A TALE OF TWO BOUNDARIES: BEGINNING AND END OF THE PALEOCENE

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Cross section benthic foraminifer *Nuttallides truempyi*, Laura Foster, Bristol, UK

Schimper, 1874 (876 pages!): first defined Paleocene, lower part of Lyell's Eocene (not including the Danian). Based on fossil floras.

TRAITÉ

DE

PALÉONTOLOGIE VÉGÉTALE

OU

LA FLORE DU MONDE PRIMITIF

DANS SES RAPPORTS

AVEC LES FORMATIONS GÉOLOGIQUES

ET

LA FLORE DU MONDE ACTUEL

PAR

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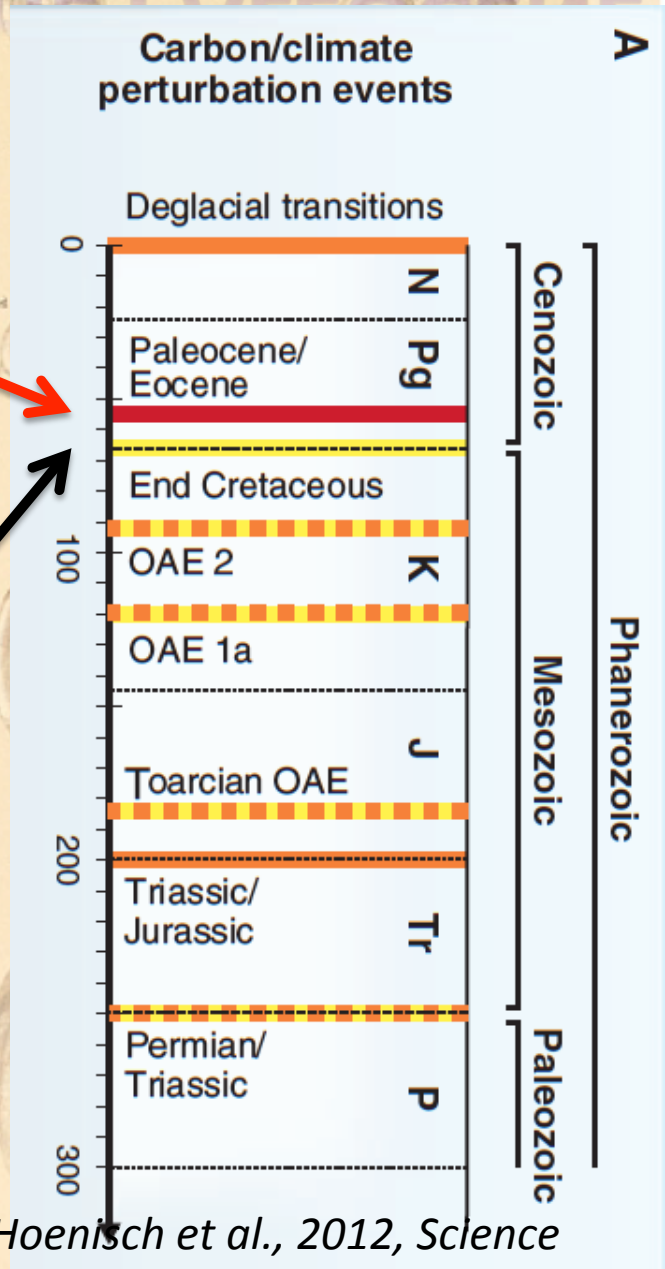
AVEC UN ATLAS DE 100 PLANCHES GRAND IN-QUARTO LITHOGRAPHIÉES.

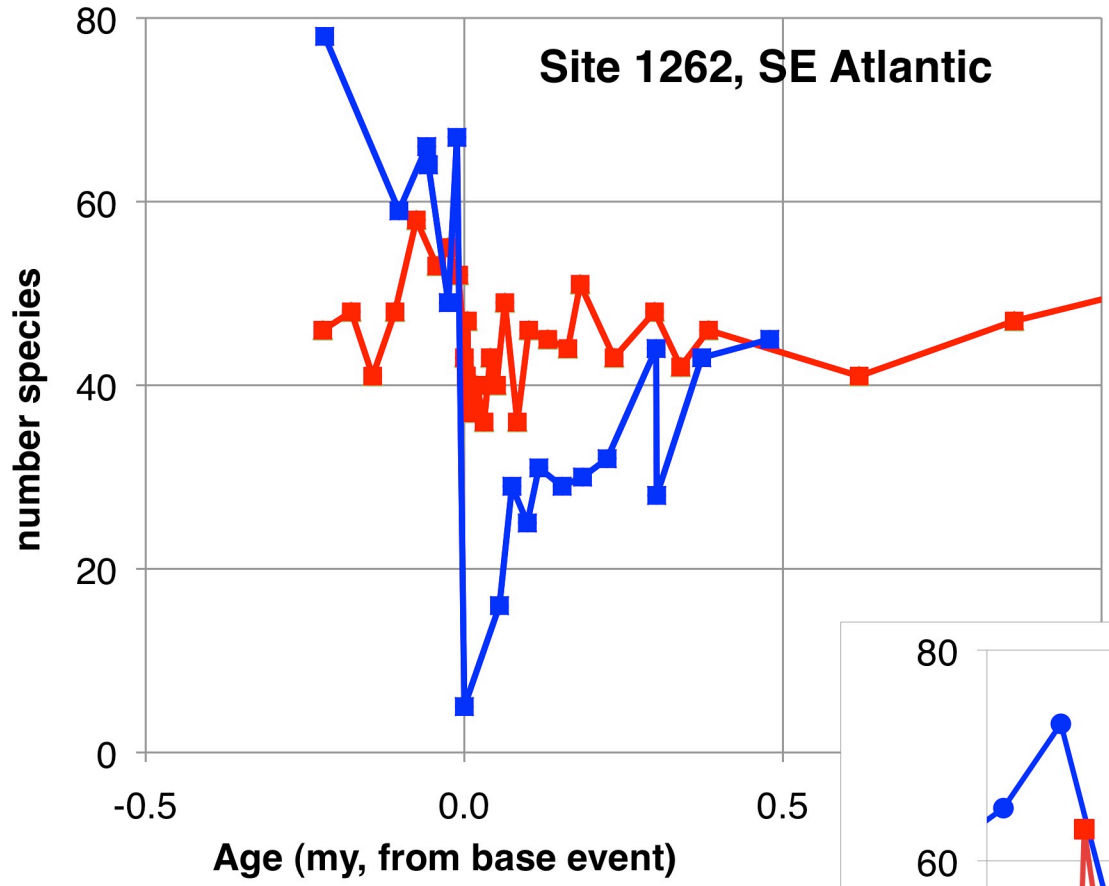
BEGINNING AND END OF THE PALEOCENE

- Global warming – carbon cycle disturbance (emission of isotopically light carbon compounds): Paleocene-Eocene Thermal Maximum (~ 56 Ma)
- Asteroid Impact: The Cretaceous-Paleogene (K/Pg) mass extinction (~ 66 Ma)



Hoenisch et al., 2012, Science

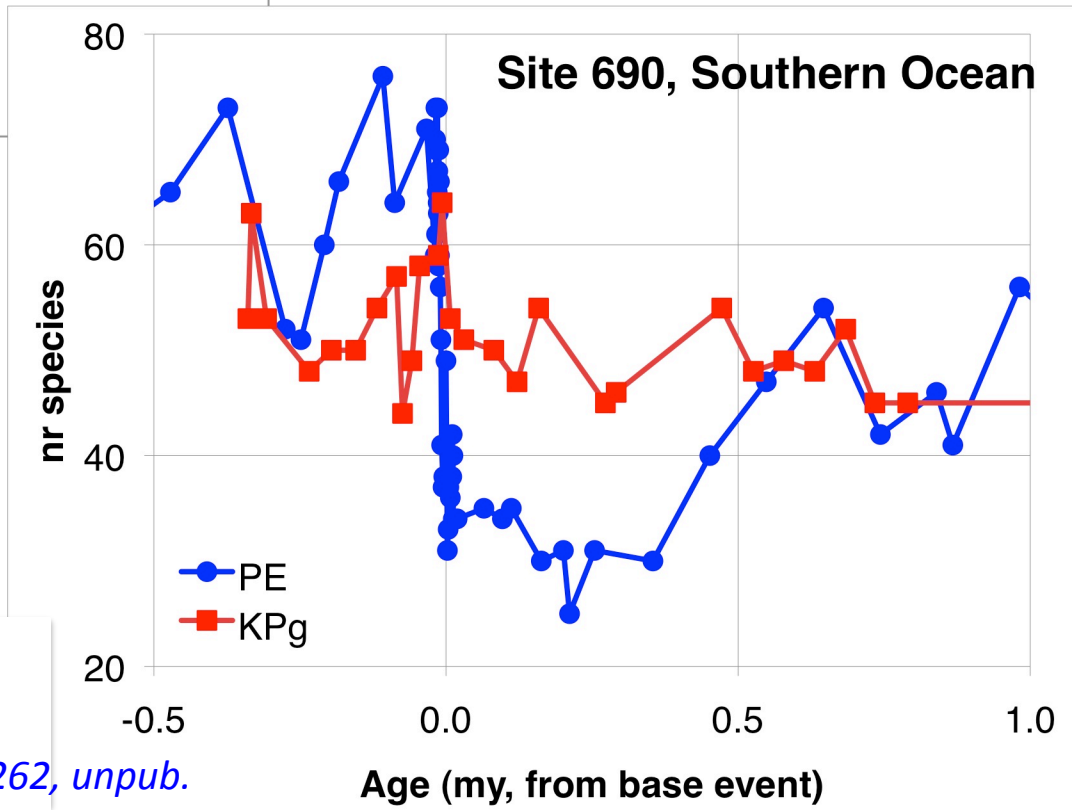
Two boundaries	K/Pg (~ 66 Ma)	PETM (~ 56 Ma)
Pelagic Calcifiers (planktic foraminifera, calcareous nannoplankton)	Severe extinction (>95% of species) 	Temporary assemblage changes, migration, evolution of short-lived species
Benthic Foraminifera (deep-sea)	Temporary assemblage changes	Severe extinction (~35-50% common cosmopolitan species) 



Number of species of <u>benthic foraminifera</u>, from 0.5 million years before until 1.0 million years after the event.

K/Pg (no extinction)

P/E (severe extinction)



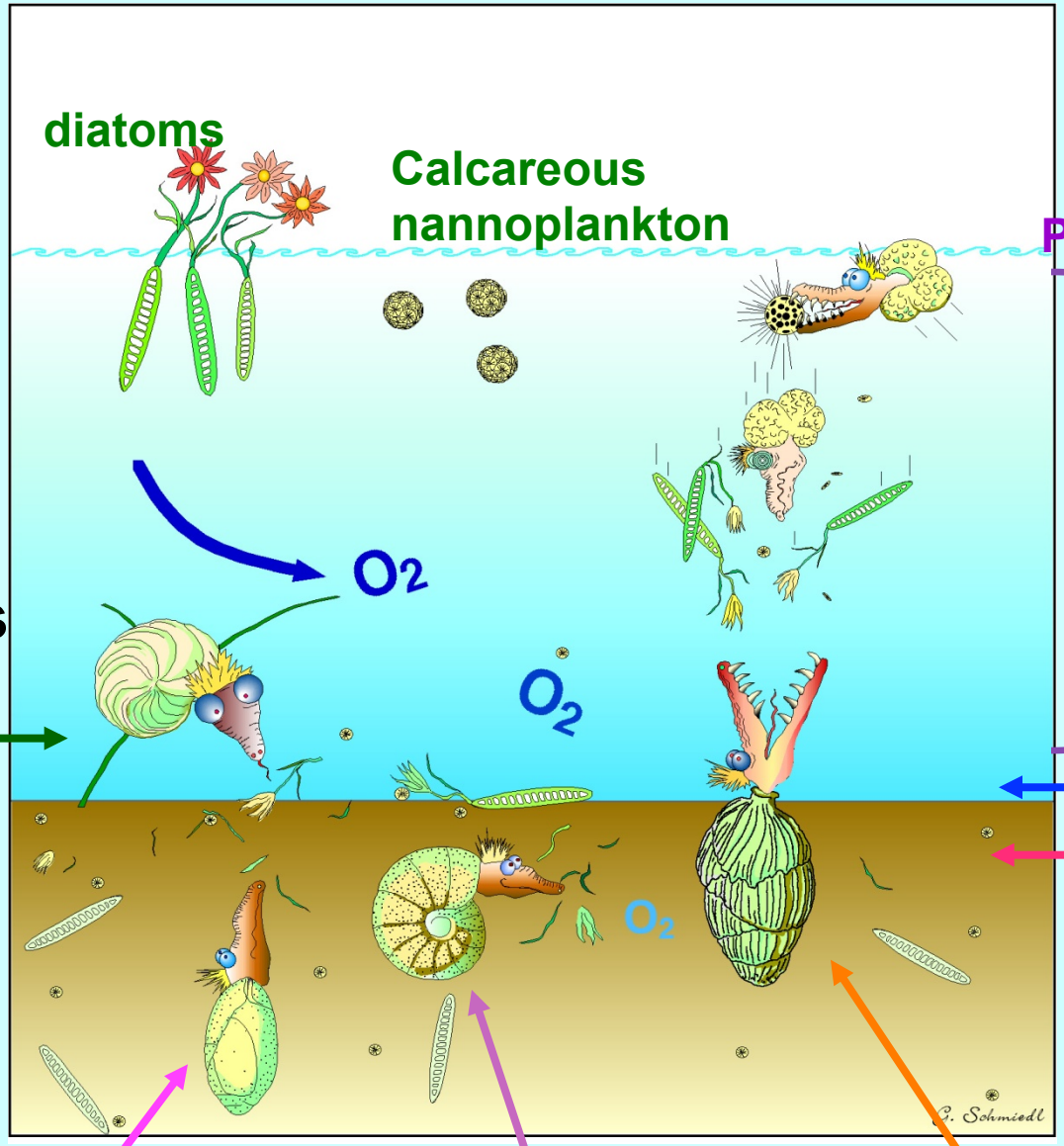
<u>Decoupling of marine extinctions</u>:

- **K/Pg**: severe **planktic**, not benthic extinction
- **P/E**: **benthic**, not planktic extinction

K/Pg data Site 690: Alegret & Thomas, 2013;
Site 1262: Alegret & Thomas, 2007;
PETM data Site 690: Thomas 1990, 2003; Site 1262, unpub.

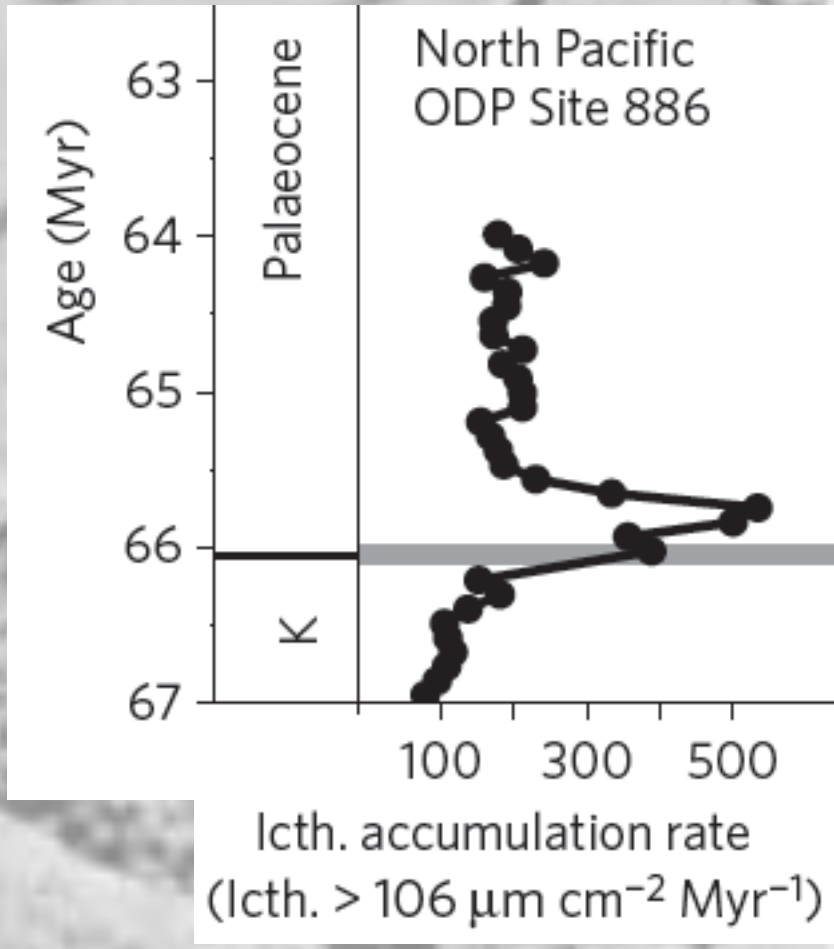
DECOUPLING OF PLANKTIC-BENTHIC EXTINCTION SURPRISING

Deep-Sea: FOOD-POOR, depending on surface photosynthesis



Gerhard Schmiedl, Hamburg University : Foram Cartoon

- **The severe K/Pg extinction of pelagic calcifiers was not linked to significant seafloor (benthic foram) extinction**, therefore does not imply **global, long-term, extreme reduction in food supply to the seafloor, i.e., in overall primary productivity and the biological pump.**

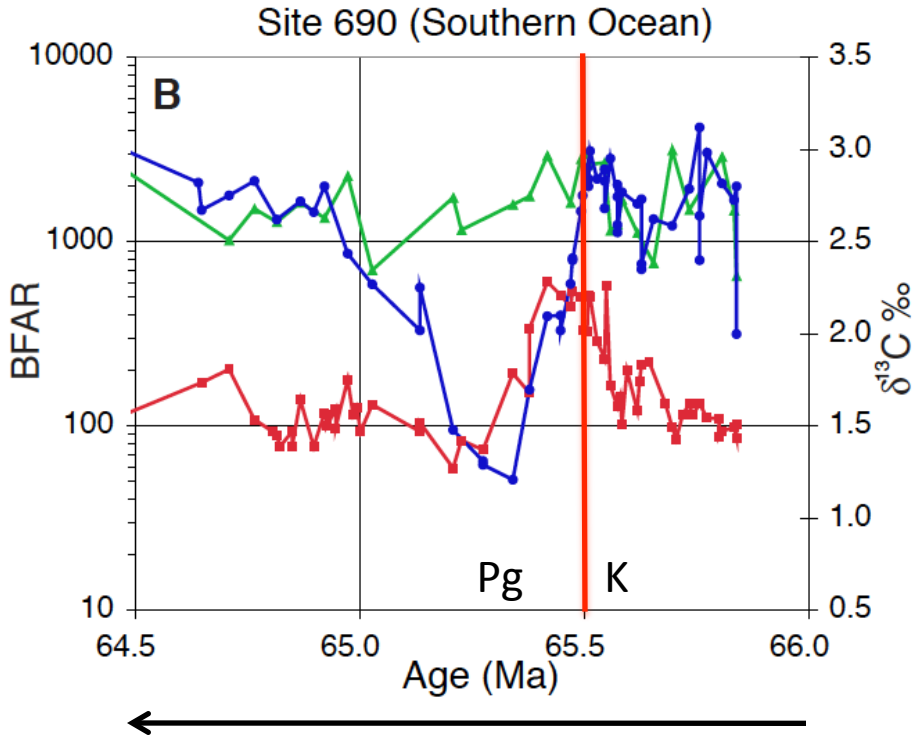


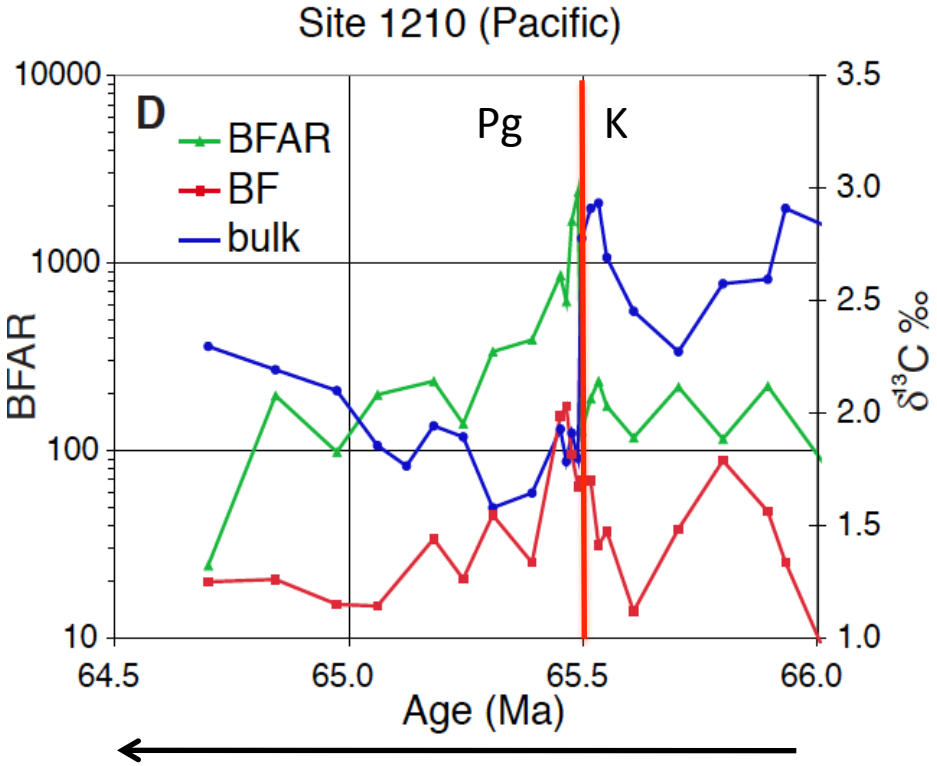
Supported by evidence from Ba in sediments (Hull & Norris, 2011, *Paleoceanography)*, Resilience of pelagic fish to extinction (Sibert et al., 2014, *Nature Geoscience)*.

Carbon isotopes: collapse of export productivity (red-blue lines).

Benthic foraminifera: no significant extinction at K/Pg, no collapse in BFAR and other food-proxies

EXTINCTION OF CALCIFYING PHYTOPLANKTON AT LEAST REGIONALLY COMPENSATED BY BLOOMS OF NON-CALCIFIERS





- $\delta^{13}C$ in bulk carbonate (nannoplankton – upper waters)
- $\delta^{13}C$ in benthic foraminifera (sea floor)
- BFAR: Benthic Foram Accumulation Rate, proxy for food reaching the sea floor.

Alegret et al., PNAS, 2012

At the end of the Cretaceous:

- Neither productivity (in terms of biomass) nor the biological pump collapsed
- The collapse of carbon isotope gradients could have been caused (mainly) by changes in calcareous planktic assemblages before and after extinction, i.e., by the extinction itself.
- Preferential extinction of pelagic calcifyers – acidification and effects on ecosystem structure?

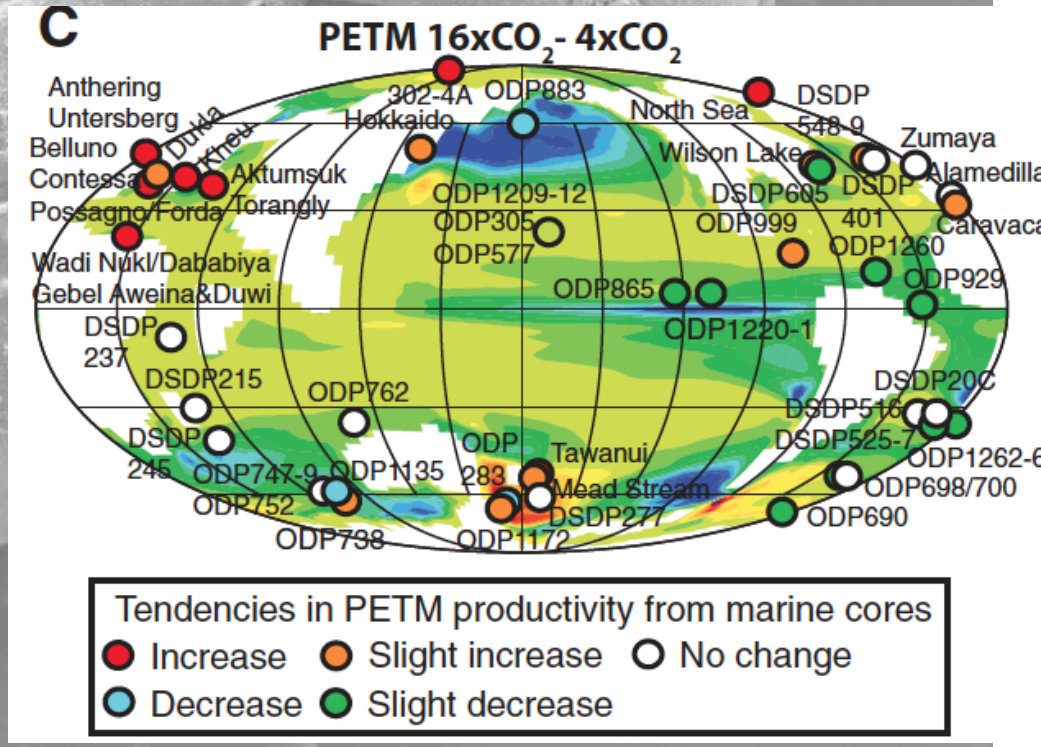
How about the PETM deep-sea benthic foraminiferal extinction?

- **Pelagic Settings: productivity decline at increased stratification, increased remineralization in the water column -> deep-ocean starvation**

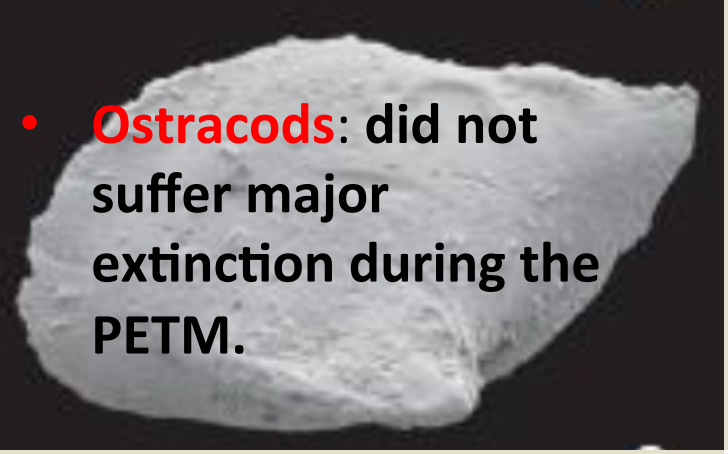
Deoxygenation: possibly not important for benthic foram extinction, **may have affected planktonic communities – expanded Oxygen Minimum Zones.**

100 µm

Acidification?



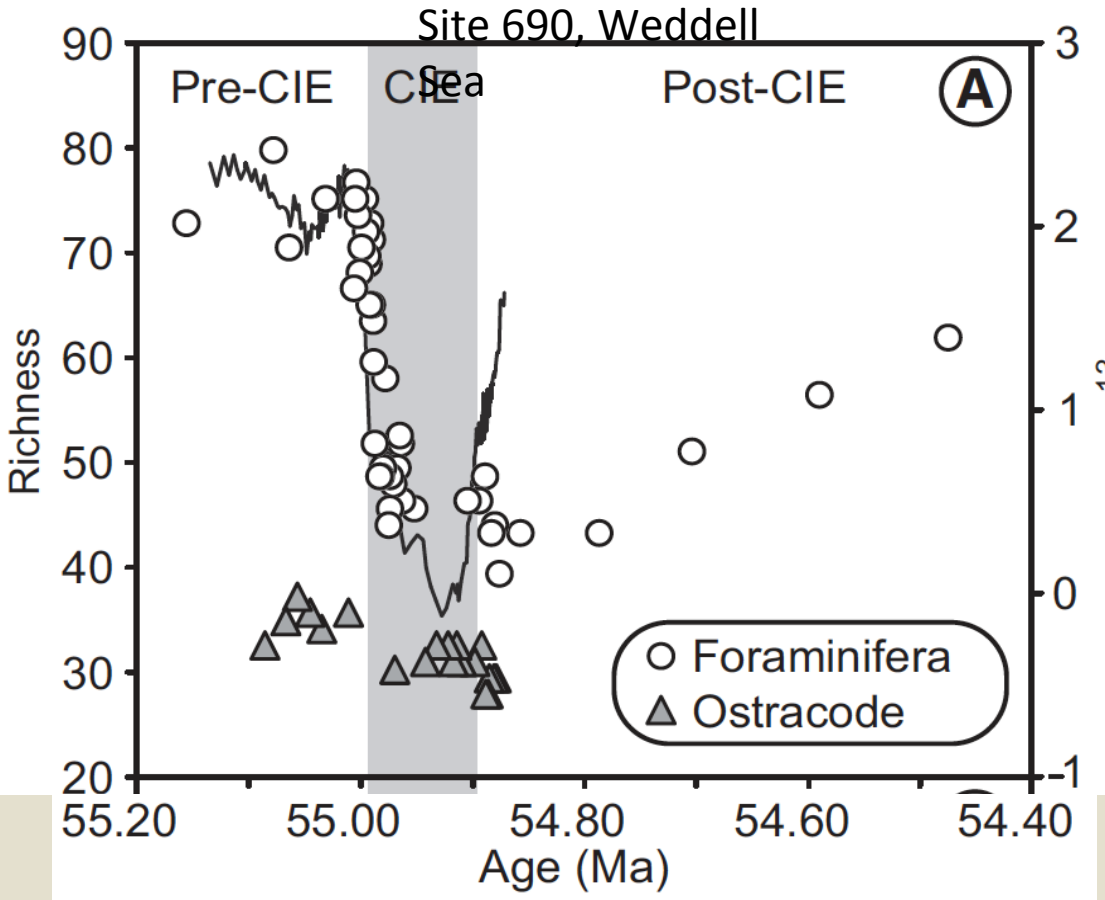
Winguth et al., 2012, *Geology*



- **Ostracods**: **did not suffer major extinction during the PETM.**

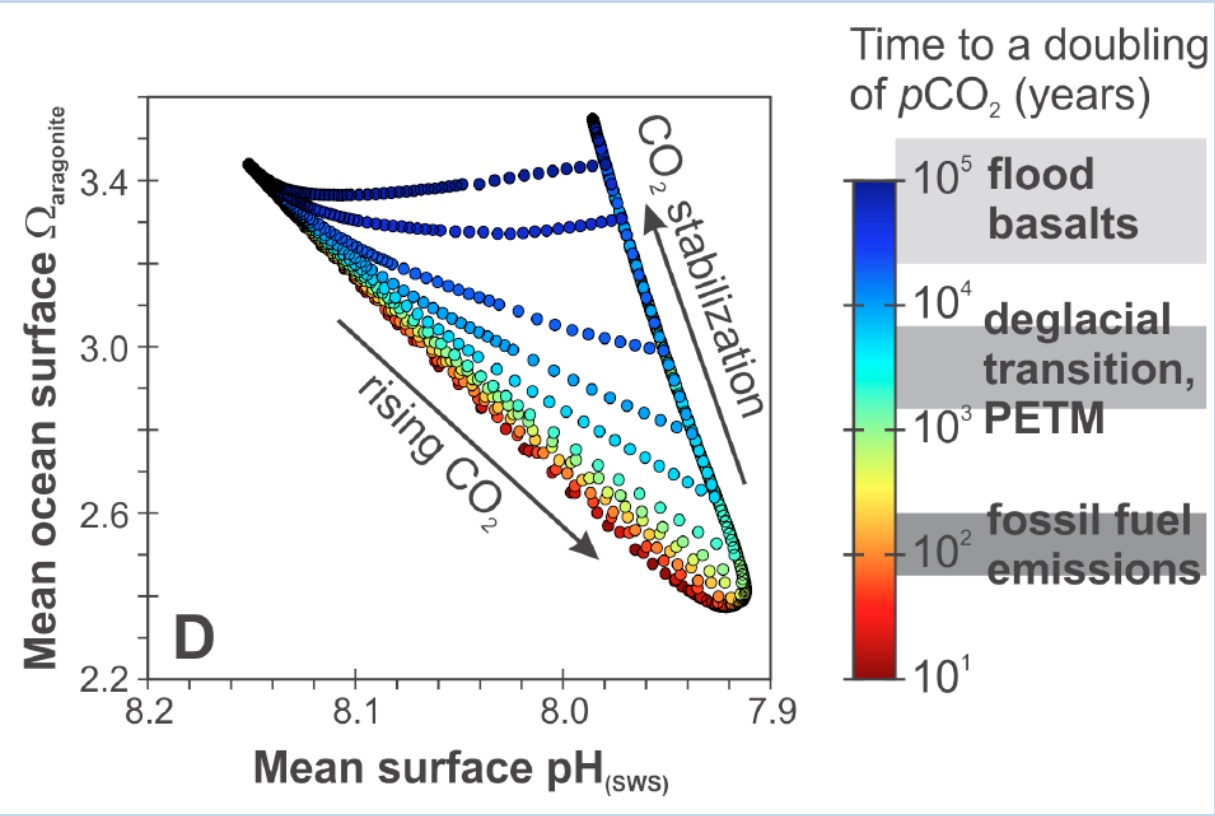
Why ocean acidification rather than deoxygenation important cause of PETM benthic foram extinction ?

- **Metazoans** with extensive extracellular fluid **less sensitive** to ocean acidification than protists (Wittmann and Poertner, 2013 *Nature Climate Change*).
- Active **metazoans (animals) more sensitive** than **protists** to oxygen depletion



Webb et al., 2009, Geology

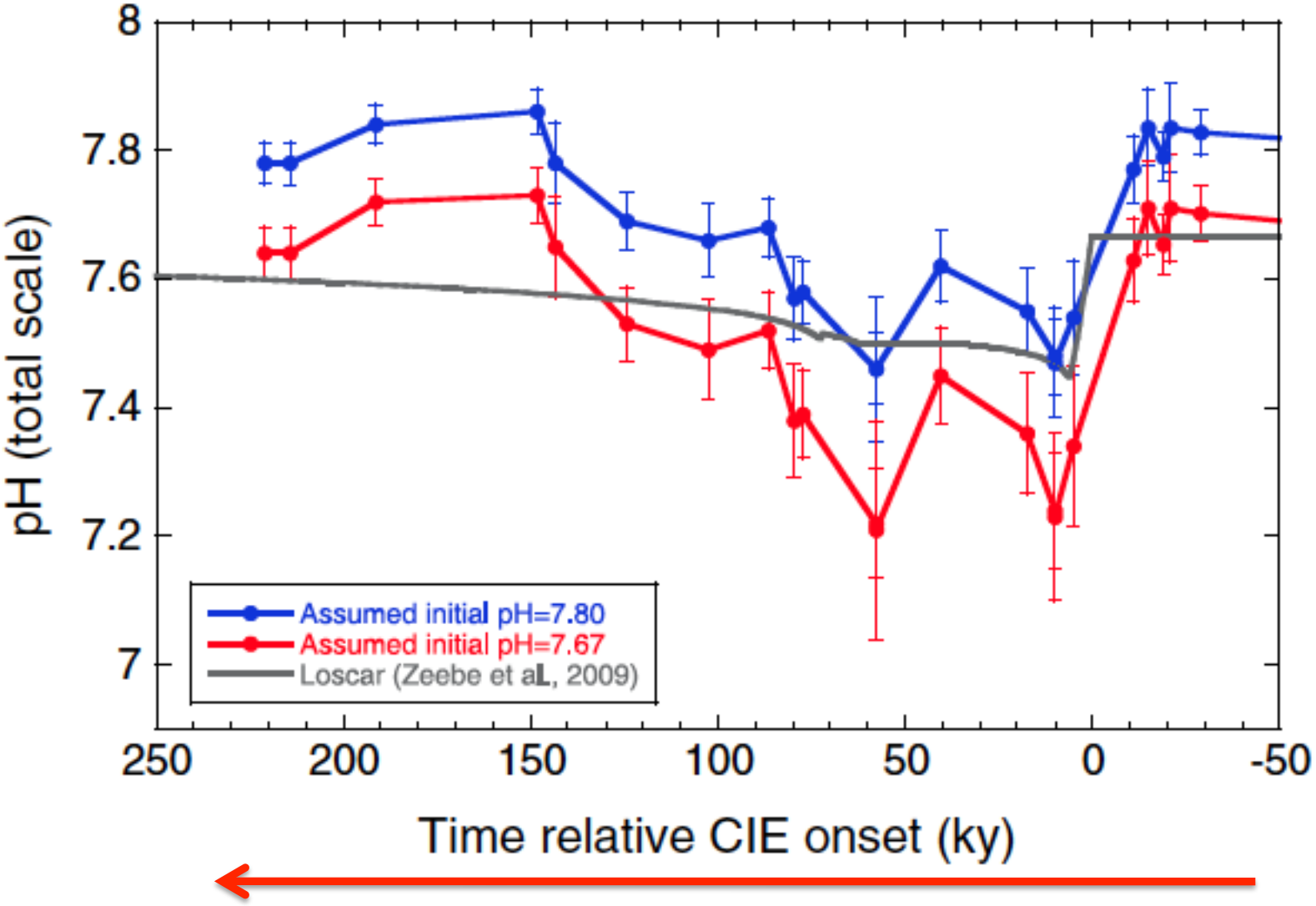
Ocean acidification could have been a major cause of the **differential planktic-benthic patterns of extinction** at the beginning and end of the Paleocene, because its effects **depend upon the rate of acidification (century – 100 kyr).**



Trajectories of mean ocean surface pH and saturation (Ω) become progressively <u>decoupled</u> as the rate of atmospheric pCO_2 change decreases. Slow rates (millennia) affect surface ocean less, deep-sea more –> carbonate dissolution.

Hoenisch et al., 2012, Science

Surface ocean acidified during the PETM: ΔpH= ~ 0.27 units.



Penman et al., 2014, *Paleoceanography*

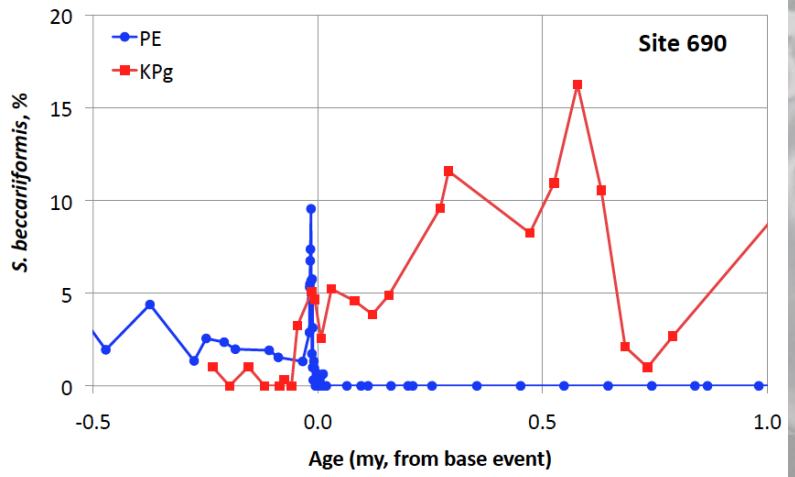
K/Pg mass extinction:

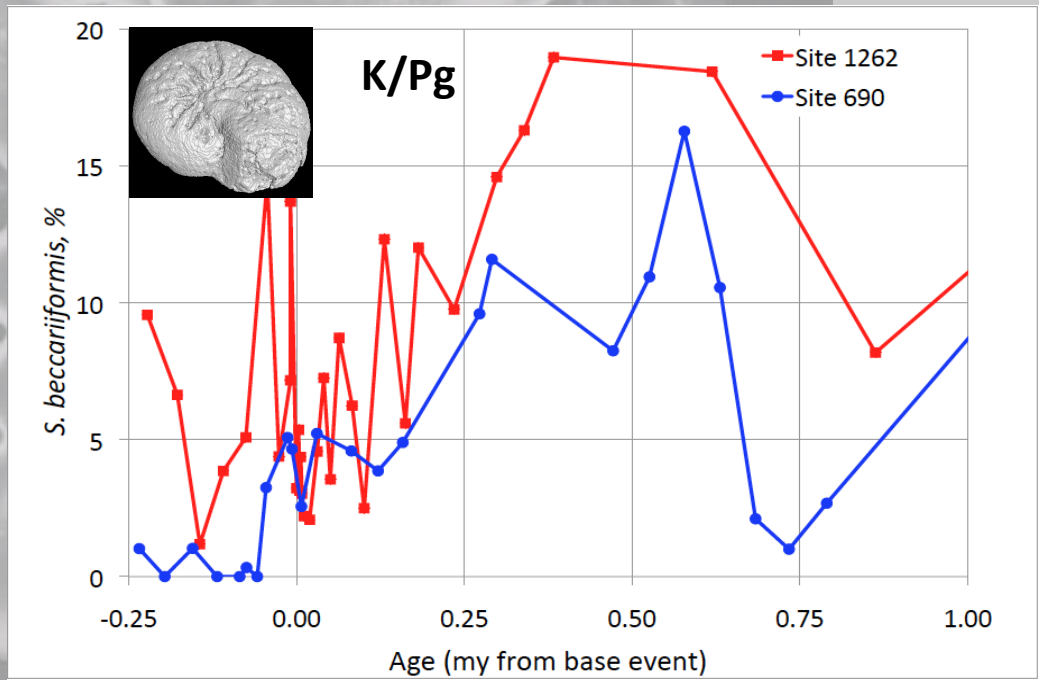
- Rapid ocean acidification (strong acids, **H_2SO_4**-HNO_3) due to asteroid impact may have decimated **pelagic calcifiers** (including phytoplankton, foraminifera, aragonitic ammonites?), but was buffered before it could penetrate into the deep oceans.
- Primary productivity (regionally) taken over by non-calcifying phytoplankton (diatoms, prokaryotes, dinoflagellates)
- **Changes in ecosystem structure may have kept biological pump going despite extinction – e.g., increased jelly fish (good for transport of organic matter) after extinction of top-level predators and ammonites?**

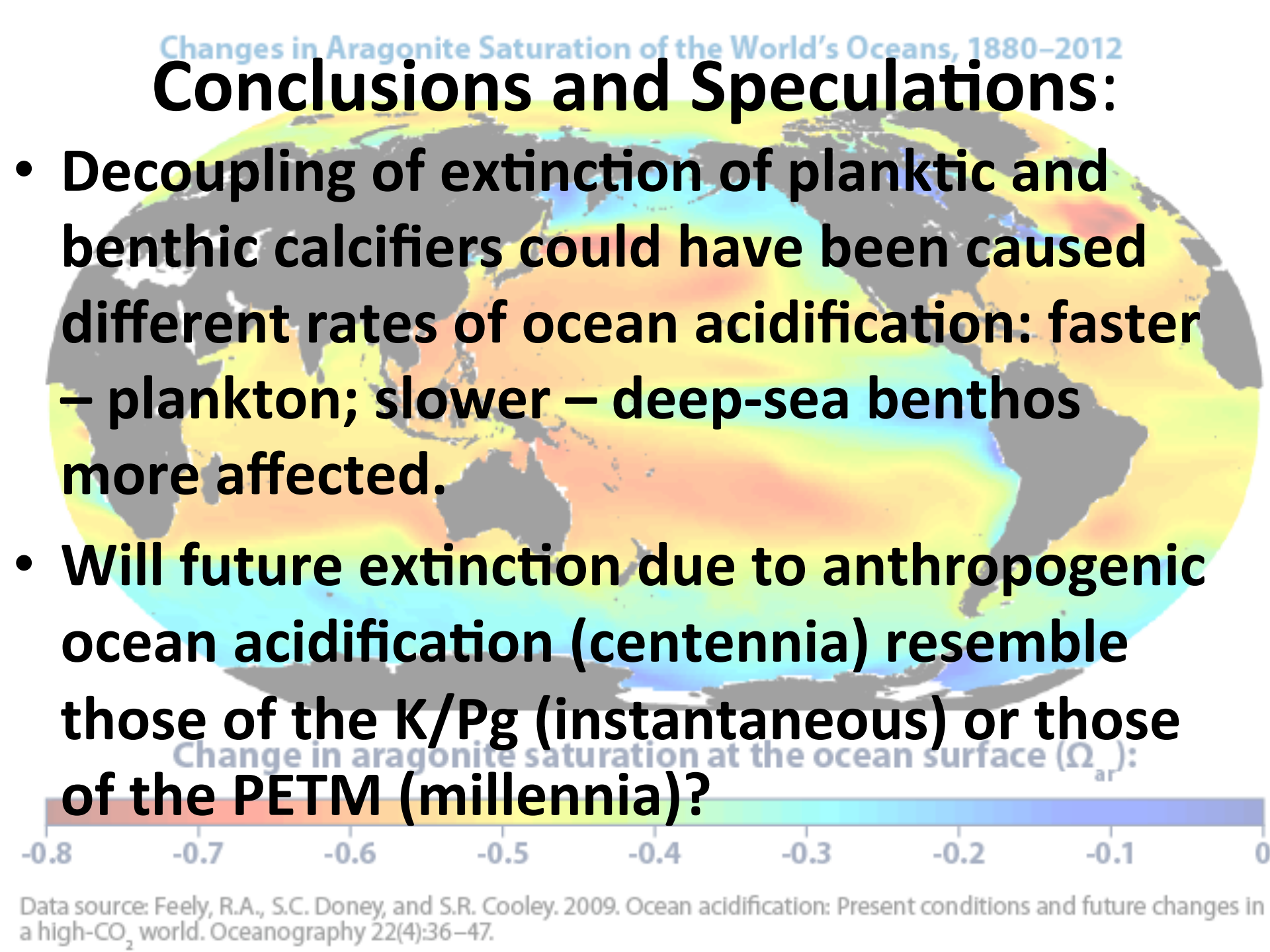
K/Pg rapid surface ocean acidification -> extinction of pelagic calcifiers led to deep-ocean carbonate supersaturation on long time scales.

- Mass extinction of **calcifying plankton** -> collapse of **deep-sea carbonate deposition**
- **Weathering input of Ca^{2+}, CO_3^{2-} did not decline** -> supersaturation
- Benthic foraminifer: ***Stensioeina beccariiformis*** **– super-saturation indicator (survived K/Pg, extinct at PE)**

K/Pg and P/E compared:







Conclusions and Speculations:

- **Decoupling of extinction of planktic and benthic calcifiers could have been caused different rates of ocean acidification: faster – plankton; slower – deep-sea benthos more affected.**
- **Will future extinction due to anthropogenic ocean acidification (centennia) resemble those of the K/Pg (instantaneous) or those of the PETM (millennia)?**

Thanks to:

- Funding by NSF Grant OCE-720049
- Leverhulme Foundation (UK)
- Laia Alegret (Zaragoza), Dani Schmidt, Andy Ridgwell and Laura Foster (Bristol)
- Samples from IODP