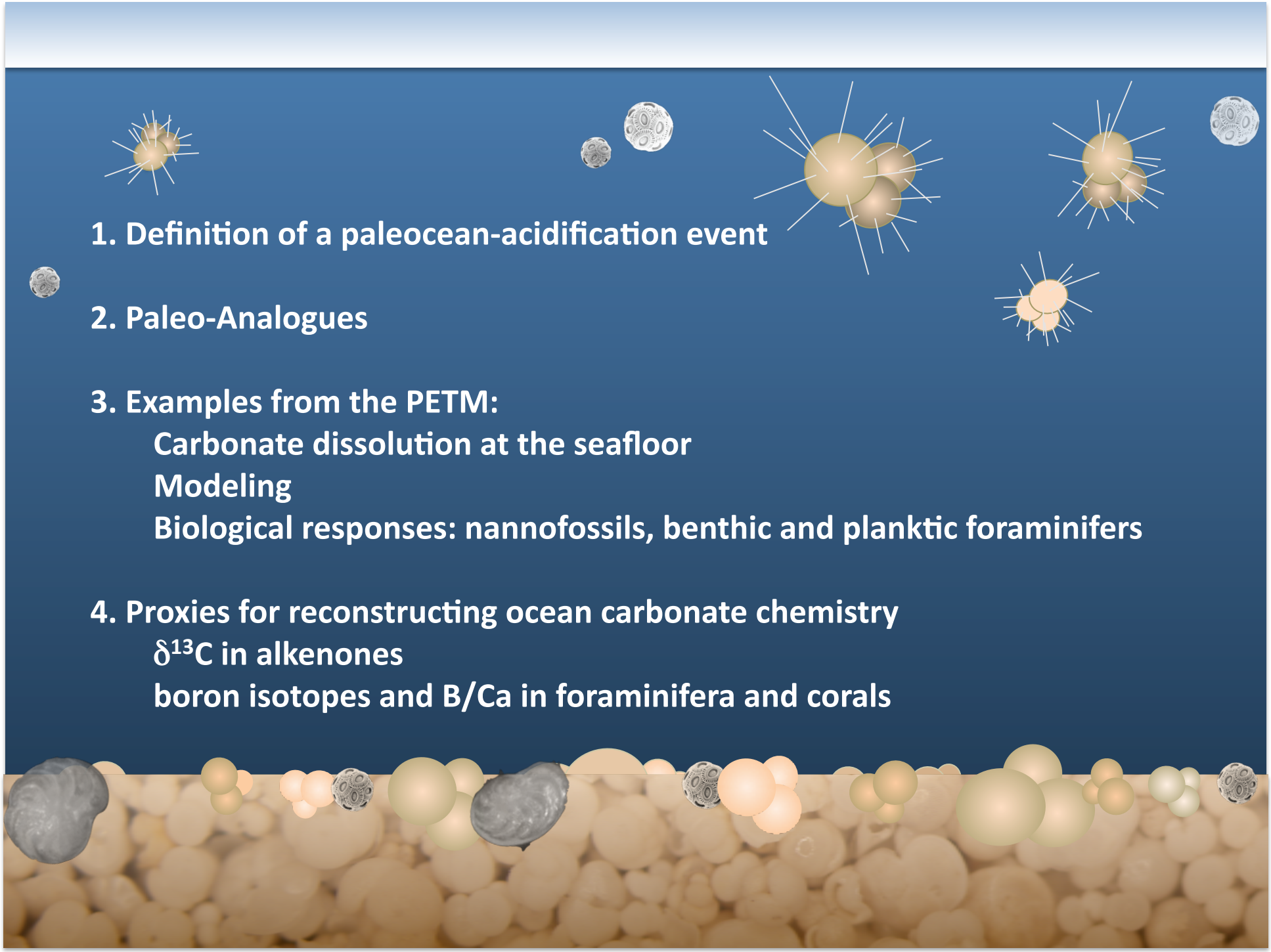
Paleocean acidification, proxies & modeling

Bärbel Hönisch
Andy Ridgwell, Richard Zeebe
Jim Zachos, Ellen Thomas
Appy Sluijs, Sam Gibbs, Clay Kelly
Kat Allen
Don Penman, Linda Anderson
Markus Raitzsch, Nina Ruprecht






1. Definition of a paleocean-acidification event
2. Paleo-Analogues
3. Examples from the PETM:
Carbonate dissolution at the seafloor
Modeling
Biological responses: nannofossils, benthic and planktic foraminifers
4. Proxies for reconstructing ocean carbonate chemistry
$\delta^{13}C$ in alkenones
boron isotopes and B/Ca in foraminifera and corals

Decoupling of seawater-pH and saturation state on long time scales

An ‘ocean acidification *event*’ is a time interval in Earth’s history that involved geologically ‘rapid’ changes of ocean carbonate chemistry on timescales <10,000 years.

Independent evidence for ocean acidification is required. The fossil record of calcareous organisms does not provide proof for an ocean acidification event.

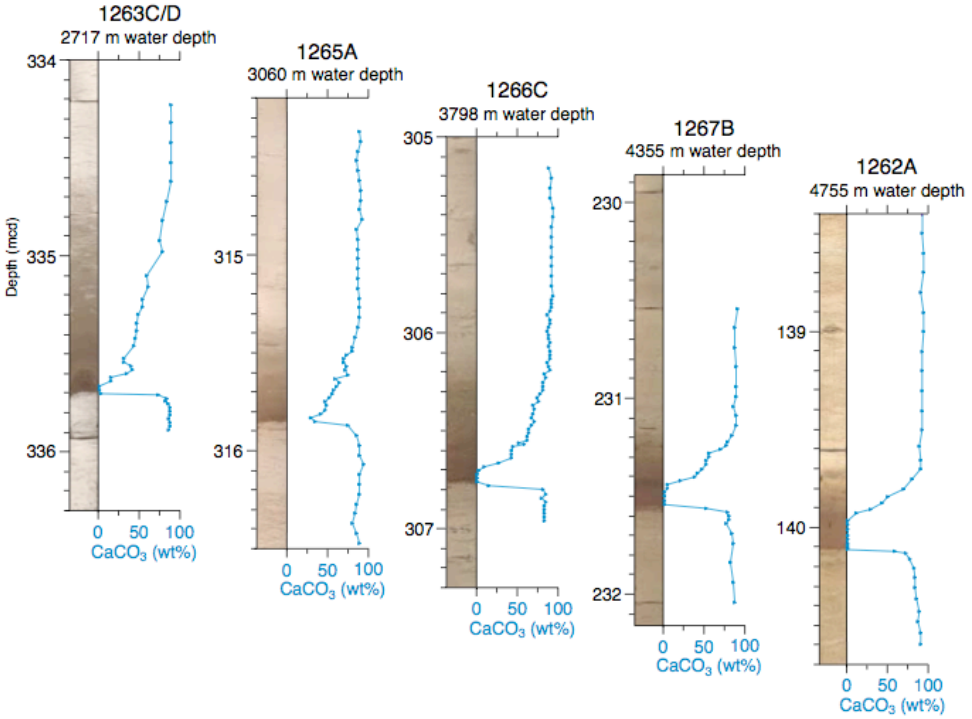
similarity of paleo-events to modern OA:

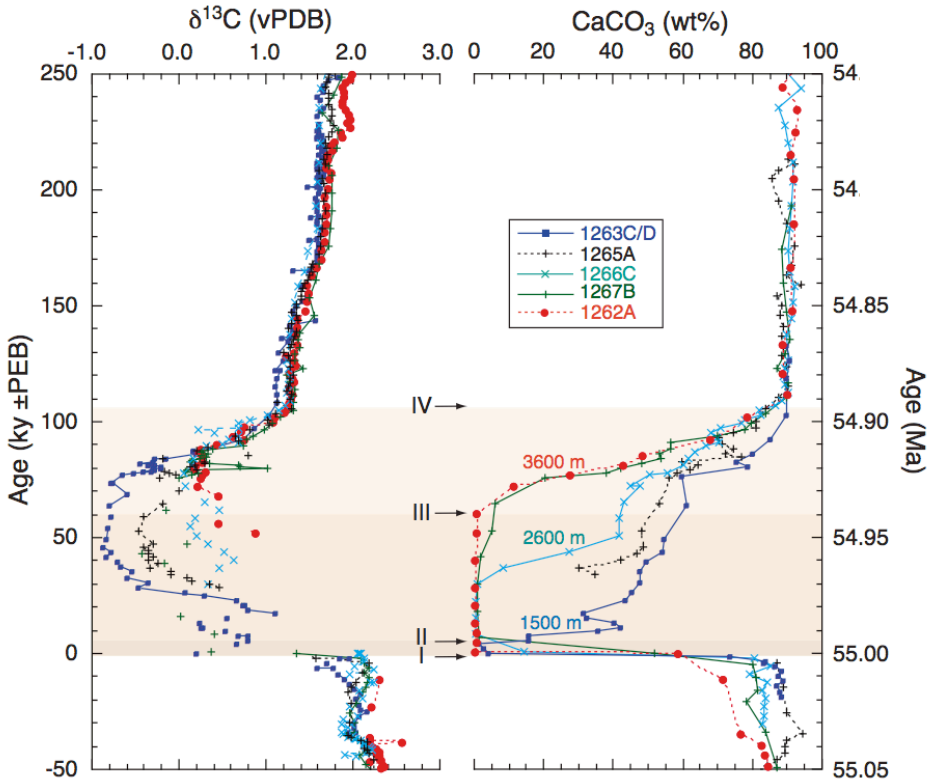
- pH decrease
- saturation decrease
- temperature increase
- negative $\delta^{13}C$ excursion
- global or regional extent

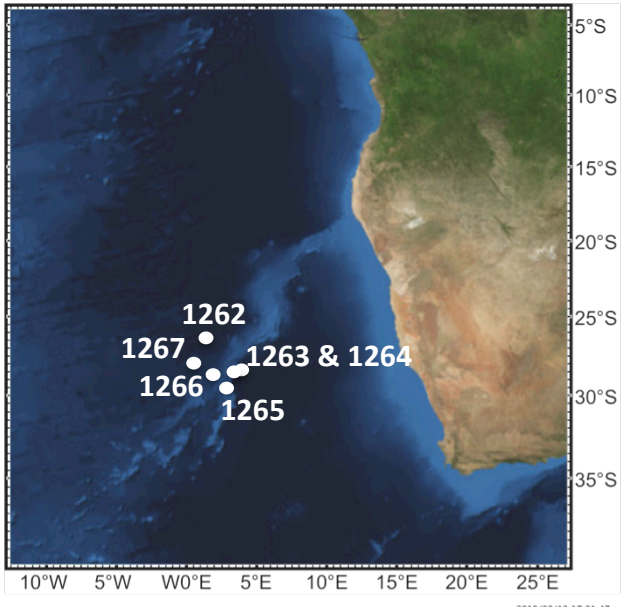
Rapid Acidification of the Ocean During the Paleocene-Eocene Thermal Maximum

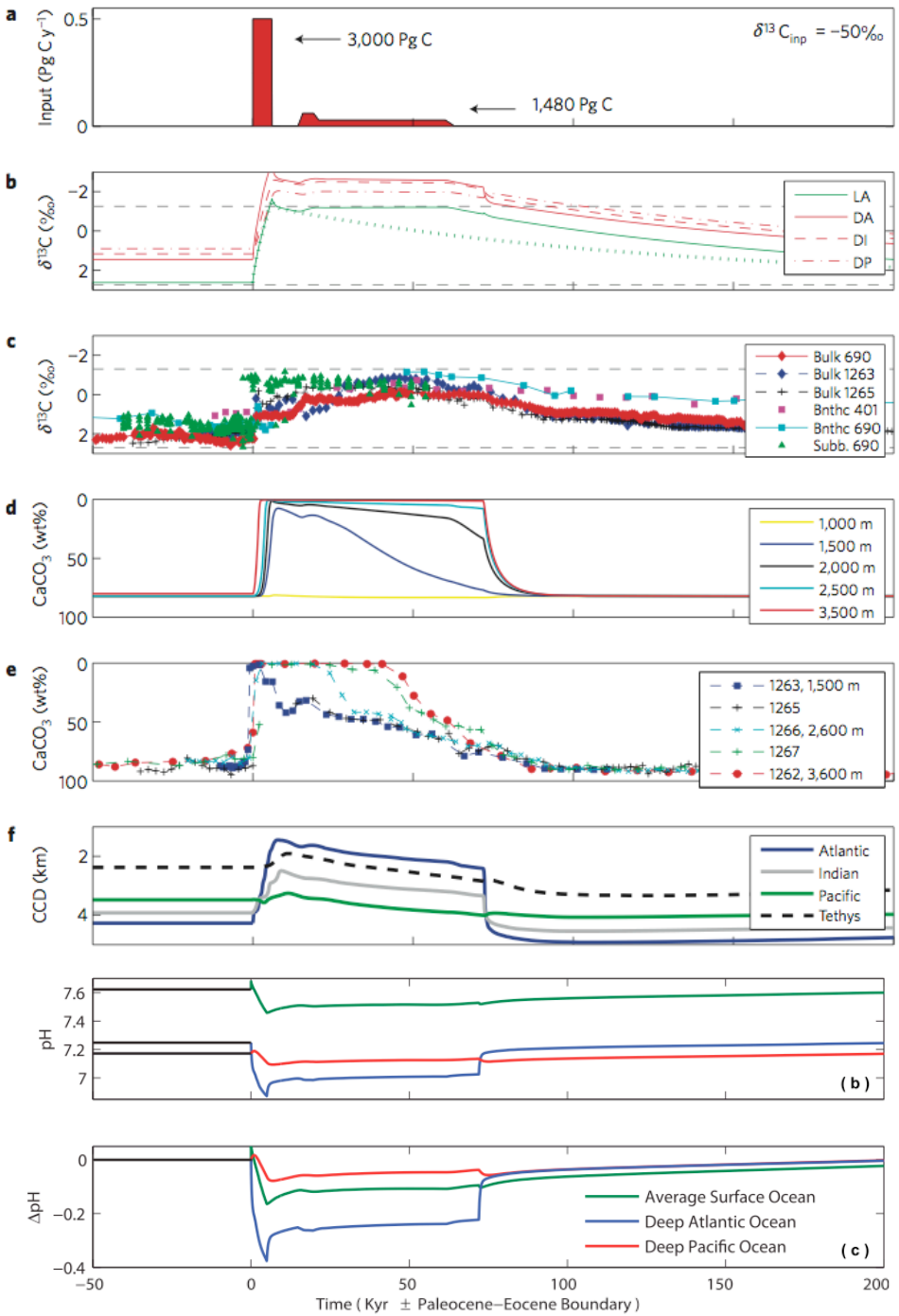
James C. Zachos,[1*] Ursula Röhl,[2] Stephen A. Schellenberg,[3] Appy Sluijs,[4] David A. Hodell,[6] Daniel C. Kelly,[7] Ellen Thomas,[8,9] Micah Nicolo,[10] Isabella Raffi,[11] Lucas J. Lourens,[5] Heather McCarren,[1] Dick Kroon[12]

(Science, 2005)





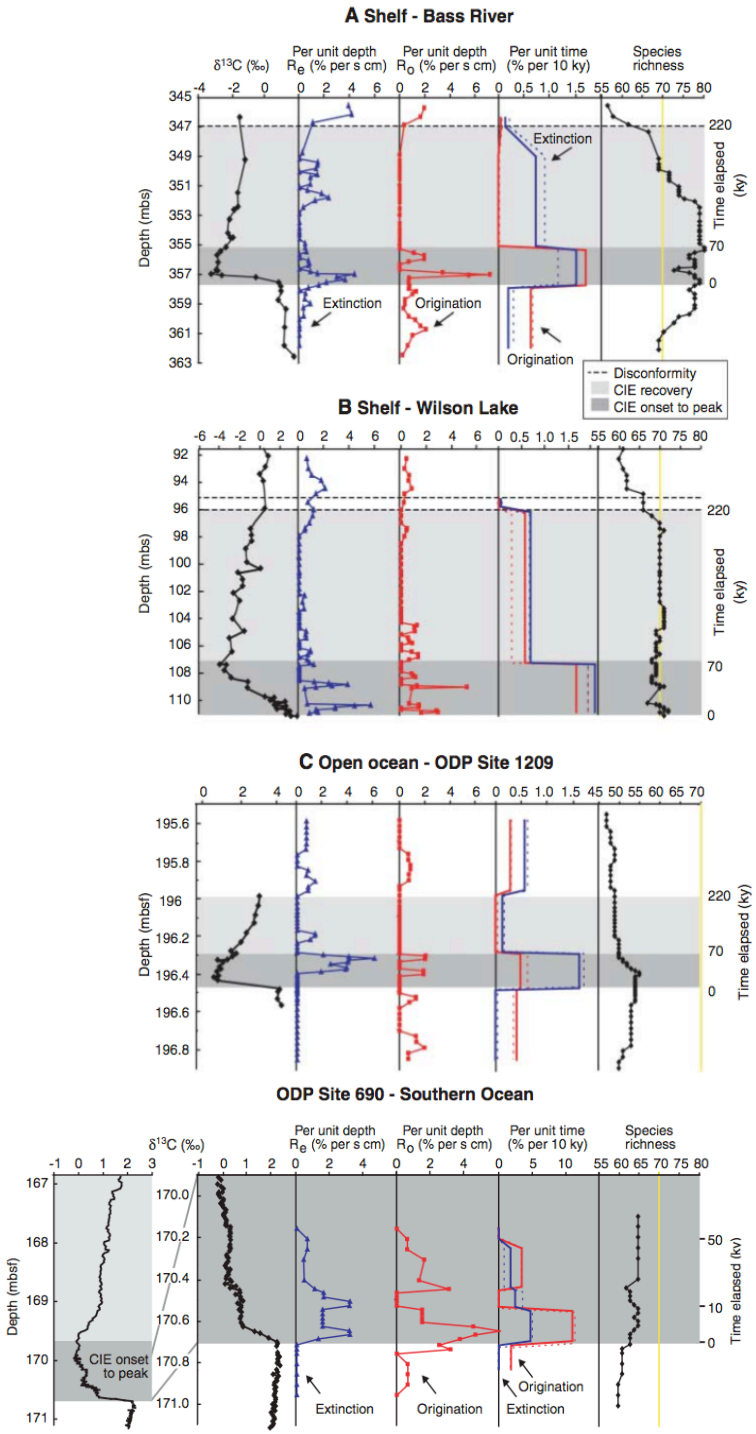




estimated CO_2 release rate at the PETM smaller compared modern release rate: relatively small surface ocean pH decrease

Zeebe et al.,
Nature Geoscience, 2009

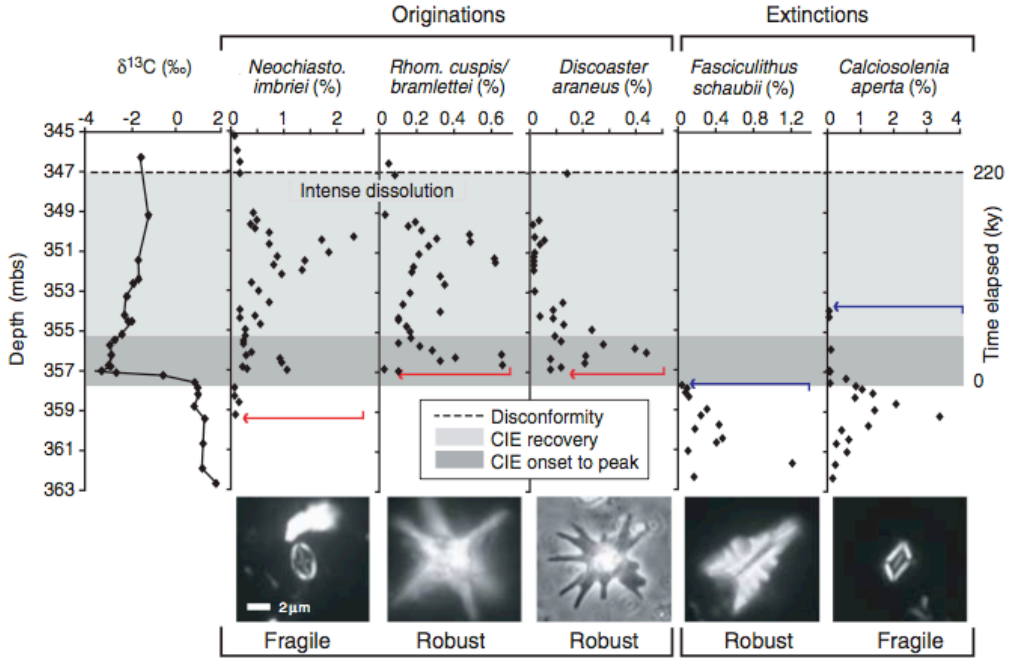
Uchikawa & Zeebe,
Paleoceanography, 2010



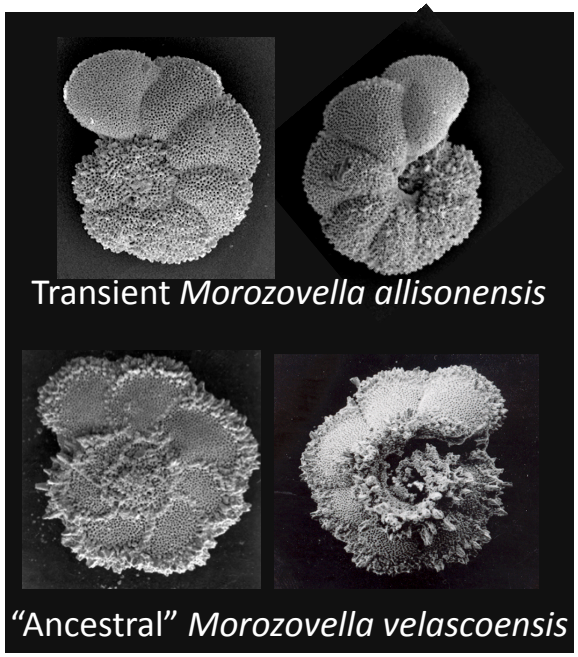
Nannoplankton Extinction and Origination Across the Paleocene-Eocene Thermal Maximum

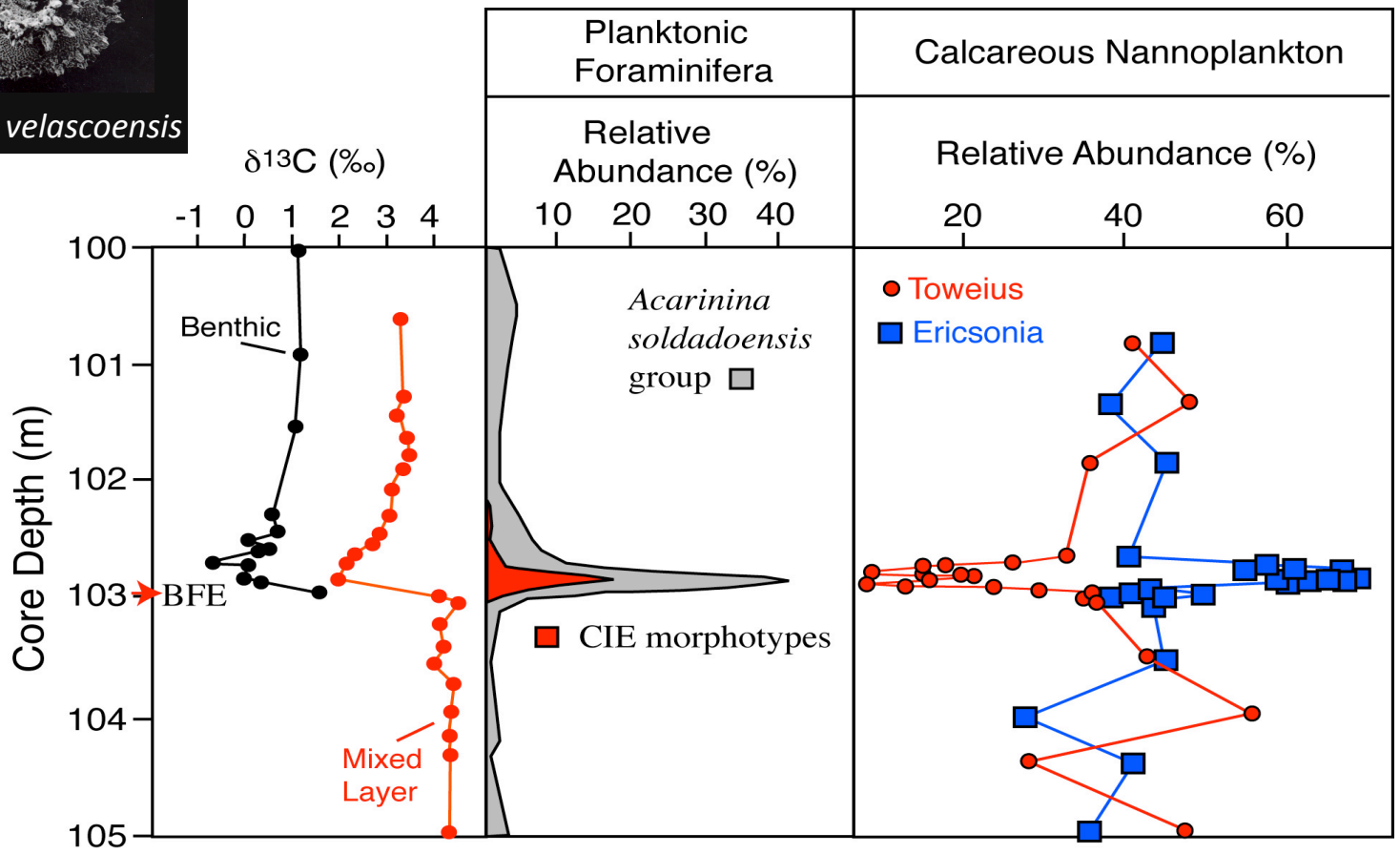
Samantha J. Gibbs,[1]* Paul R. Bown,[2] Jocelyn A. Sessa,[3] Timothy J. Bralower,[3] Paul A. Wilson[1]

(Science, 2006)



PETM Record from Tropical Pacific Ocean (ODP Site 865)



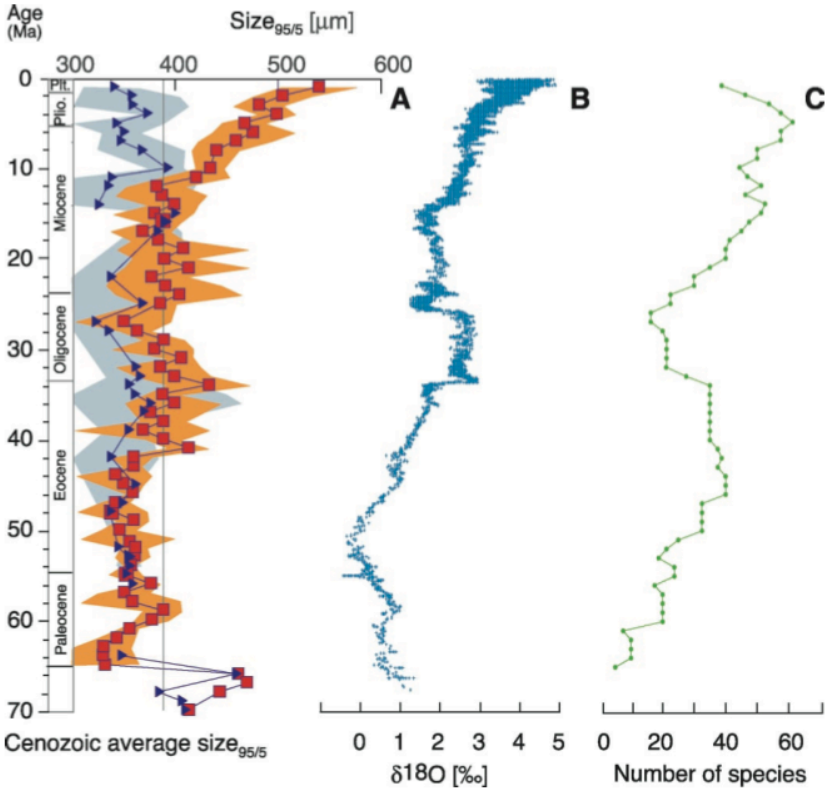


Kelly et al., 1996

Abiotic Forcing of Plankton Evolution in the Cenozoic

Daniela N. Schmidt,*† Hans R. Thierstein, Jörg Bollmann, Ralf Schiebel

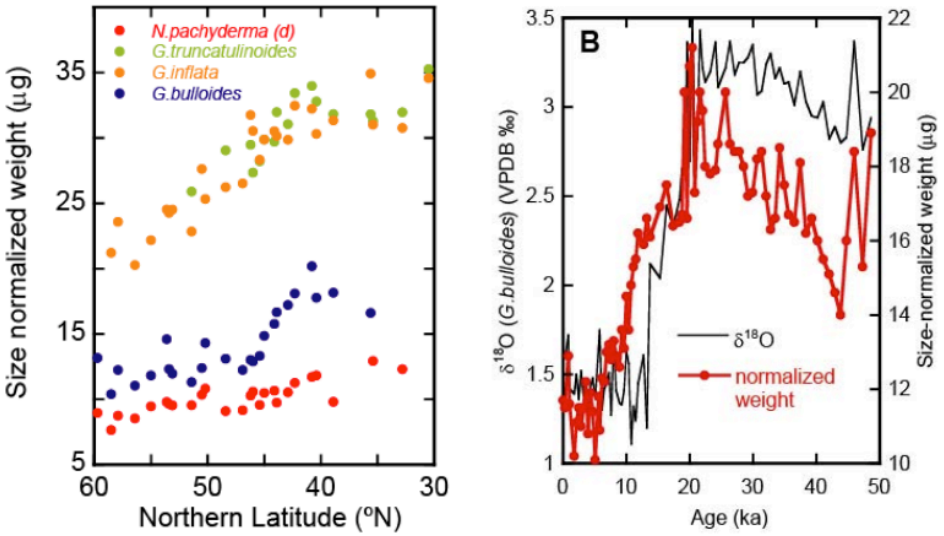
Science, 2004

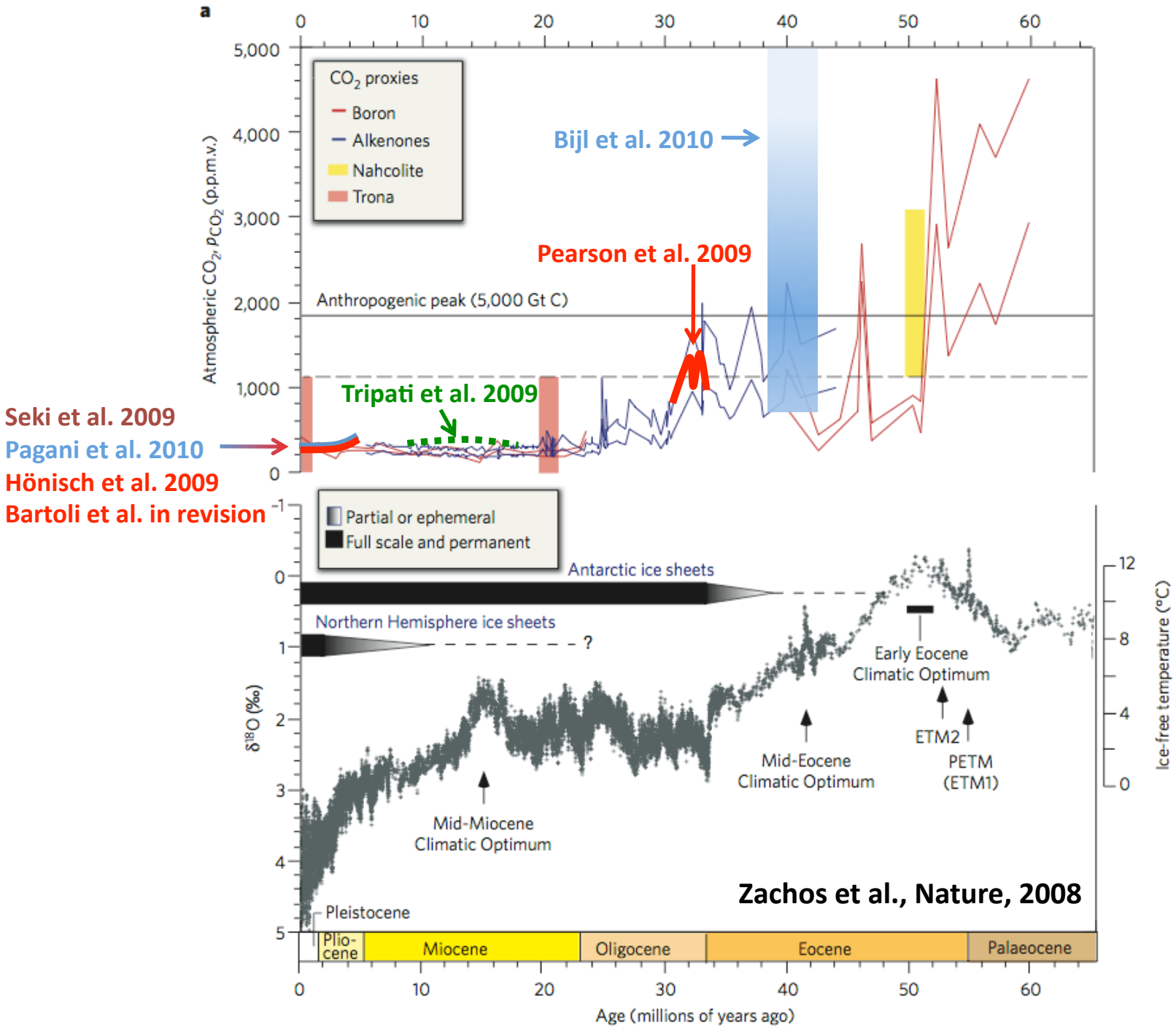


Foraminiferal Calcification Response to Glacial-Interglacial Changes in Atmospheric CO_2

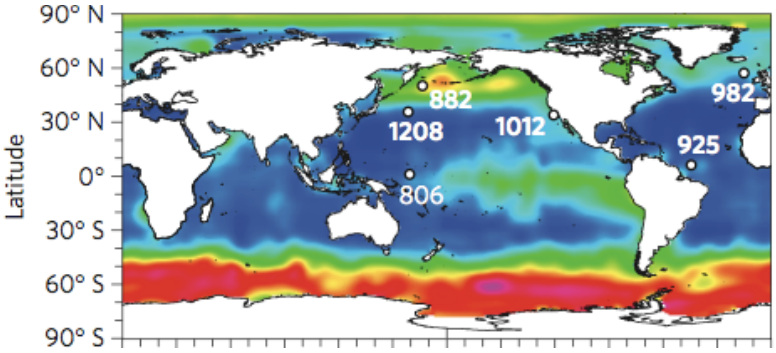
Stephen Barker* and Henry Elderfield

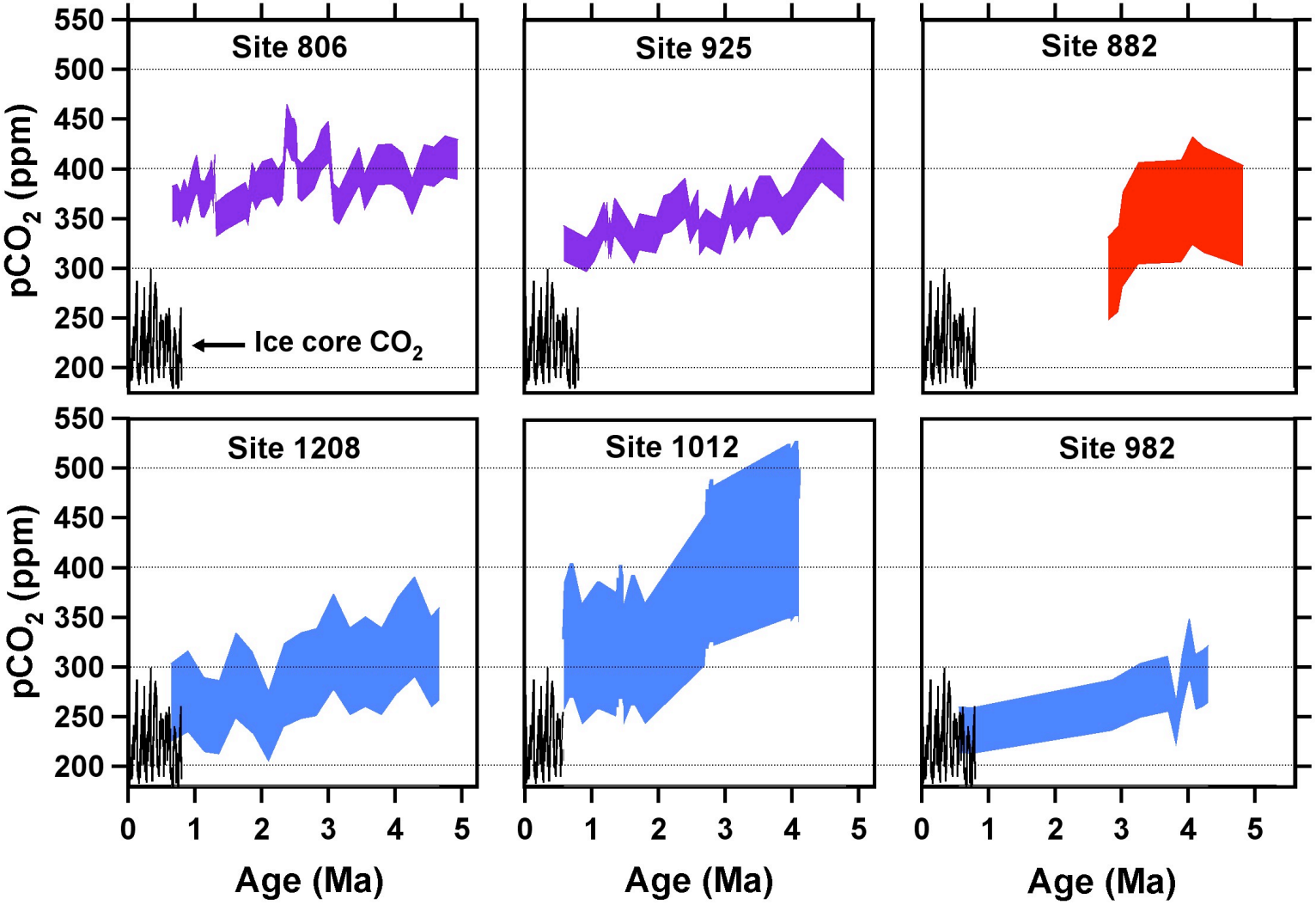
Science, 2002



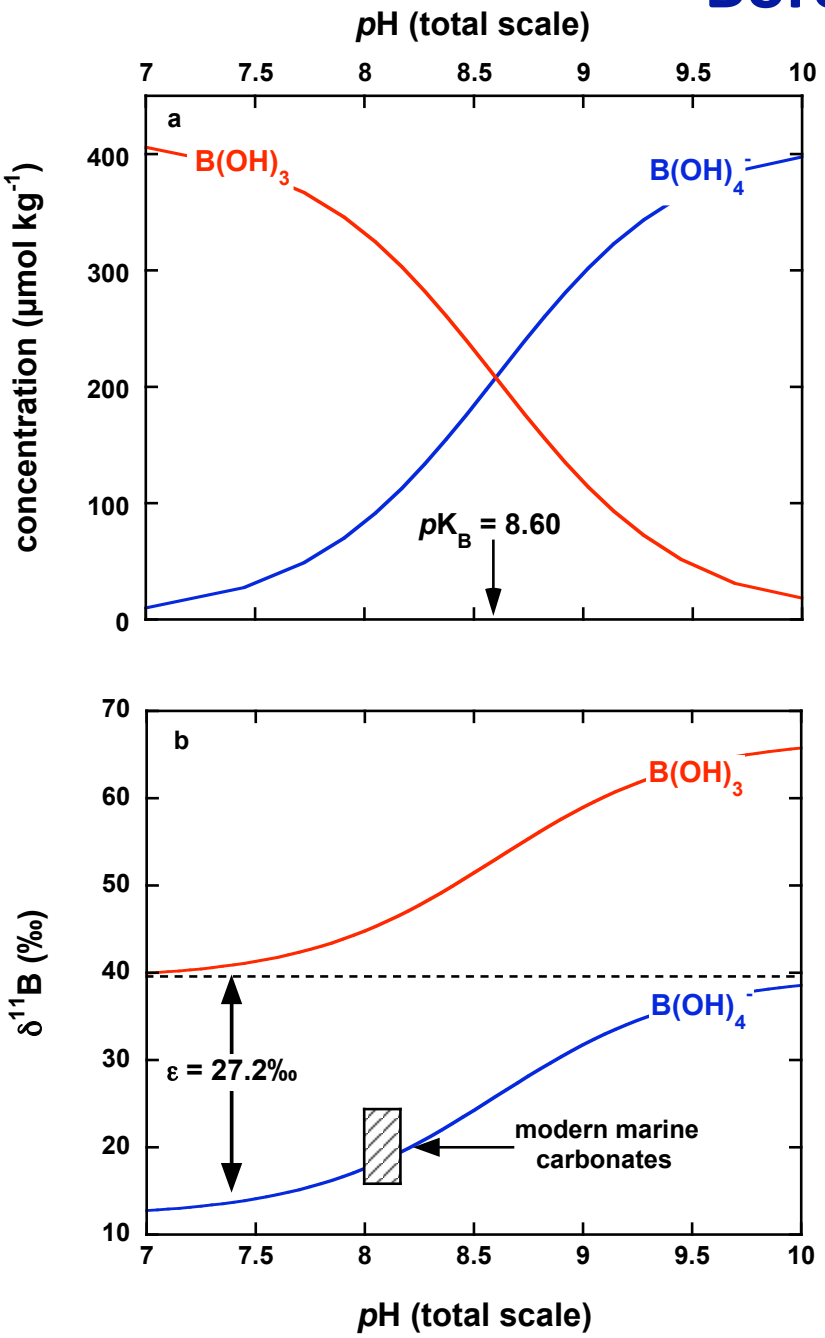

a
CO_2 proxies
Boron
Alkenones
Nahcolite
Trona
Bijl et al. 2010
Pearson et al. 2009
Anthropogenic peak (5,000 Gt C)
Tripati et al. 2009
Seki et al. 2009
Pagani et al. 2010
Hönisch et al. 2009
Bartoli et al. in revision
Atmospheric CO_2, p_{CO_2} (p.p.m.v.)
Partial or ephemeral
Full scale and permanent
Antarctic ice sheets
Northern Hemisphere ice sheets
?
Early Eocene Climatic Optimum
ETM2
PETM (ETM1)
Mid-Eocene Climatic Optimum
Mid-Miocene Climatic Optimum
Pleistocene
Plio-cene
Miocene
Oligocene
Eocene
Palaeocene
$\delta^{18}O$ (‰)
Ice-free temperature (°C)
Age (millions of years ago)
Zachos et al., Nature, 2008

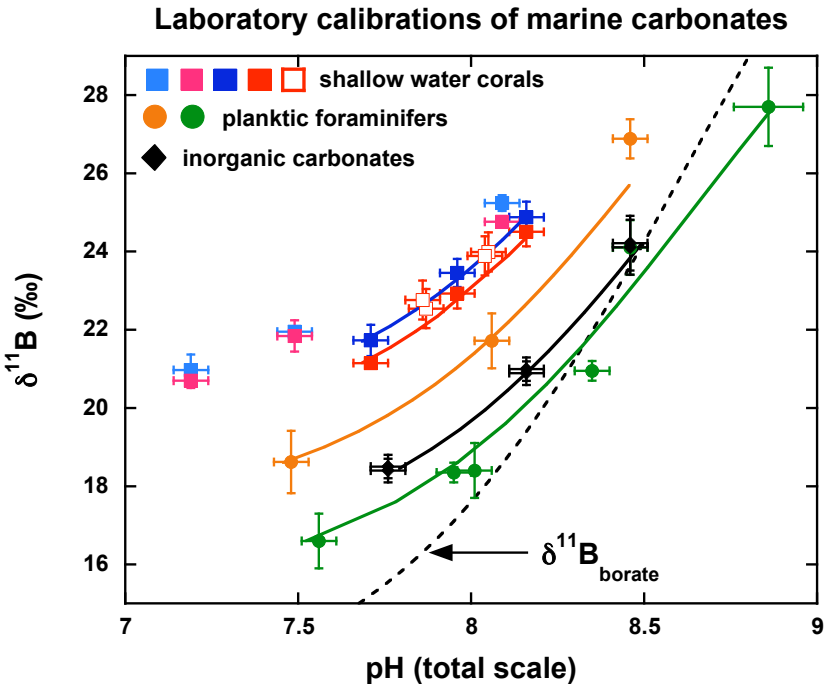
Pagani et al. Nature Geoscience, 2010
(rescaled)





Boron proxies for past seawater-pH



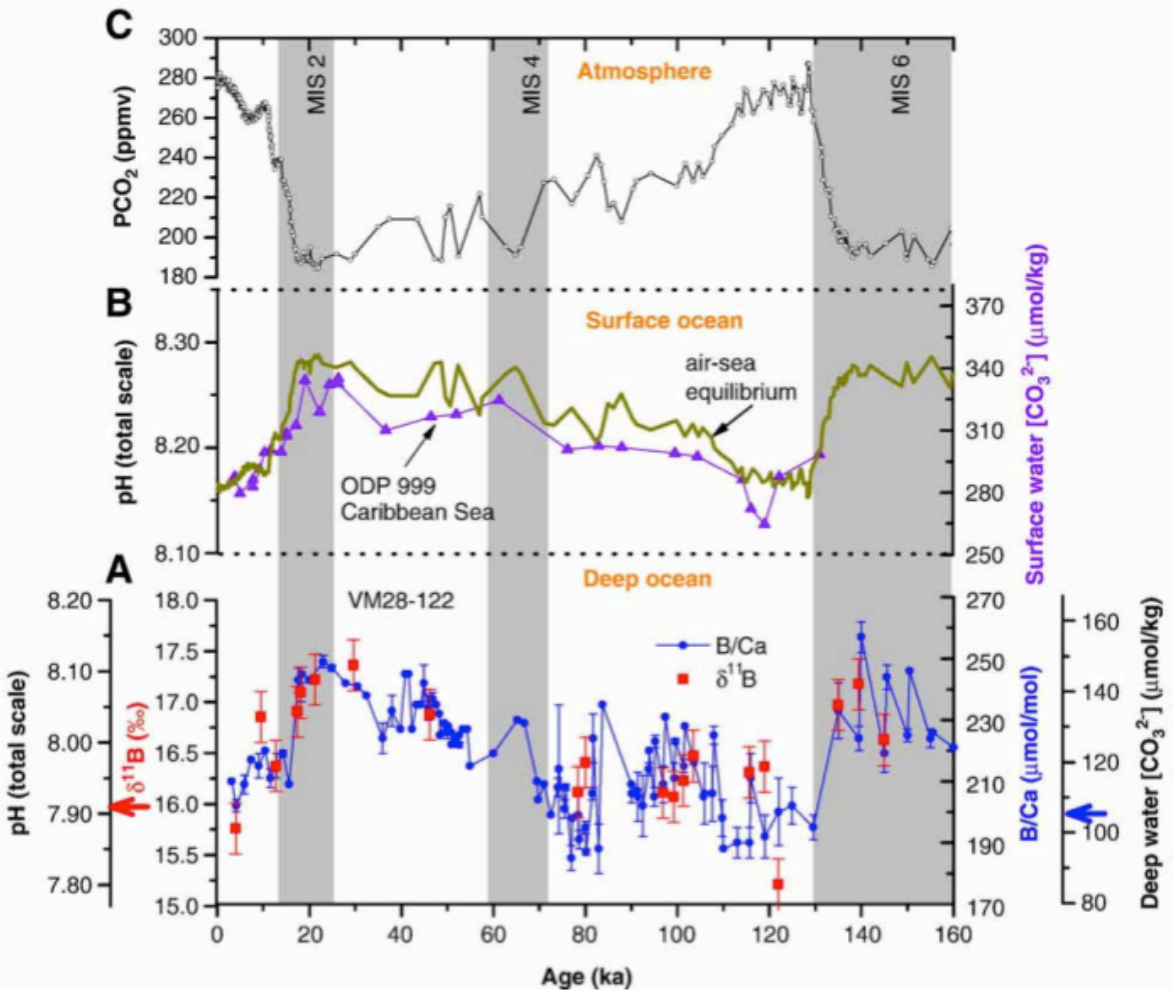


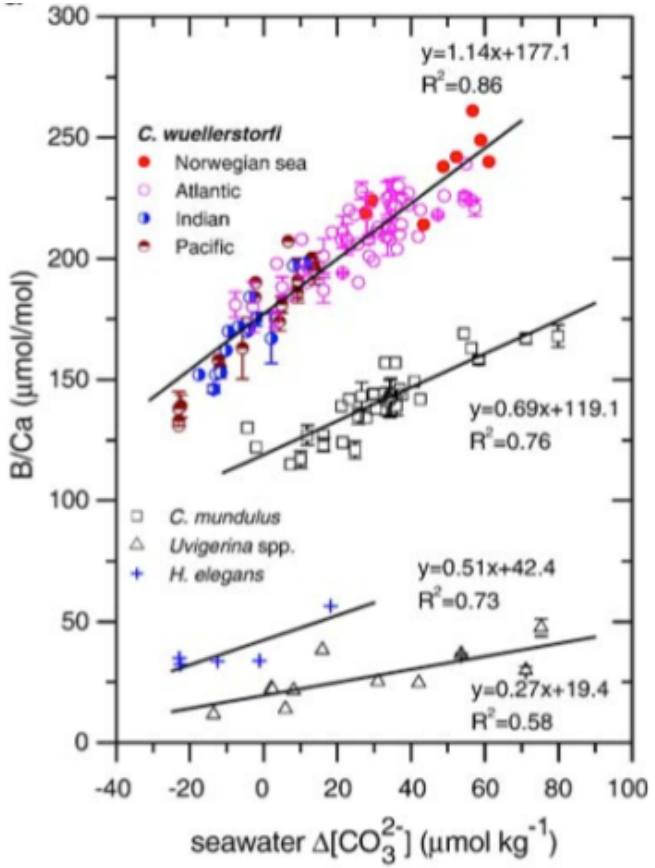
Benthic foraminiferal B/Ca ratios reflect deep water carbonate saturation state

(EPSL, 2008)

Jimin Yu *, Henry Elderfield

J. Yu et al. / Earth and Planetary Science Letters 293 (2010) 114–120

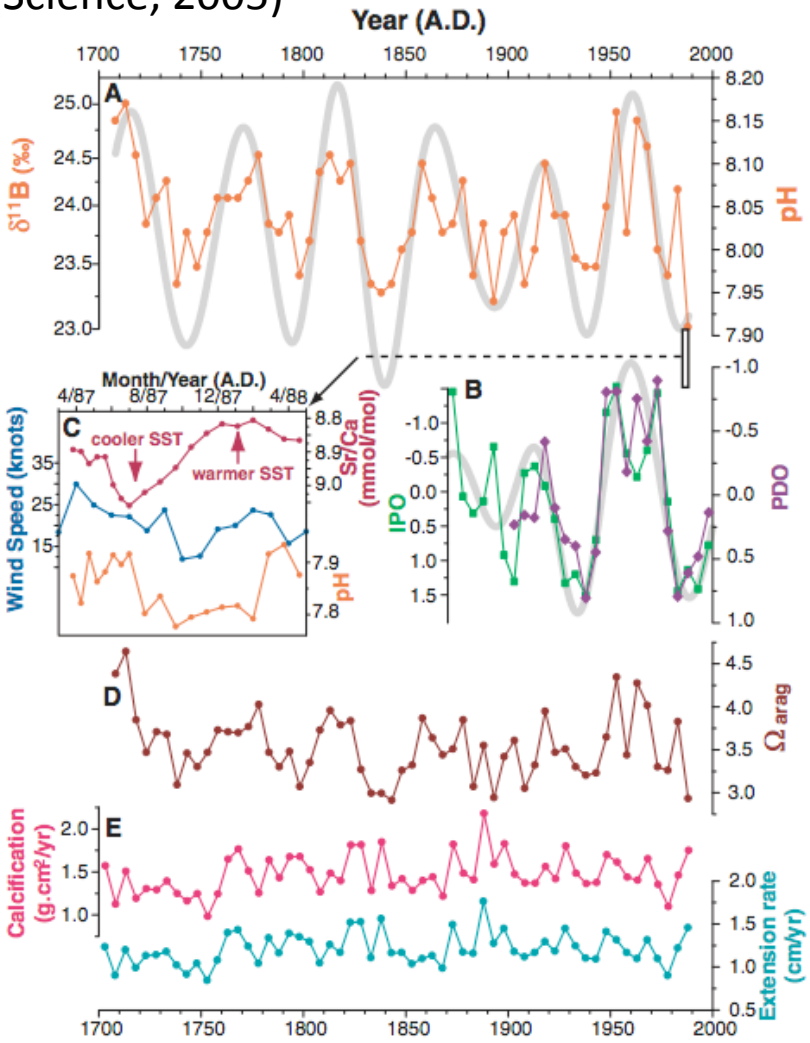


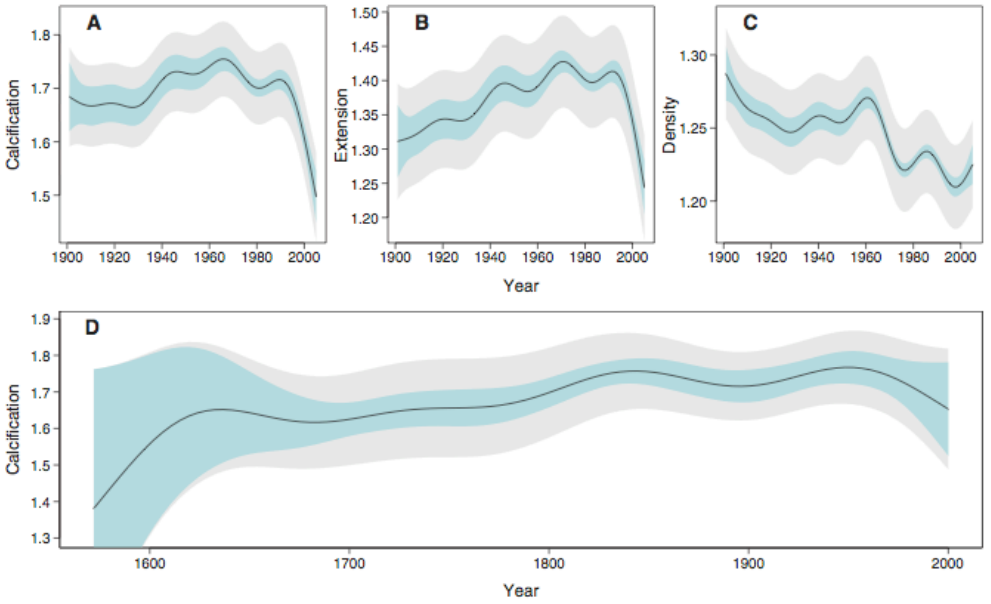


Preindustrial to Modern Interdecadal Variability in Coral Reef pH

Carles Pelejero,[1*†] Eva Calvo,[1*†] Malcolm T. McCulloch,[1†] John F. Marshall,[1] Michael K. Gagan,[1] Janice M. Lough,[2] Bradley N. Opdyke[3]

(Science, 2005)





Declining Coral Calcification on the Great Barrier Reef

Glenn De'ath,* Janice M. Lough, Katharina E. Fabricius

(Science, 2009)

Summary

1. Carbonate preservation is an indicator for corrosive conditions but does not allow for interpretation of calcification crises.

2. Extinctions and originations occur in benthos, micro- and nannoplankton but ecological changes may be dues to synergistic effects of temperature, stratification, nutrient availability, oxygenation.

3. Independent proxy evidence is required to identify ocean acidification.

4. Several paleoproxies are available but not all controls are understood and in particular the use of now extinct species is problematic, and the chemical composition of paleo-seawater is poorly constrained.

5. Modern OA is unprecedented in the past. The ocean buffers changes in saturation state on long timescales and only rapid (<10 kyr) changes in carbonate chemistry allow for suitable comparison with modern OA.