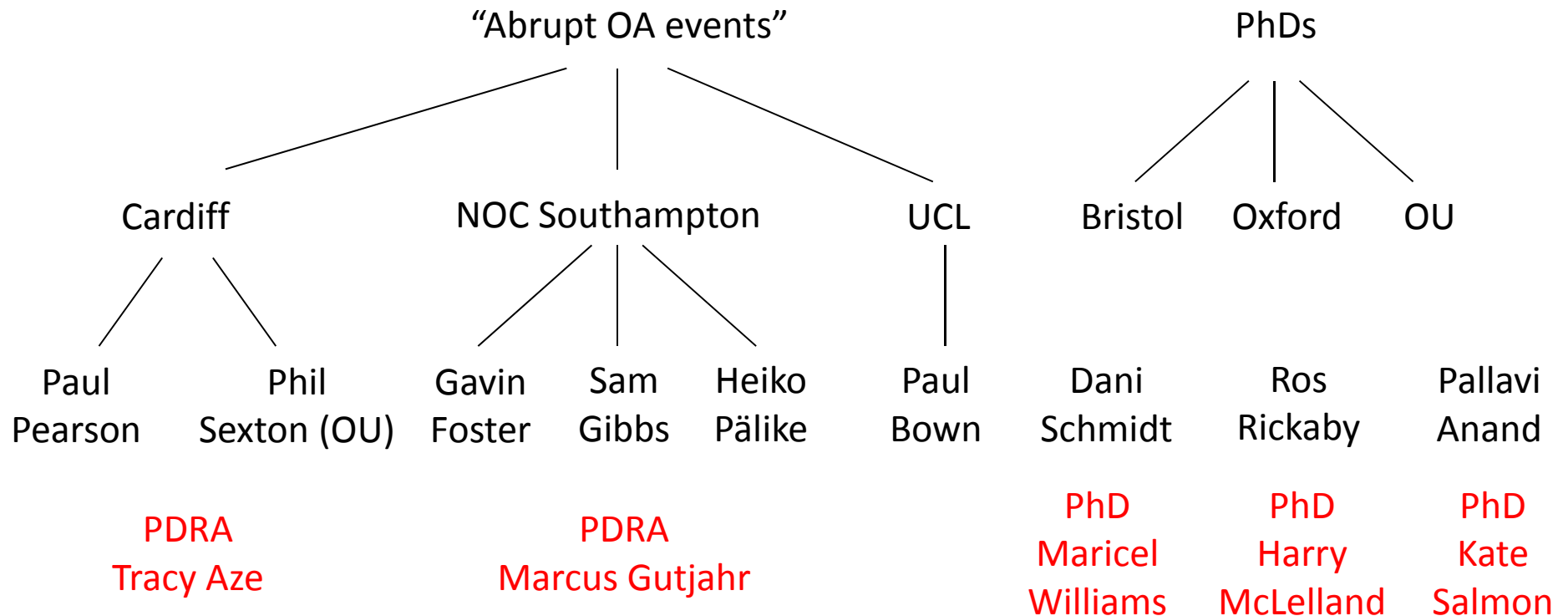


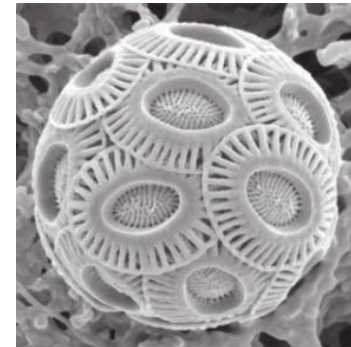
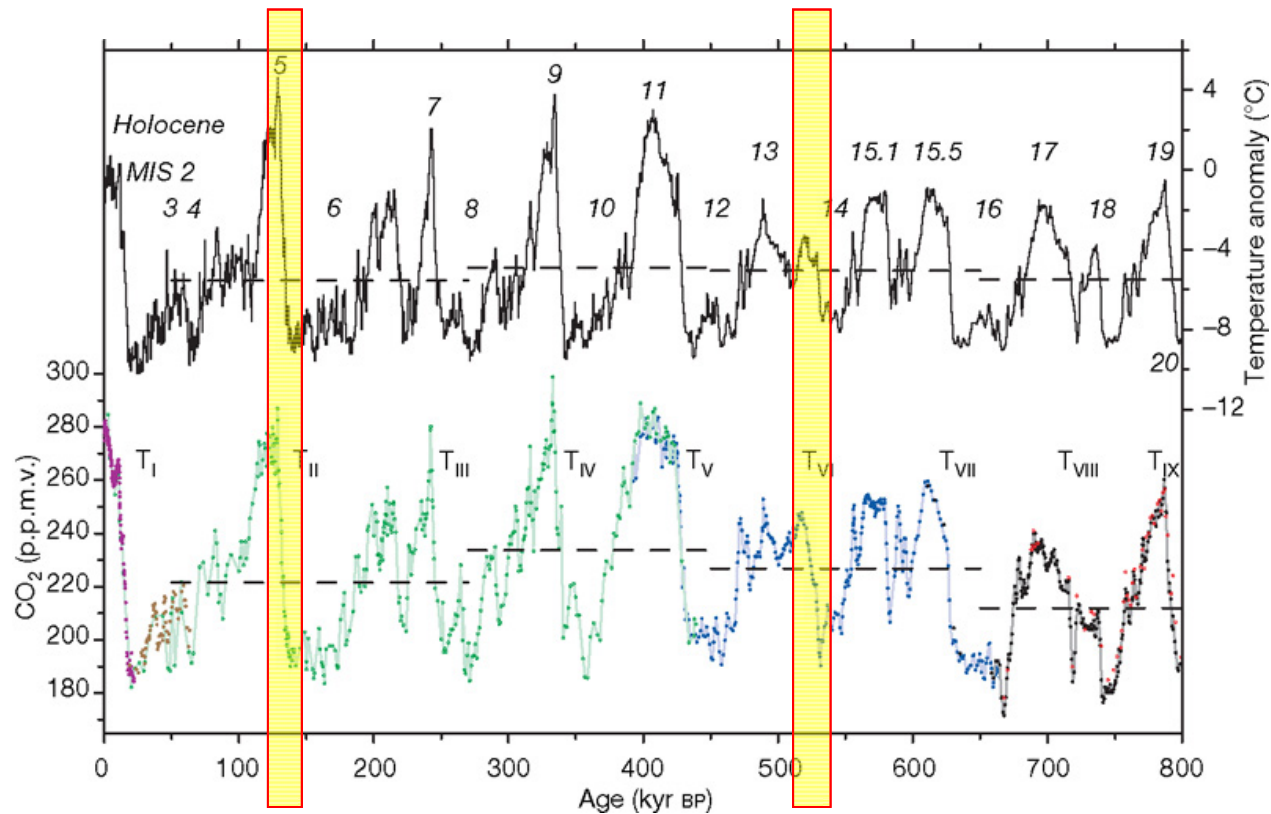


Ocean Acidification: have we been here before?



+ Sarah O’Dea (Southampton), Alex Dickson (OU), Rich Pancost (Bristol), Marcus Badger (Bristol), Kirsty Edgar (Cardiff), Melanie Leng (Leicester)

Harry McClelland (Oxford): A mechanistic field investigation of the physiological response of phytoplankton to past fluctuations in surface water carbonate chemistry

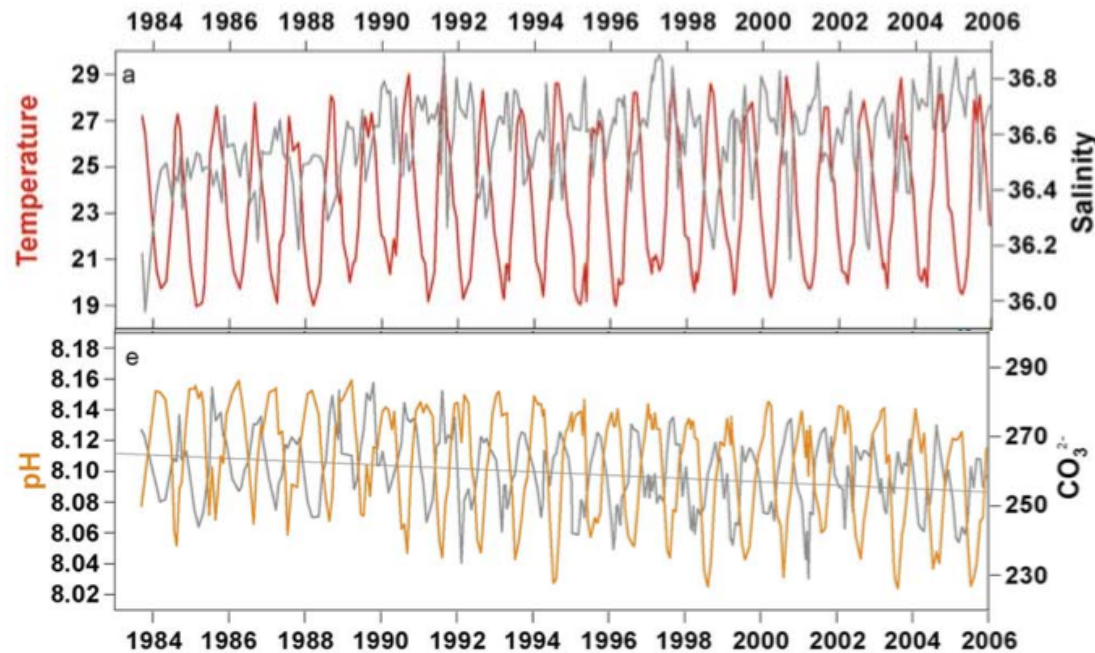


“To use the geological record as a laboratory to study changes in calcification ability, and species-specific changes in photosynthetic efficiency of coccolithophores (& diatoms) in response to ocean acidification.”

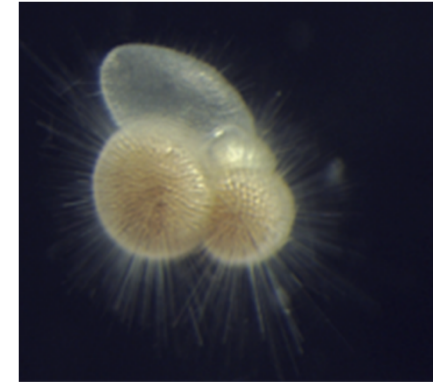
Lith size, $\delta^{13}\text{C}$ fractionation of individual species

Kate Salmond (Open University): How will anthropogenic Ocean Acidification affect bio-calcification?

Bermuda Atlantic Time Series



Bates (2007)

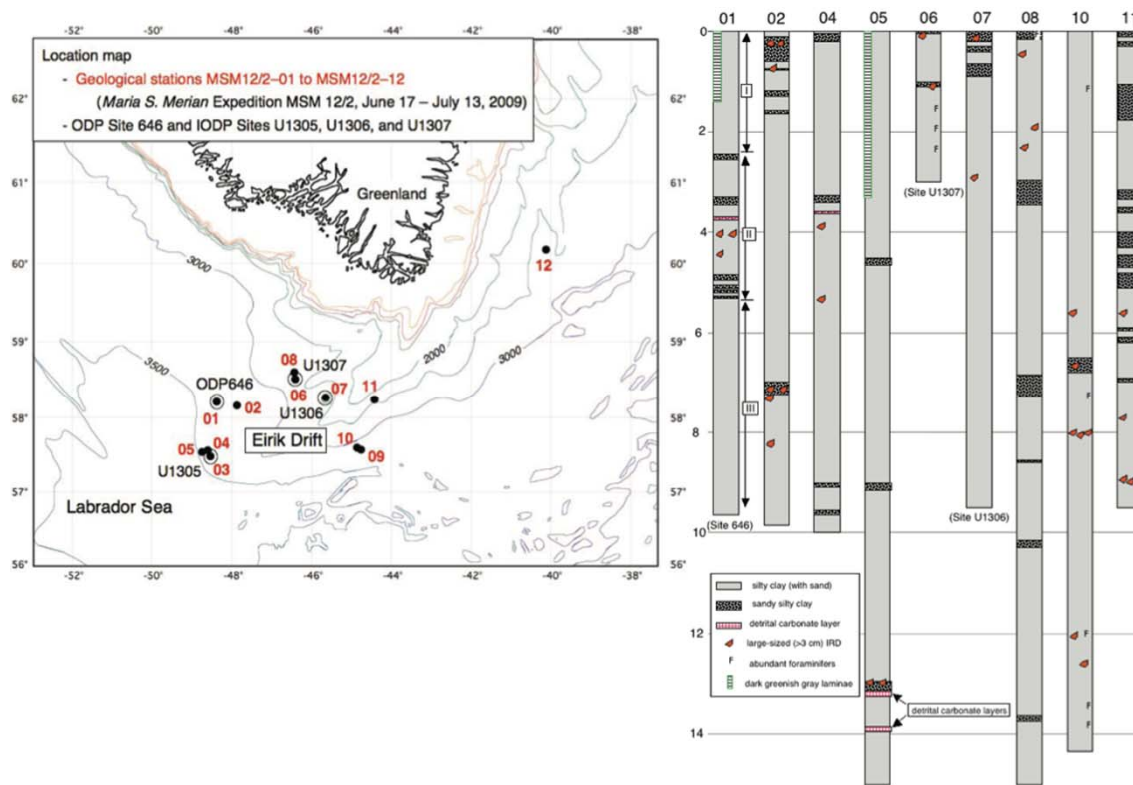


“How has recent ocean acidification affected the shell calcification of planktonic foraminifera? How has seawater [CO₃²⁻] in the upper water column changed due to recent ocean acidification?”

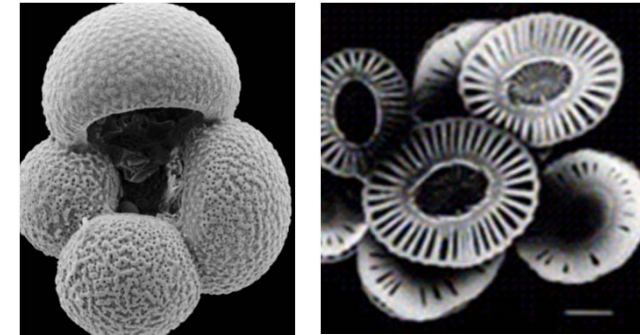
**Three species, 3 – year resolution:
trace elements, biometrics.
Comparison with pre-industrial
and glacial-interglacial samples**

Maricel Williams (Bristol University): The pelagic record of ocean acidification and plankton calcification in high latitudes

Sediment cores from Labrador Sea



Bates (2007)



“To determine whether historical changes in carbonate ion concentration and pH since industrialisation have already had discernible impacts on coccolithophores and foraminifers in high latitude environments”

Size, weight and thickness, Fourier shape analysis, coccolith mass and assemblages to compare with plankton samples since the 1960s

“Abrupt Ocean Acidification Events”

“To ascertain the rate and amplitude of ocean acidification to which species and ecosystems can adapt and the threshold of acidification that would lead to enhanced evolutionary turnover and extinction of species”

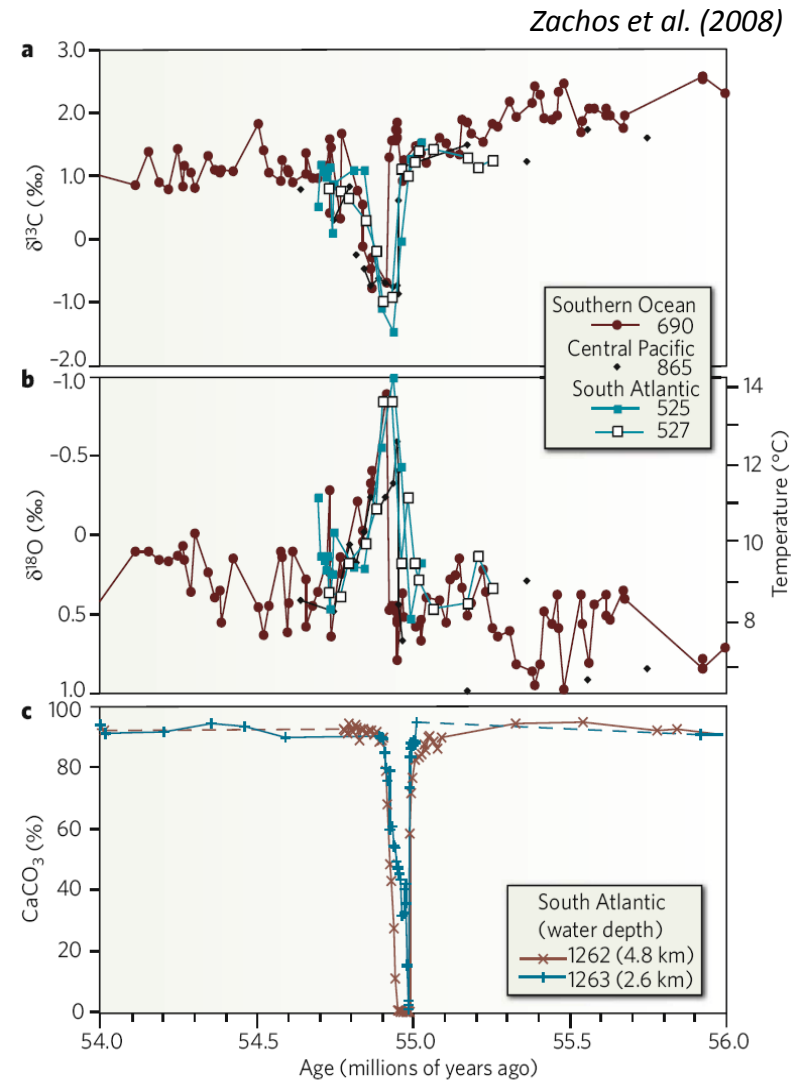
- Large events – involving extinction
- Multiple events
- Calcifying plankton – but also benthic & shelf taxa

Which Abrupt OA events?



Palaeocene-Eocene Thermal Maximum (PETM)

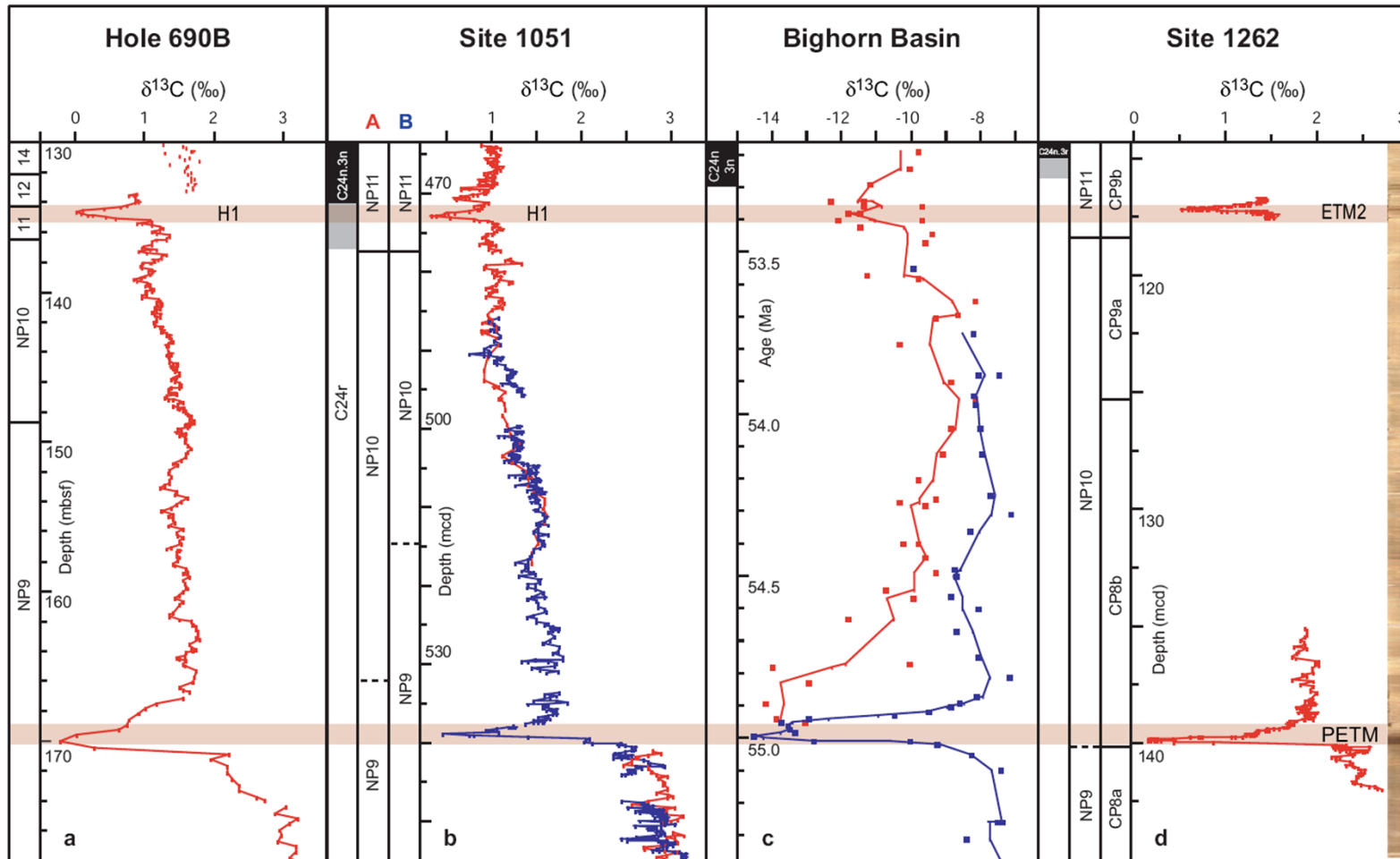
- Short lived (120-220 kyr) global warming episode (deep sea T increased by 5-8 °C)
- $\delta^{13}\text{C}$ anomaly – 3000-7000 Gt C (0.3-7 Gt C per year)
- Rapid onset
- Deep sea acidification and lysocline shoaling
- Dramatic terrestrial and marine biotic response (extinction, mi

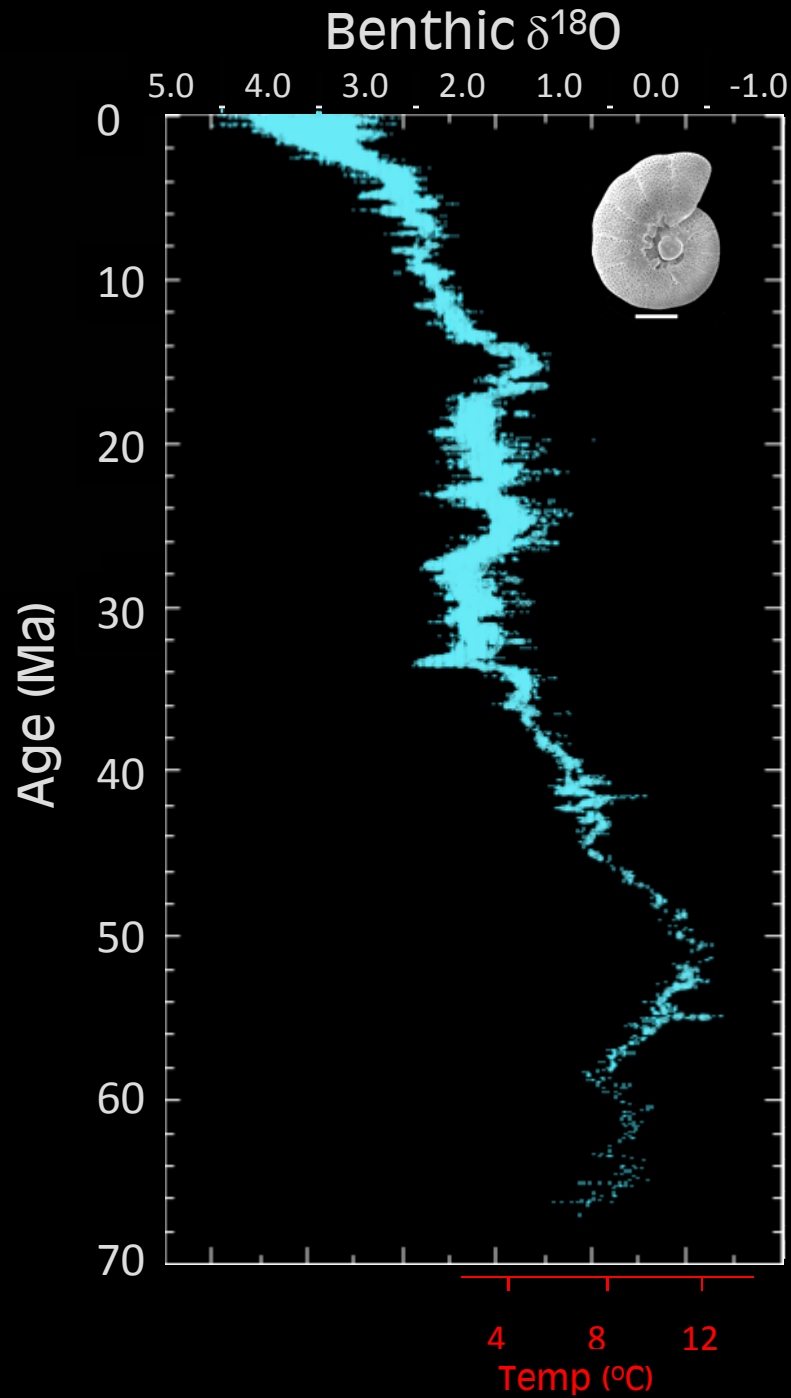


The less extreme hyperthermals

- comparable in character to PETM but less extreme in magnitude and duration

- $\delta^{13}\text{C}$ anomalies $\sim 1\text{‰}$ (PETM = $>3\text{‰}$)





Hyperthermals
In context

Deep sea
benthic foram
 $\delta^{18}\text{O}$ compilation
(Zachos et al., 2008)

←
←
←
←
Paleogene
hyperthermals

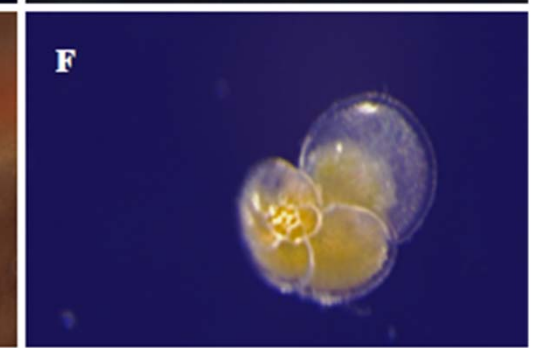
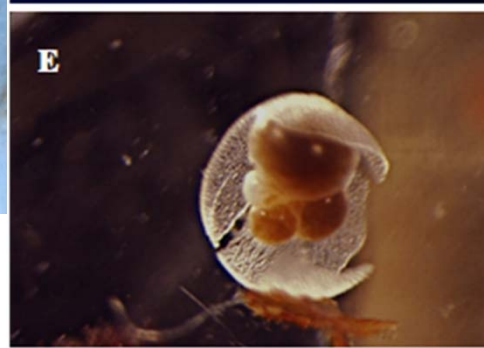
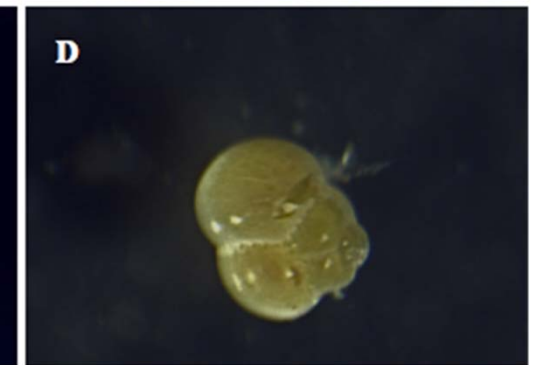
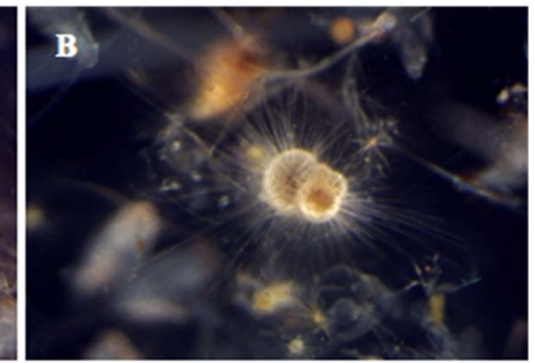
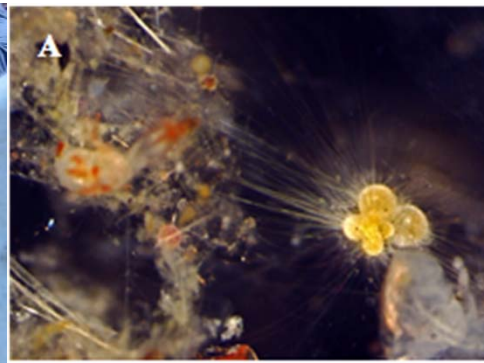
PETM - problems and uncertainties

- Deep ocean sites dissolved and truncated – destroys the evidence of biotic response
- Carbonate diagenesis affects geochemical proxies and causes biomineral overgrowth / replacement
- Divergent estimates of size of carbon isotope excursion
- Rapidity of onset and surface ocean pH change unknown



What do we propose to do?

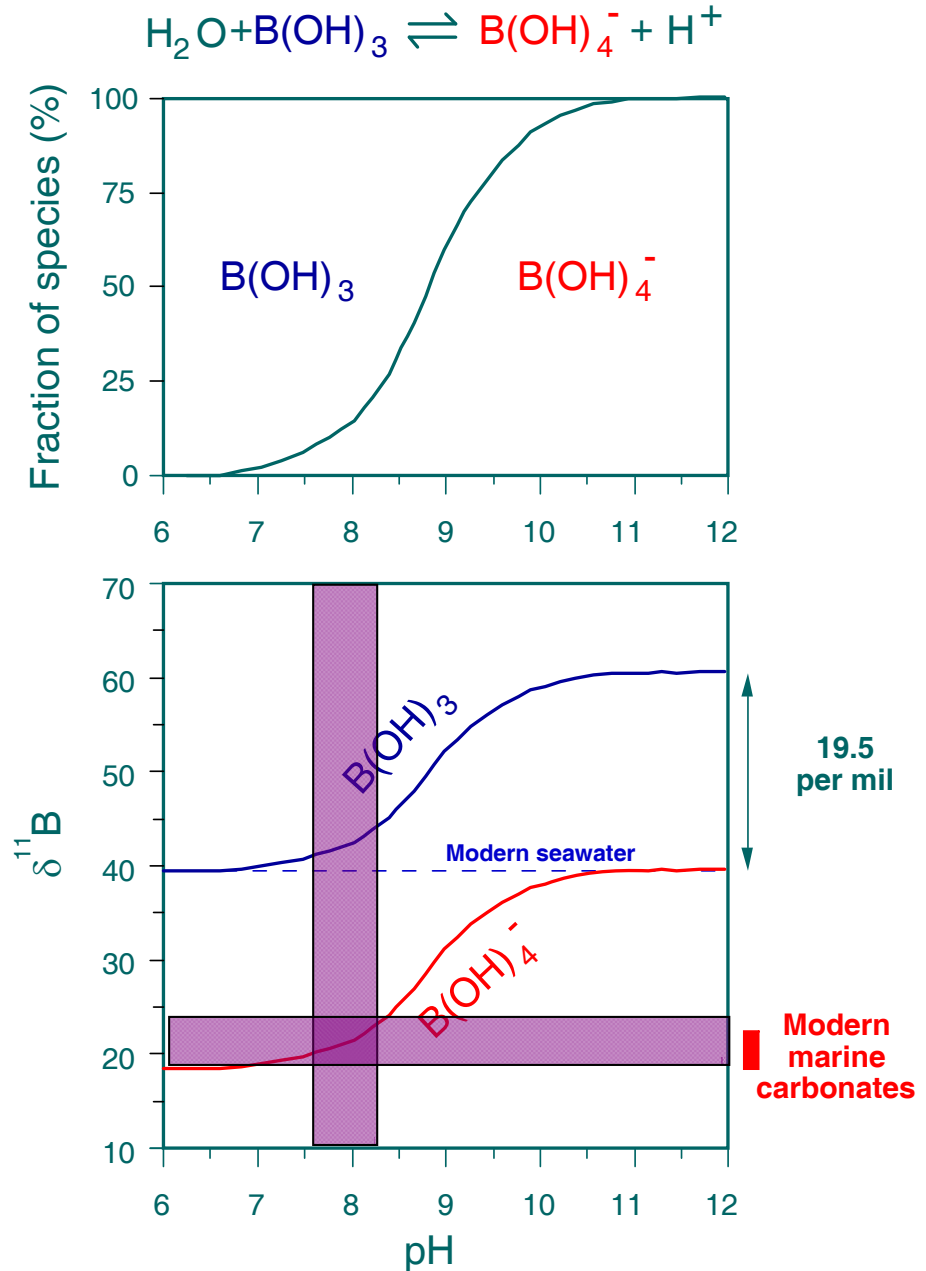
- Novel quantitative constraints on surface water and deep water pH (+temperature) change
 - $\delta^{11}\text{B}$ and B/Ca (Mg/Ca, Li/Ca) in planktic and benthic foraminifera
 - Excellently preserved material from Tanzania, Bass River plus (I)ODP sites
- Determine the biotic response (calcifying nanno- and micro-plankton) to these ancient OA events
 - Turnover, species composition, tropical exclusion and migration, abundance, weight/size
 - Range in magnitude and rate of OA events - thresholds



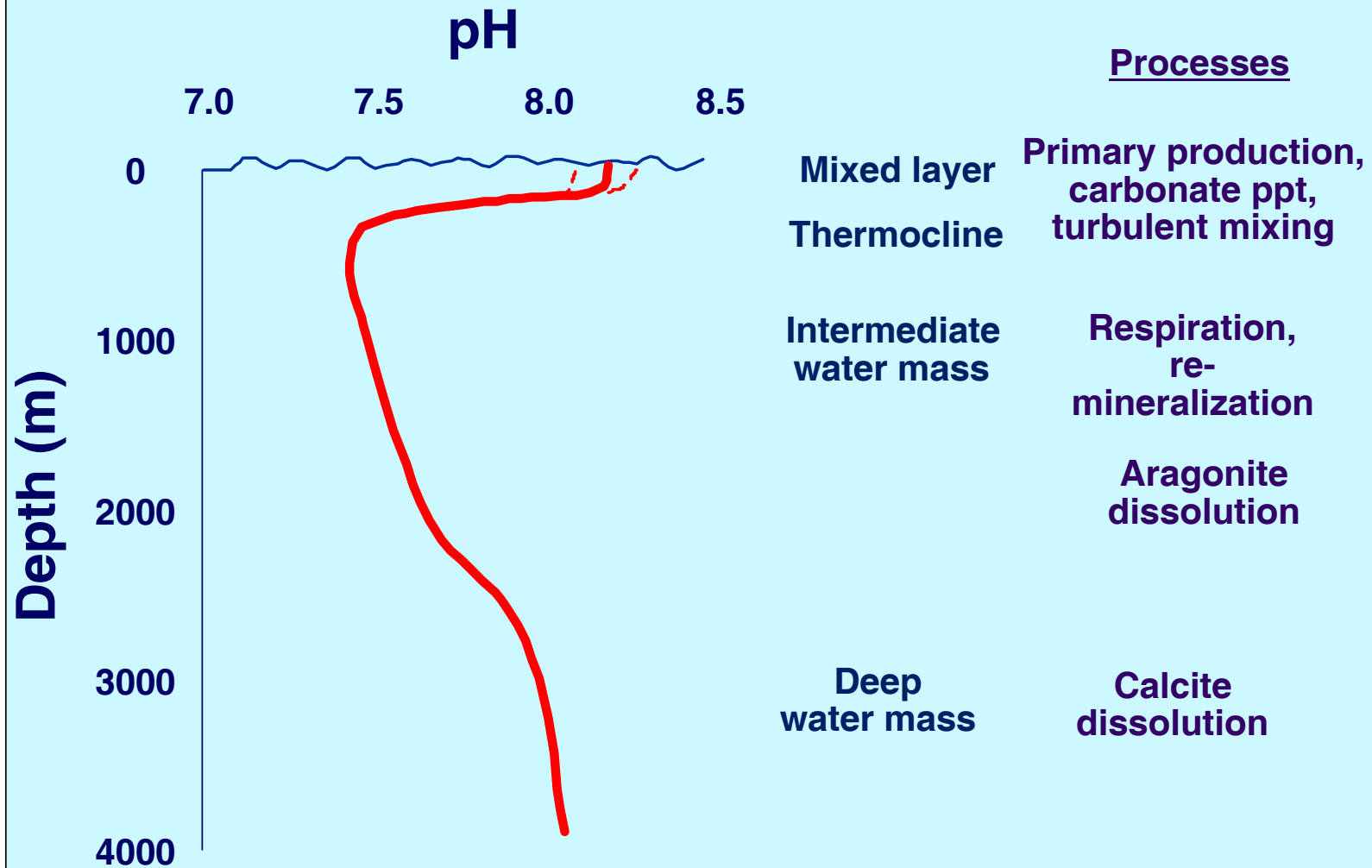
Water column profiling (biotic & chemical)

Boron isotopes
Seawater $\delta^{11}\text{B}$
= +39.5‰

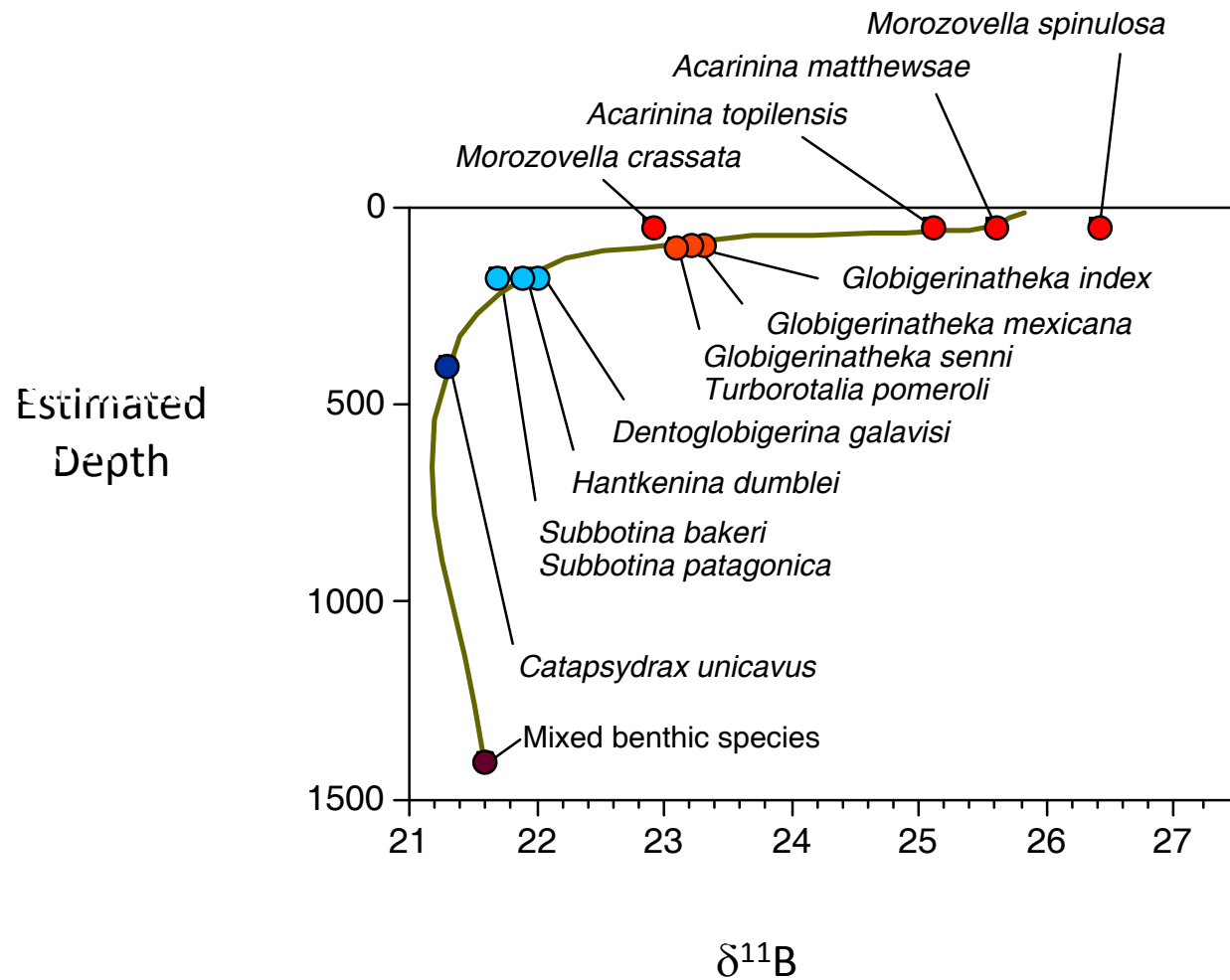
Residence time
~ 15 m.yr.



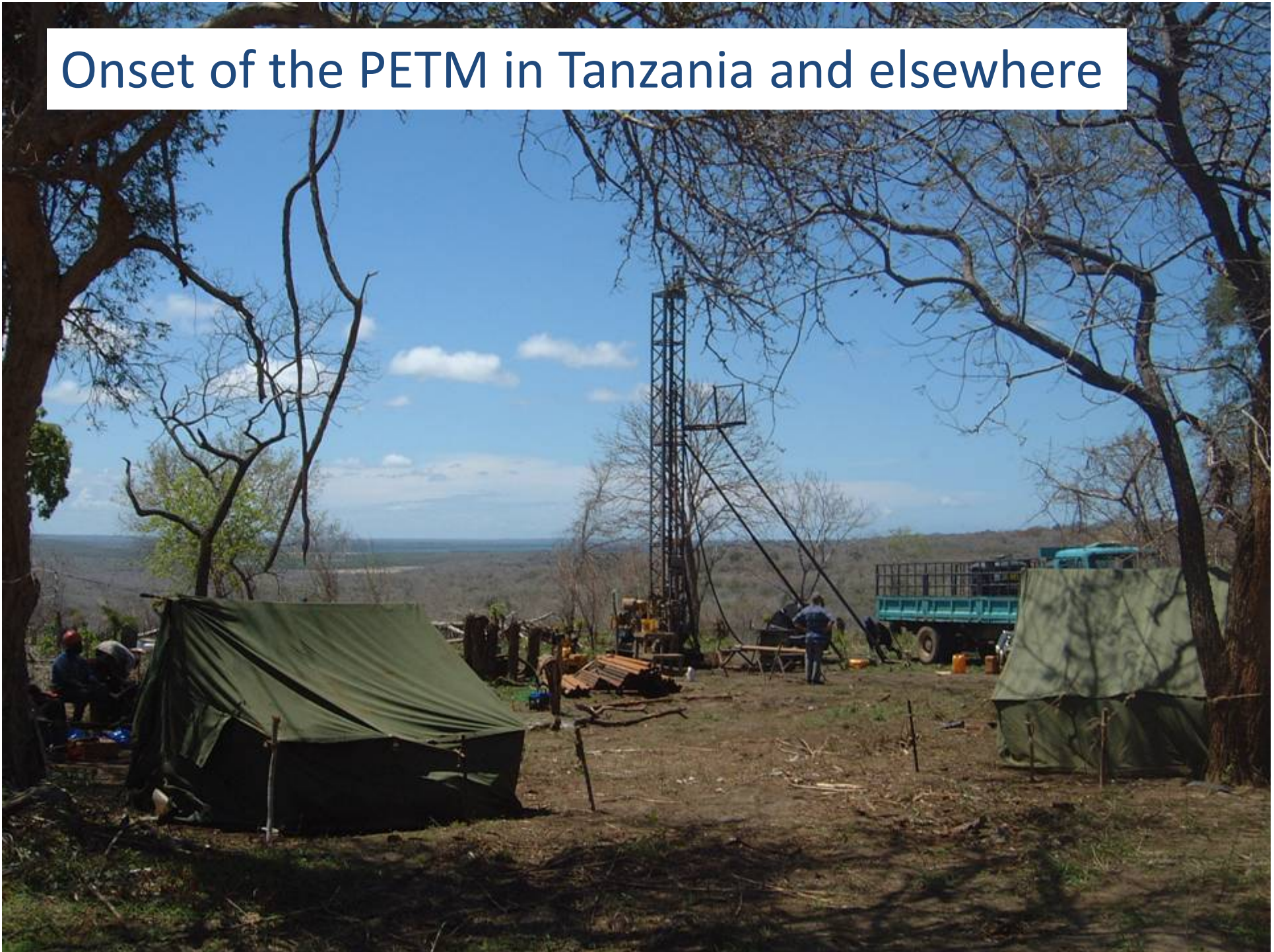
Schematic pH profile in the ocean



Middle Eocene $\delta^{11}\text{B}$ vs. relative depth



Onset of the PETM in Tanzania and elsewhere



Hole TDP 14A:

Above CCD, thick, excellent carbonate preservation



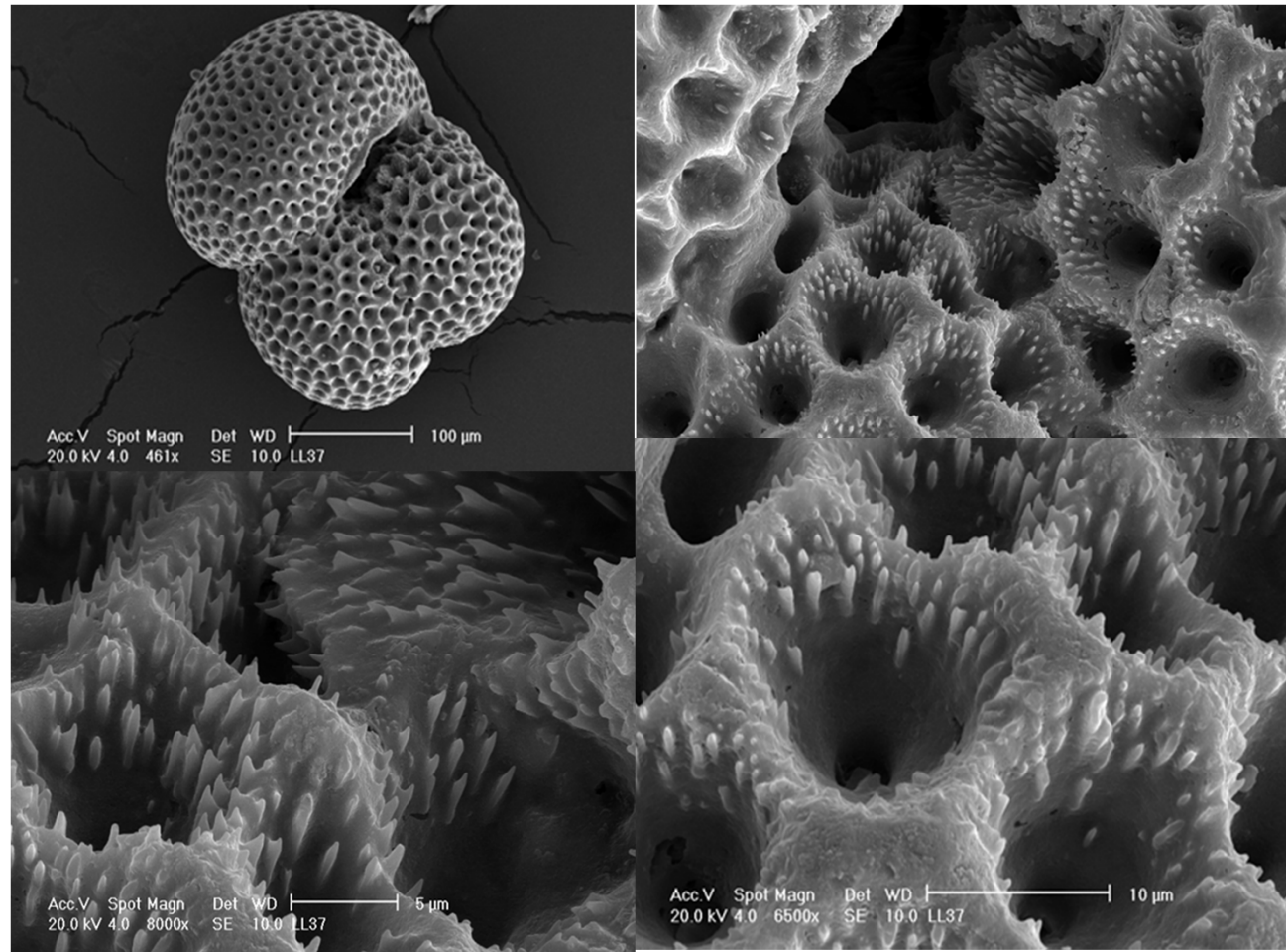
~500m water depth

Tanzania Drilling Project

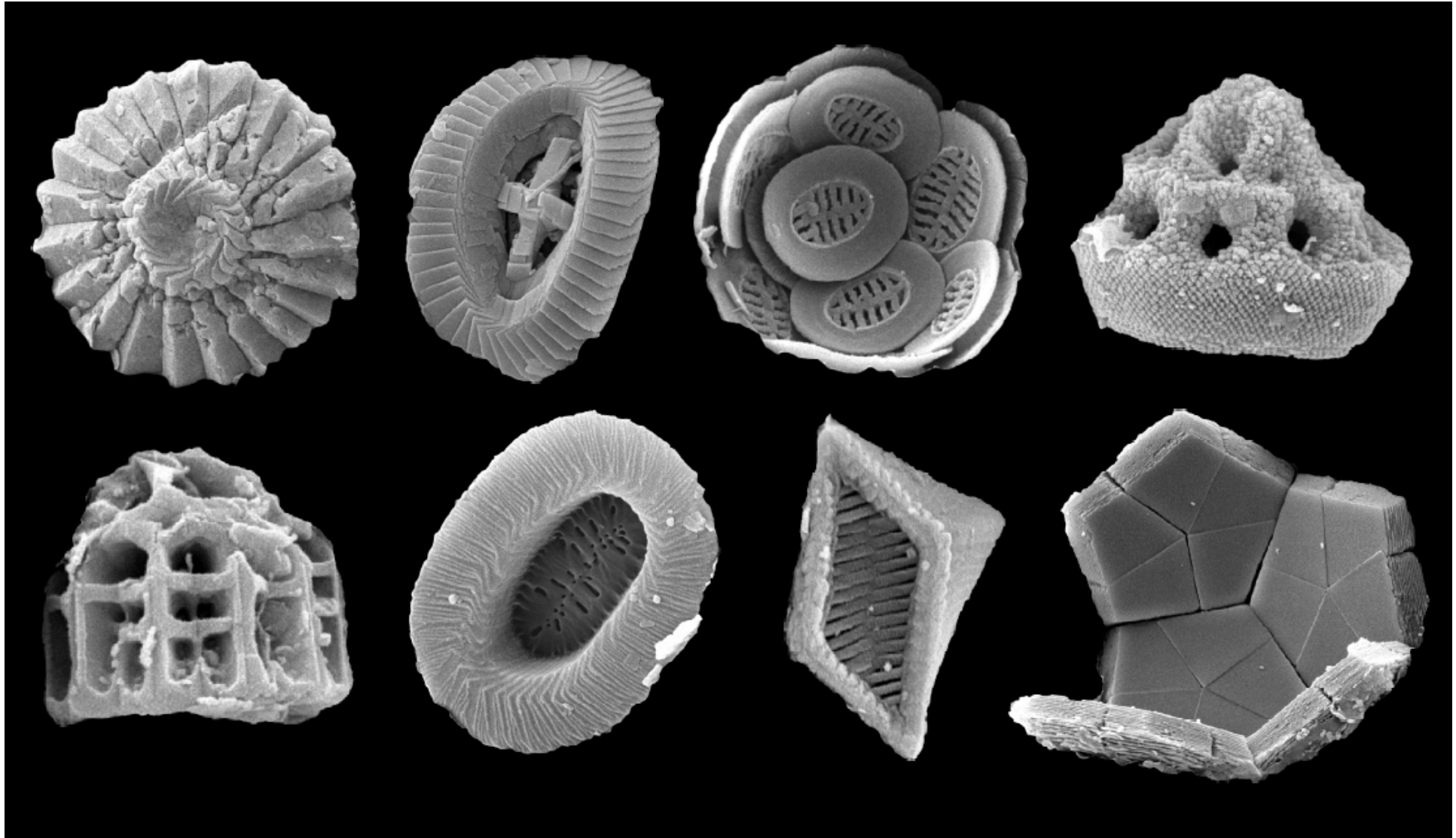
The TDP cores provide exceptionally well preserved micro- and nannofossils for geochemical analysis

The PETM section is clay rich and highly expanded
~20m

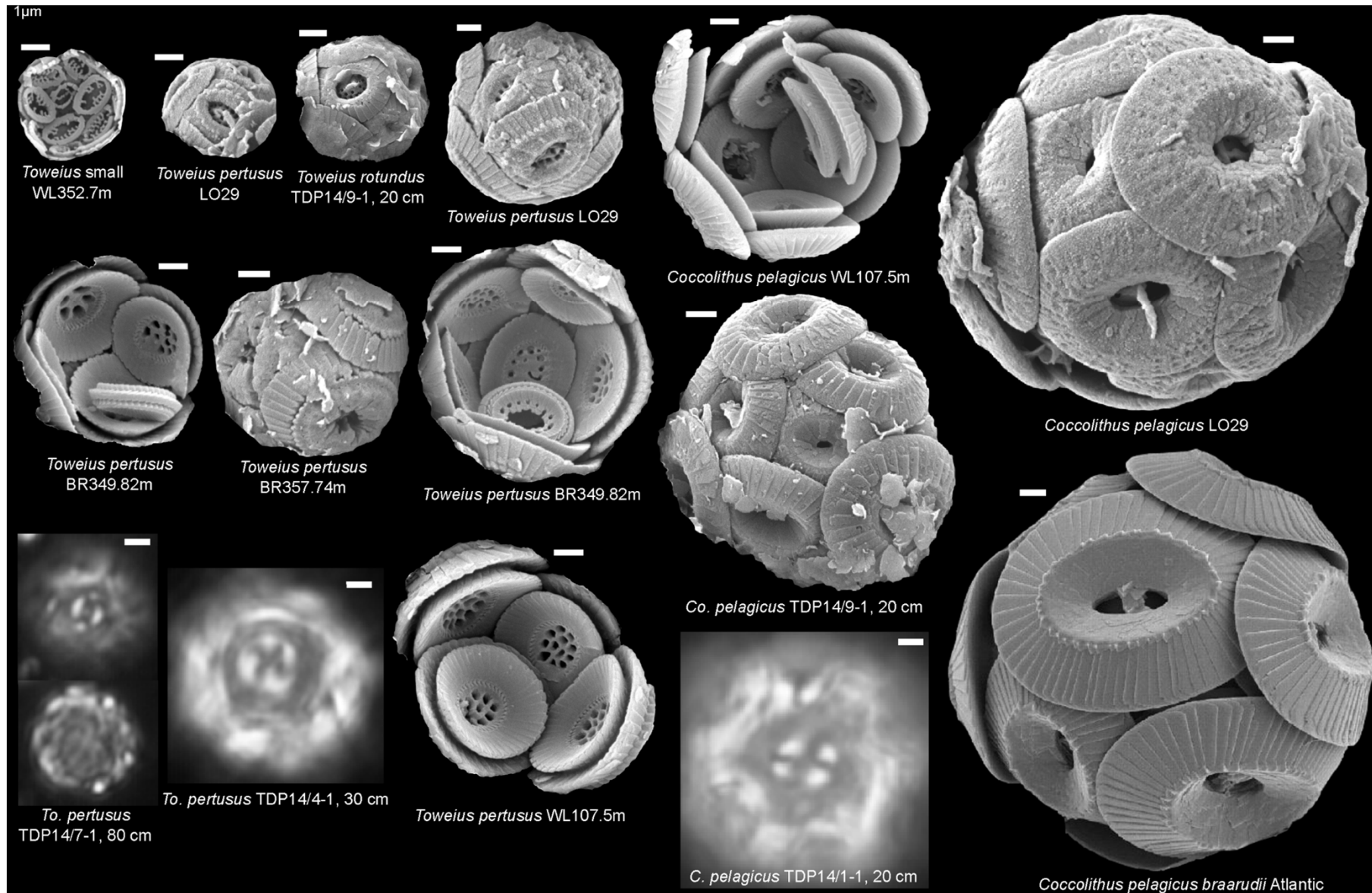
Subbotina velascoensis, SEM images illustrate primary biogenic calcite structures



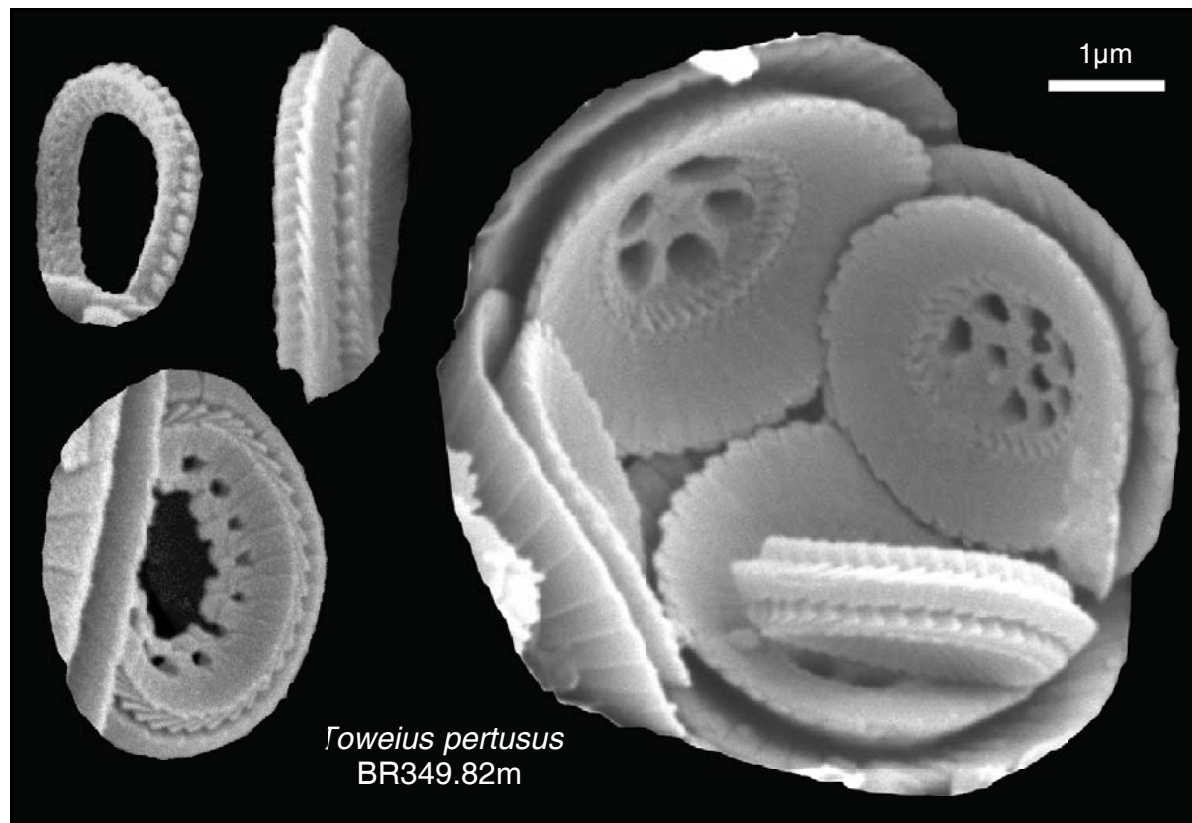
PETM nannofossils (Paul Bown)



PETM coccosphere types: Bass River NJ, Tanzania (see posters by Sam Gibbs and Sarah O'Dea)

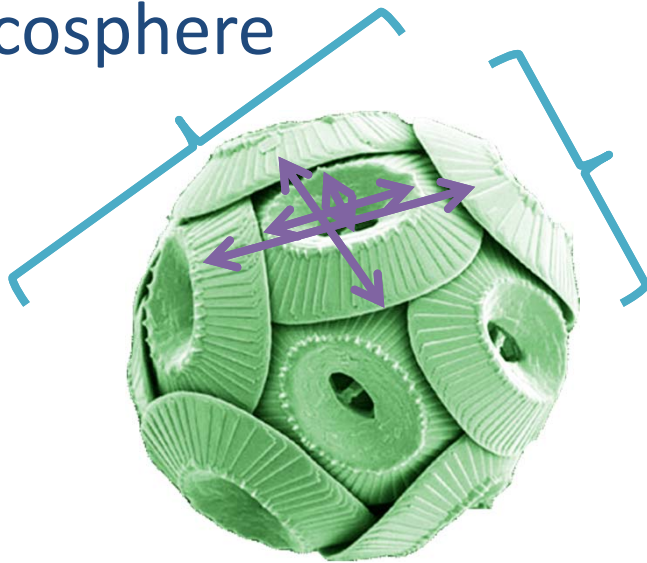


- Protococcolith rings – ontogenetic sequence
- No malformation of cell covering or disruption at the intracellular site of biomineralisation

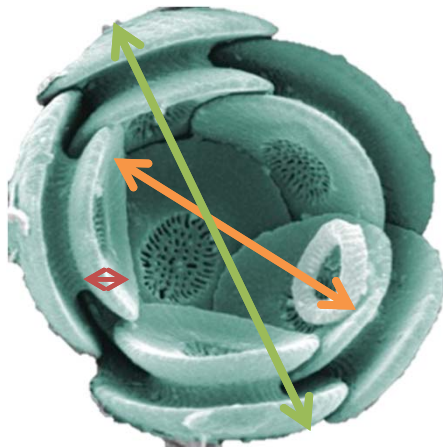


Coccosphere biometrics we can now achieve (meaningful cellular level detail!)

Coccosphere

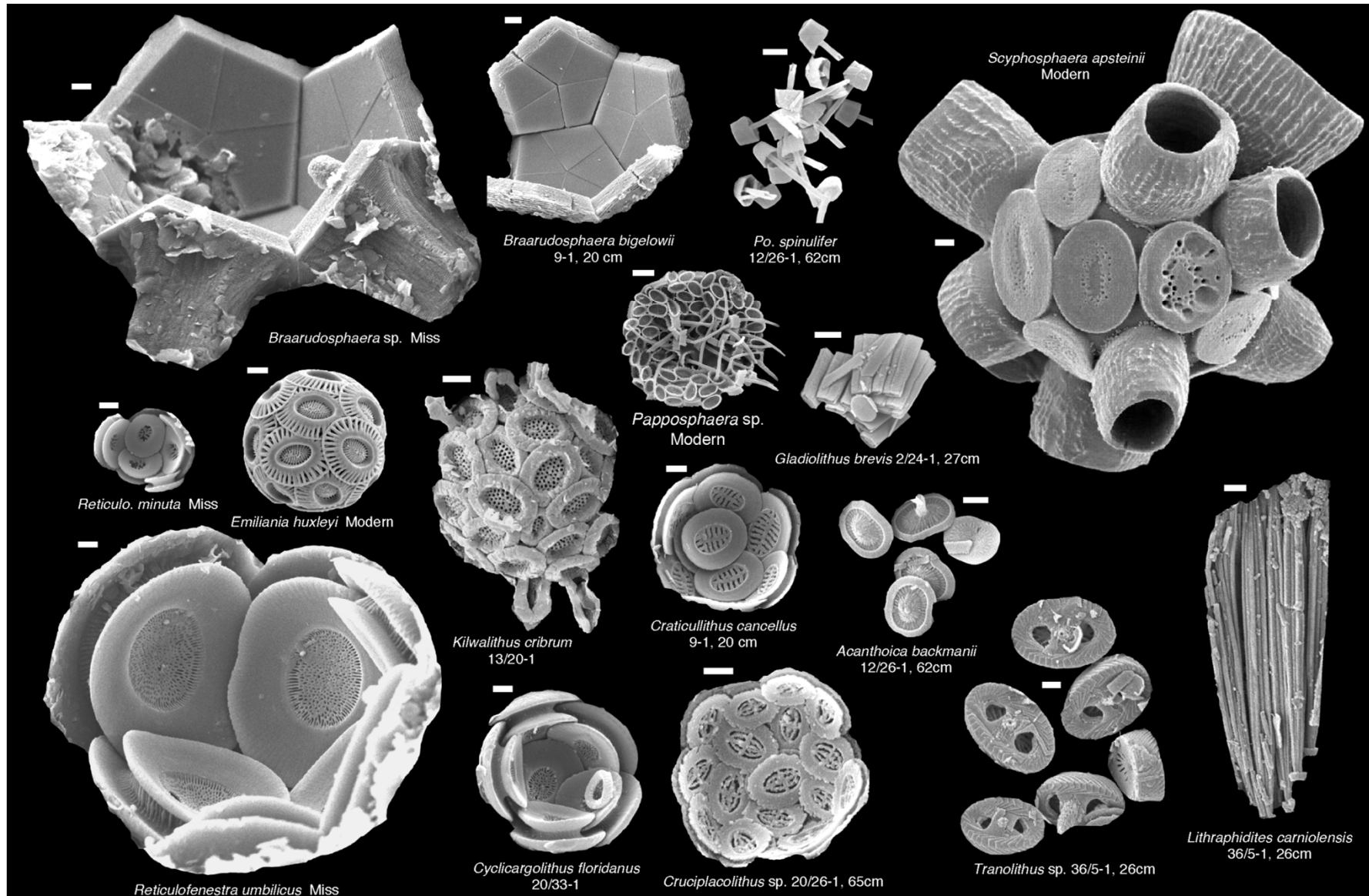


coccolith

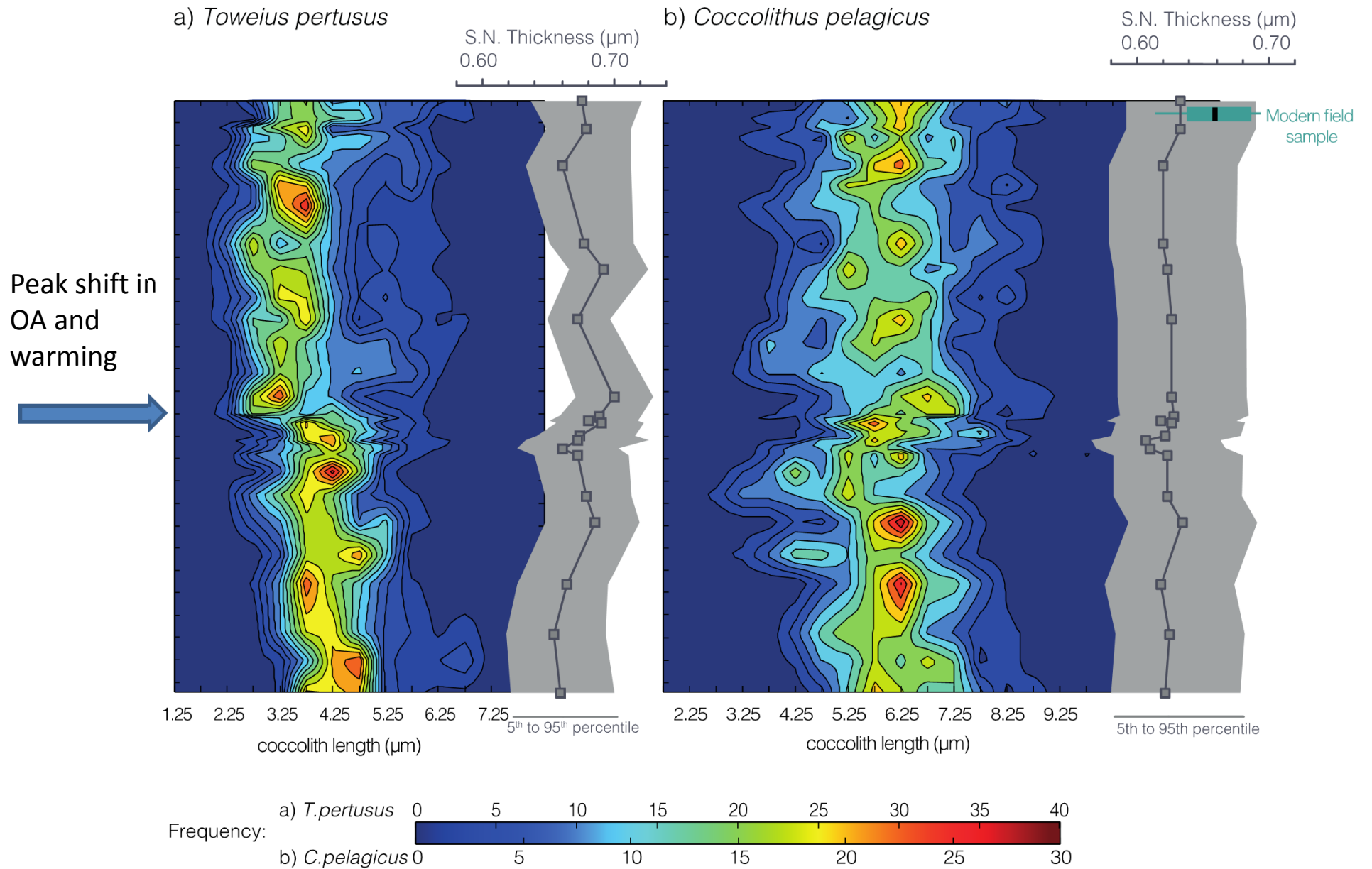


- Cell diameter
- Coccosphere diameter
- Number of coccoliths
- (Partial) proximal shield thickness
- Coccolith length and widths

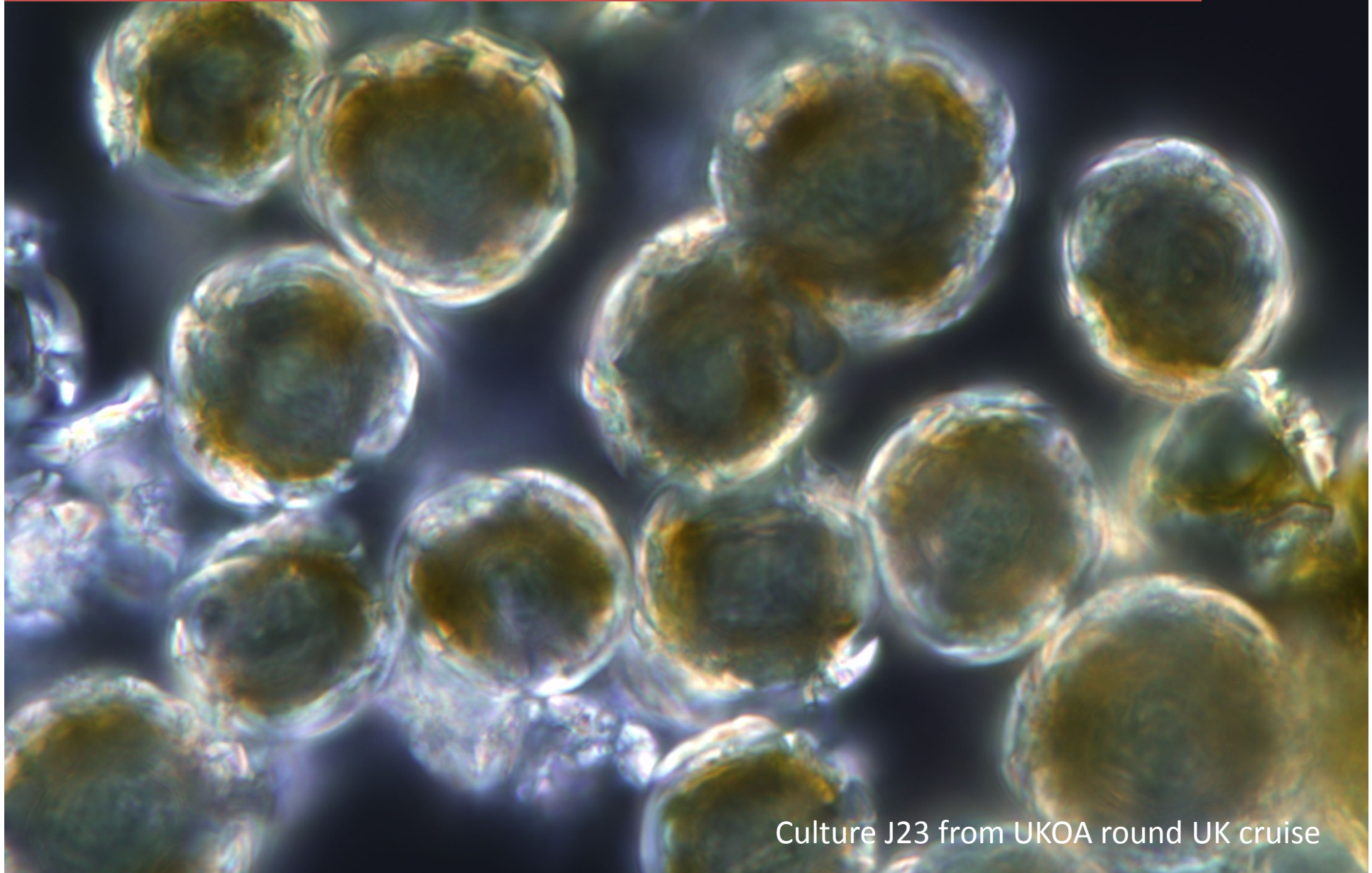
Coccosphere types – comparison of fossil and modern



- Coccolith size frequency (Bass River New Jersey)
- Size normalised coccolith thickness



Questions from fossil record have required re-examination of the modern (Sam Gibbs and others) – collaboration with the surface water consortium (new AV award)

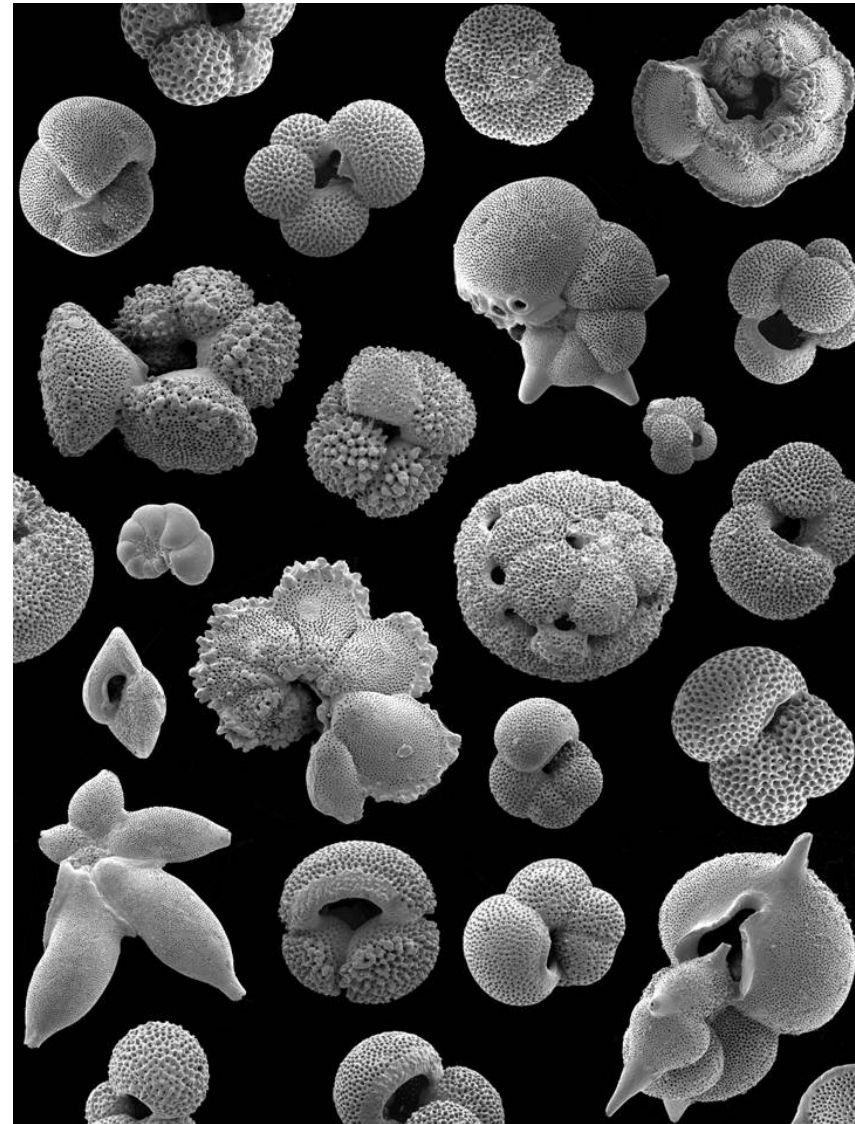


Culture J23 from UKOA round UK cruise

Other progress

The project is in the data gathering stage and all results are preliminary

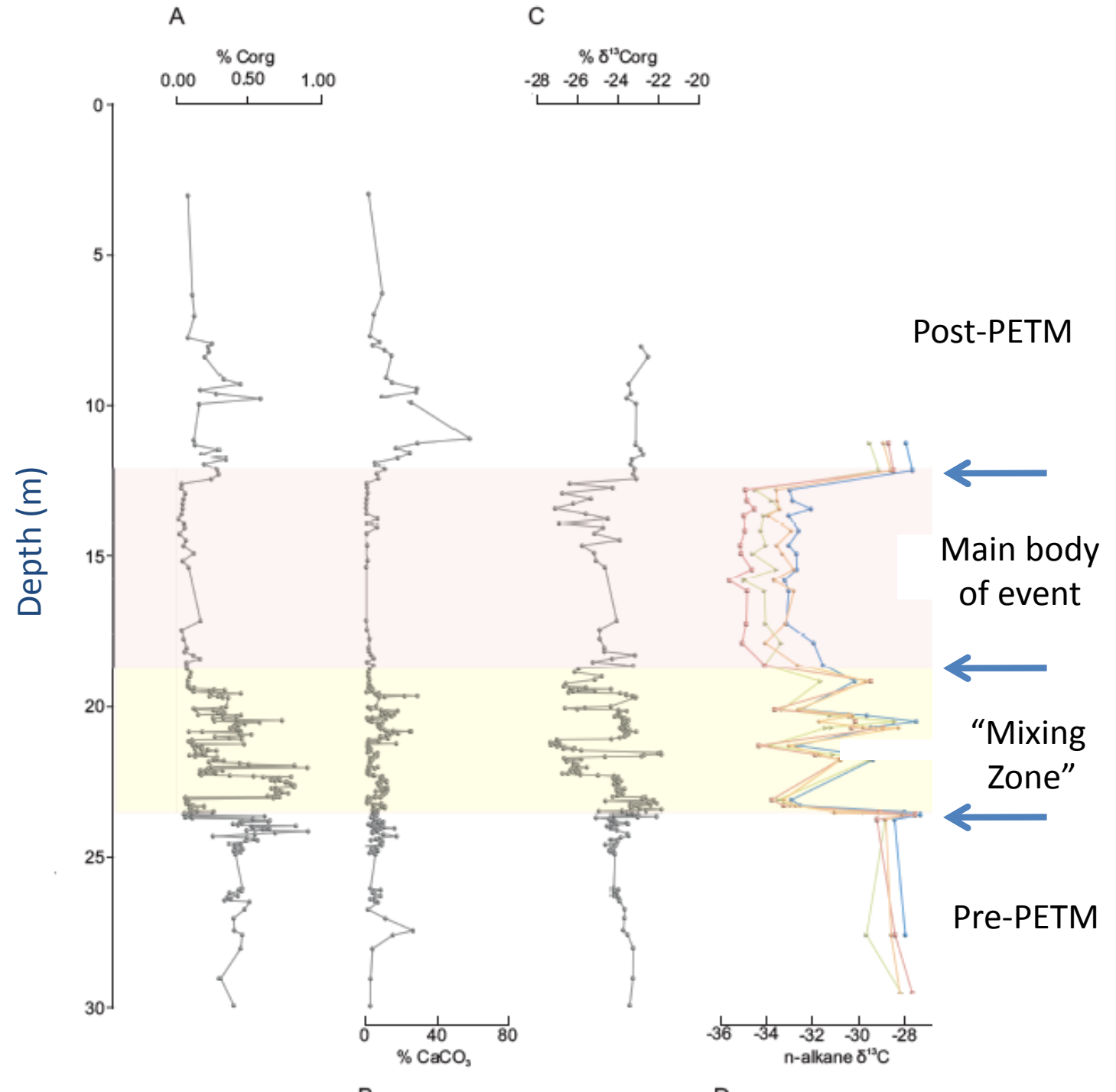
- Tanzania bulk geochemical analyses conducted
- Detailed assemblage counts of ~450 samples is under way
- NERC Isotope Geoscience Support grant for analytical work at NIGL has been funded, single specimen C & O isotope analysis is in progress
- Selected planktonic foraminifera have been imaged using X-ray tomography (Laura Foster, Bristol)



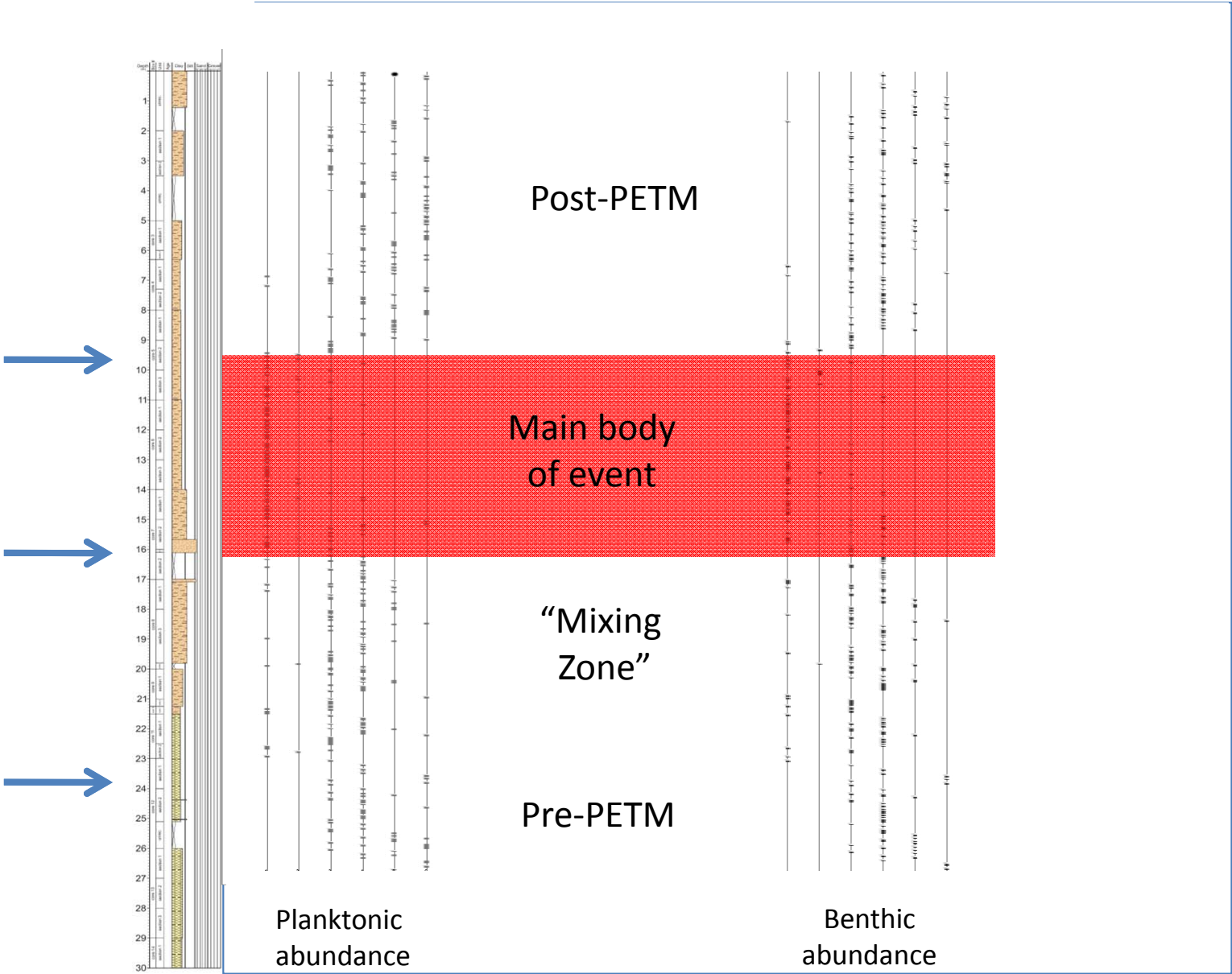
Eocene planktonic foraminifera
(~55-34 million years old)

Tanzania complexities:

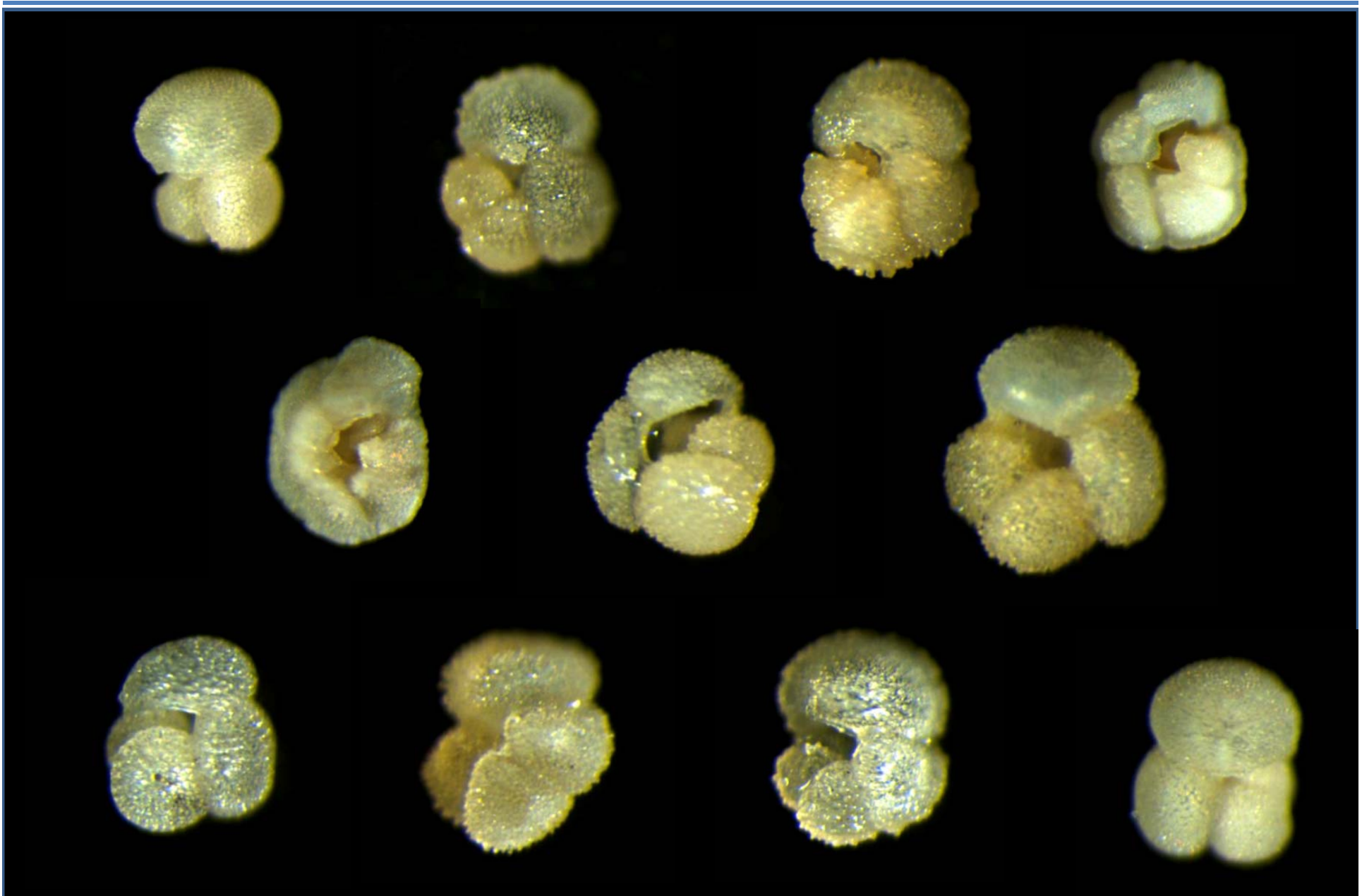
Bulk rock
Chemistry
(Alex Dickson)
and n-alkane
carbon isotopes
(Pancost lab)



Preliminary biostratigraphy (Tracy Aze)



Single specimen isotope analyses



Preliminary results:

PETM and reworked specimens distinguished

Carbon isotope excursion large (possibly x2 recrystallized deep ocean records)

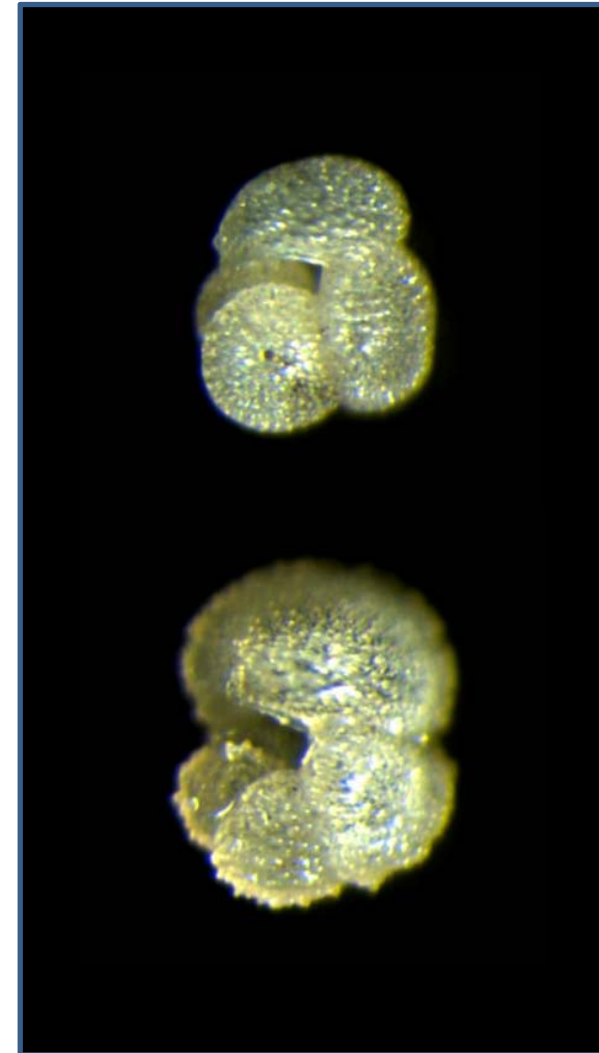
Onset abrupt (needs further study)

Foraminifera often totally absent in event or deformed

SST before event ~ 31.0 °C

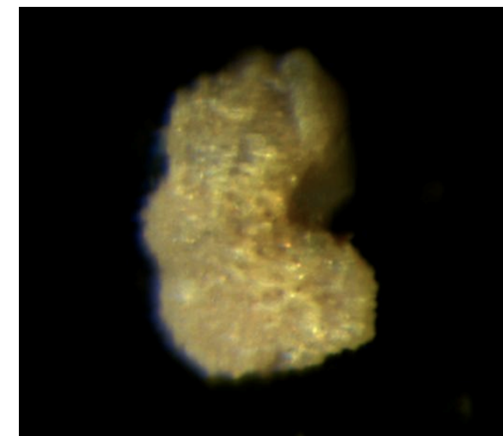
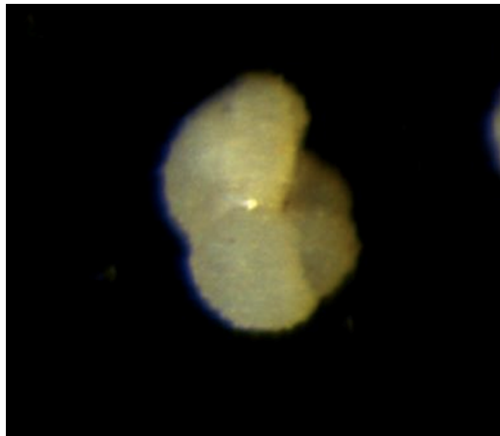
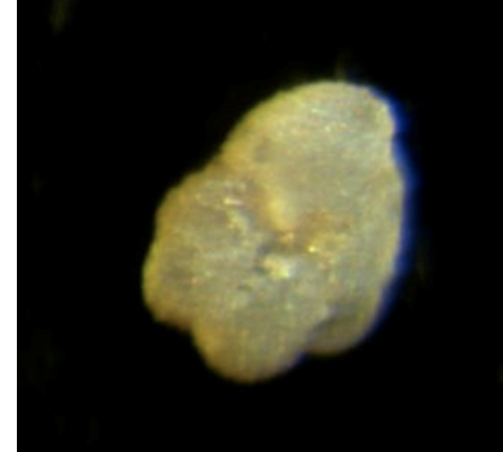
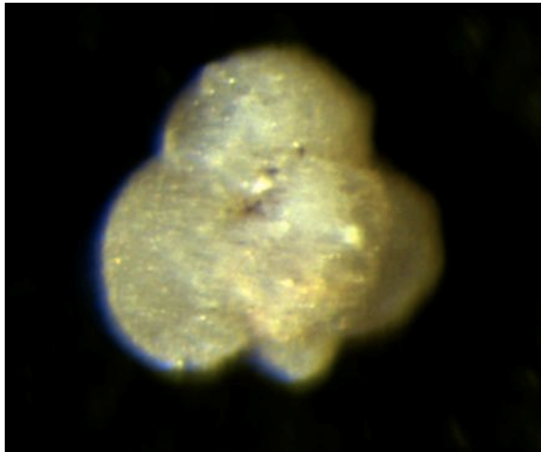
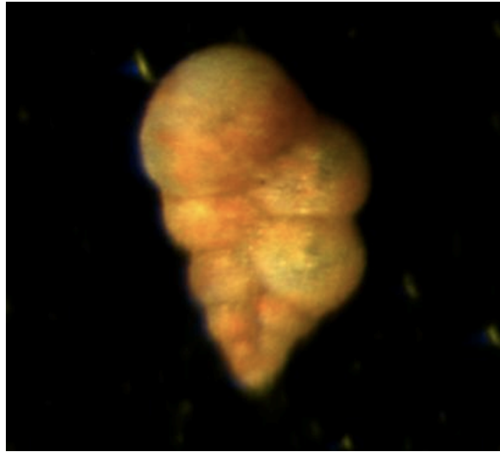
SST in event ~ 37.4 °C

pH??



Teratoid planktonic foraminifera

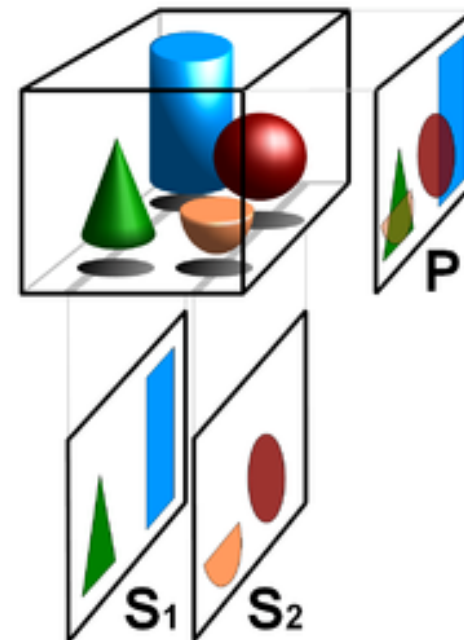
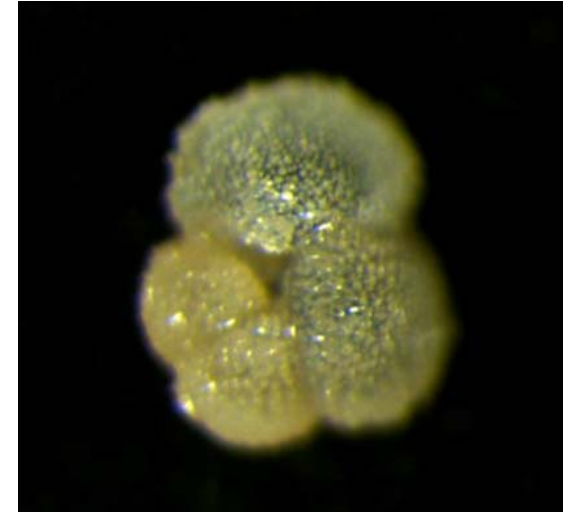
Examples of teratoid “deformed” planktonic foraminifera from the onset of the PETM, currently under detailed investigation.



X-ray tomography

Laura Foster @ Bristol University
Morozovella aequa
Before, during and after the CIE

- Calcification changes across the boundary
- Aid understanding of the muricate calcification process



Watch this space....

To do:

Complete assemblage counts

*Boron isotope analysis – pH record /
depth reconstructions*

Repeat for other hyperthermals

Thresholds?

*Comparisons with modern, pre-industrial and
glacial*

Caveats:

Small number of events, each of which is unique

*Temperature, nutrients, food supply, stratification,
ocean circulation*

The Geological Record of Ocean Acidification

Bärbel Hönisch,^{1*} Andy Ridgwell,² Daniela N. Schmidt,³ Ellen Thomas,^{4,5} Samantha J. Gibbs,⁶ Appy Sluijs,⁷ Richard Zeebe,⁸ Lee Kump,⁹ Rowan C. Martindale,¹⁰ Sarah E. Greene,^{2,10} Wolfgang Kiessling,¹¹ Justin Ries,¹² James C. Zachos,¹³ Dana L. Royer,⁵ Stephen Barker,¹⁴ Thomas M. Marchitto Jr.,¹⁵ Ryan Moyer,¹⁶ Carles Pelejero,¹⁷ Patrizia Ziveri,^{18,19} Gavin L. Foster,⁶ Branwen Williams²⁰

Ocean acidification may have severe consequences for marine ecosystems; however, assessing its future impact is difficult because laboratory experiments and field observations are limited by their reduced ecologic complexity and sample period, respectively. In contrast, the geological record contains long-term evidence for a variety of global environmental perturbations, including ocean acidification plus their associated biotic responses. We review events exhibiting evidence for elevated atmospheric CO₂, global warming, and ocean acidification over the past ~300 million years of Earth's history, some with contemporaneous extinction or evolutionary turnover among marine calcifiers. Although similarities exist, no past event perfectly parallels future projections in terms of disrupting the balance of ocean carbonate chemistry—a consequence of the unprecedented rapidity of CO₂ release currently taking place.

Science v. 335, p. 1058-1063



RANKING MEMBERS WAXMAN AND RUSH CALL FOR HEARING ON CARBON DIOXIDE EMISSIONS' EFFECTS ON OCEANS



Mar 21, 2012

Today Energy and Commerce Committee Ranking Member Henry A. Waxman and Energy and Power Subcommittee Ranking Member Bobby L. Rush sent a letter to Energy and Commerce Committee Chairman Fred Upton and Energy and Power Subcommittee Chairman Ed Whitfield urging them to hold a hearing on the rapid acidifying of oceans due to rising emissions of carbon dioxide. Studies from Columbia University, the University of Bristol, and others concluded that, due to carbon dioxide emissions, ocean acidification is occurring much faster than at any other point in Earth's history, perhaps causing unprecedented marine ecosystem change.

The full text of the letter is below and also available online [here](#).

March 21, 2012

The Honorable Fred Upton
Chairman
Energy and Commerce Committee
U.S. House of Representatives
2125 Rayburn House Office Building
Washington, D.C. 20515

The Honorable Ed Whitfield
Chairman

RECENT NEWS

[Ranking Members Waxman and Rush Call for Hearing on Role of Global Climate Change in March Heat Wave](#)
04/12/2012

[Energy and Commerce and Natural Resources Committee Ranking Members Urge the Department of Interior to Issue New Regulations on Pollution From Offshore Drilling in Alaska](#)
04/11/2012

[Rep. Waxman Statement on the WTO Ruling on Clove Cigarettes](#)
04/04/2012

[Ranking Members Waxman and DeGette Urge EPA to Review Study of Health Threats from Gas Drilling Operations](#)
04/03/2012

[Ranking Members Waxman and](#)



Science Museum, new permanent exhibit 2011- updateabl