

The geological record of ocean acidification

Bärbel Hönisch

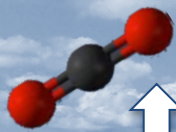
hoenisch@ldeo.columbia.edu

Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

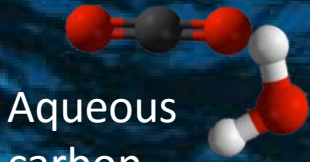
PAOGES
PAST GLOBAL CHANGES

Paleo-Ocean Acidification WG

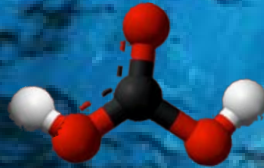




Atmospheric
carbon dioxide



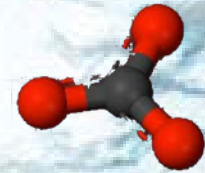
Aqueous
carbon
dioxide



Carbonic acid



Bicarbonate ion



Carbonate ion

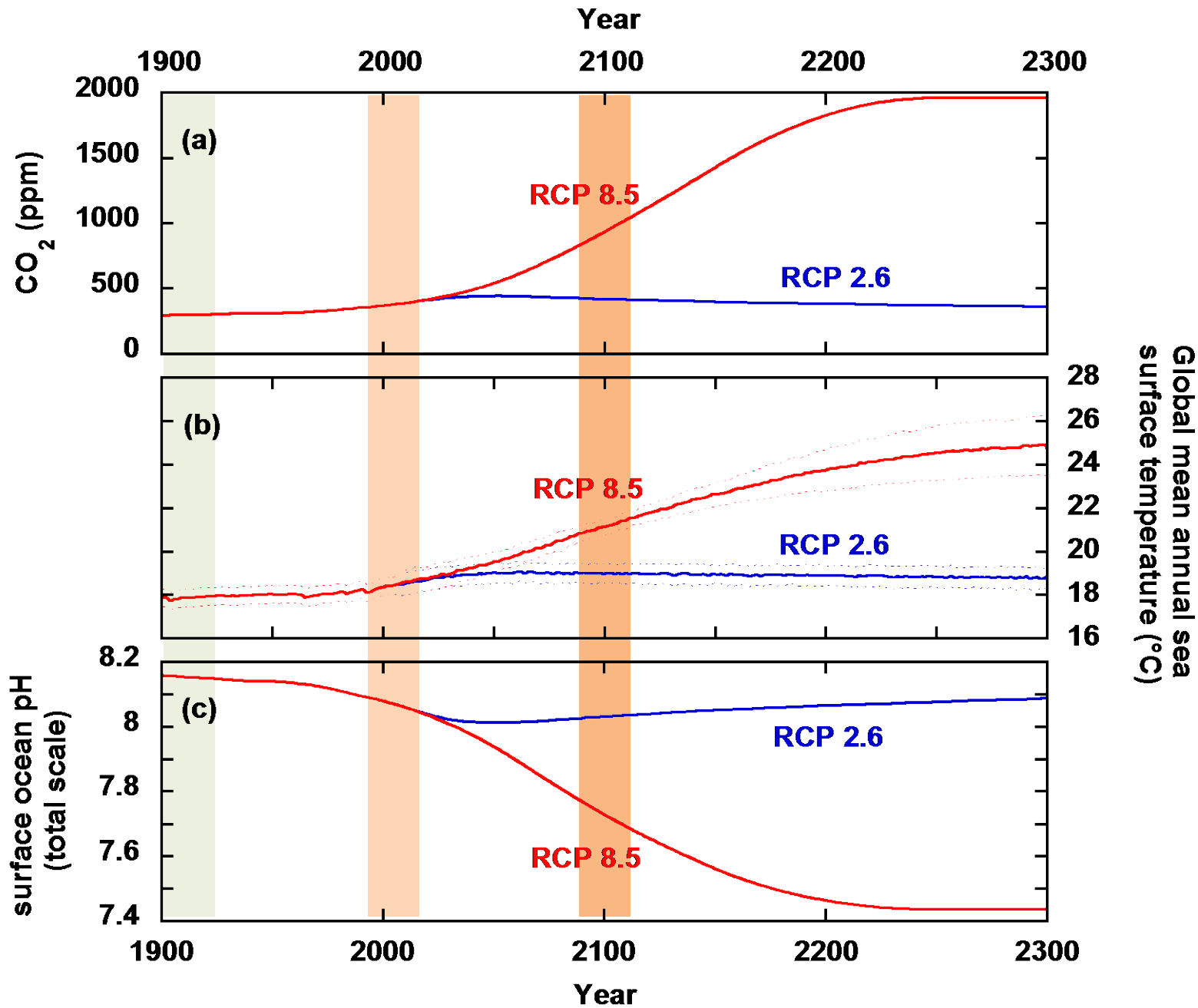


NOAA, National Geographic

More acidic

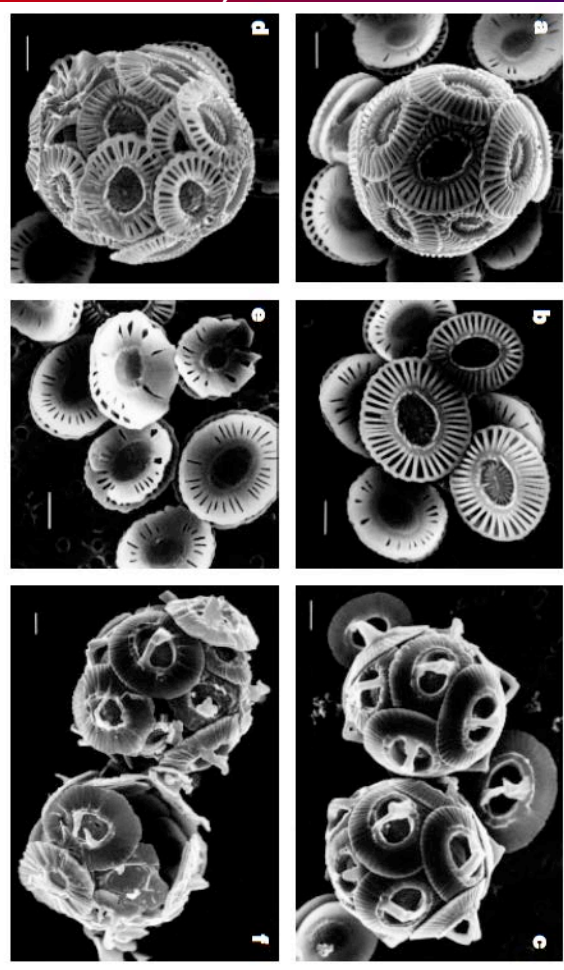


More basic





J. HALL-SPENCER



H.J. Spero



K. Fabricius



K. Fabricius

NOAA, National Geographic

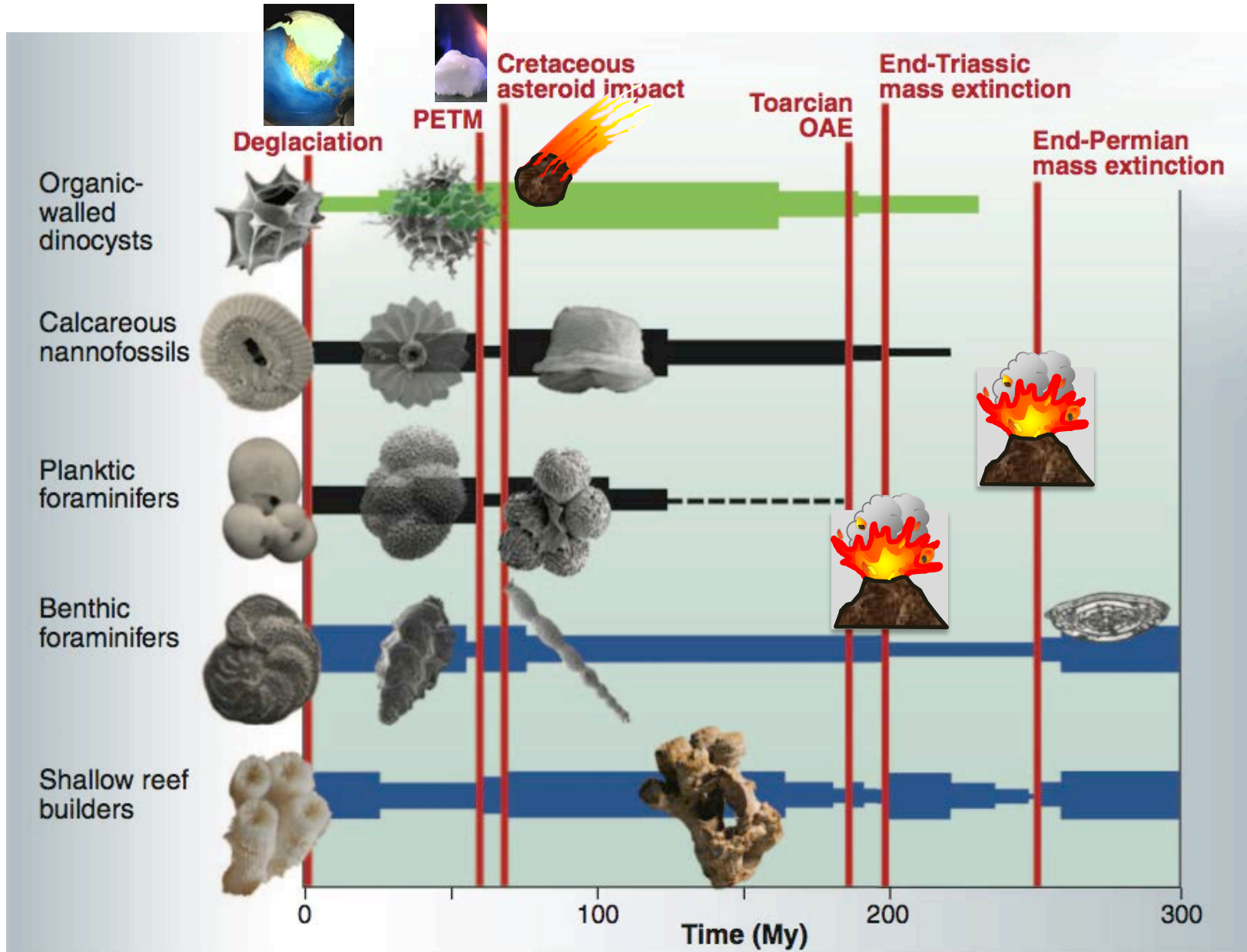


More acidic



More basic

The Geological Record of Ocean Acidification





Proxies are stand-ins for environmental parameters that can no longer be measured directly.

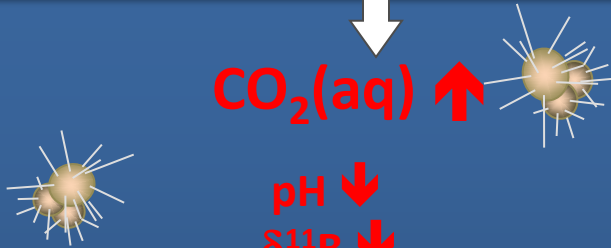


$\text{CO}_2(\text{atm}) \uparrow$



$\text{CO}_2(\text{aq}) \uparrow$

$\text{pH} \downarrow$
 $\delta^{11}\text{B} \downarrow$

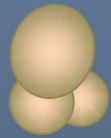
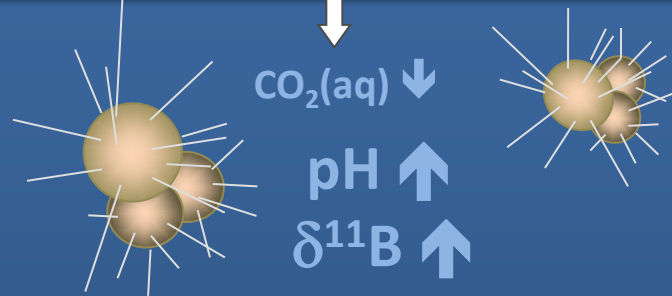


$\text{CO}_2(\text{atm}) \downarrow$



$\text{CO}_2(\text{aq}) \downarrow$

$\text{pH} \uparrow$
 $\delta^{11}\text{B} \uparrow$

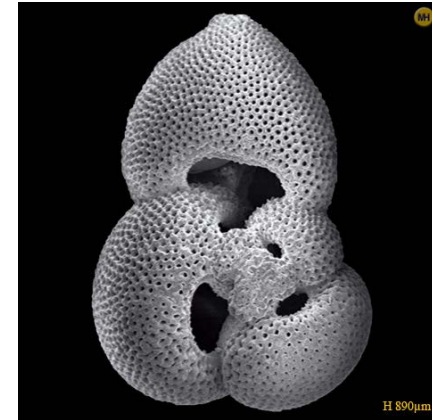
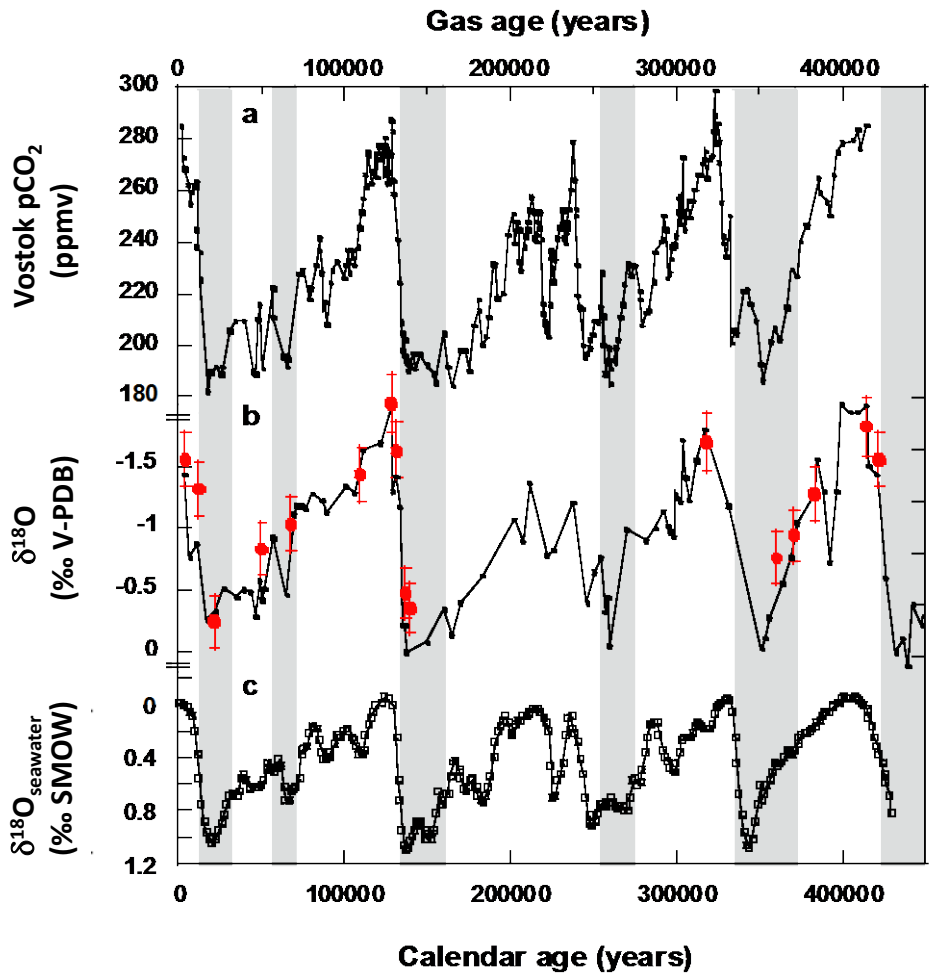
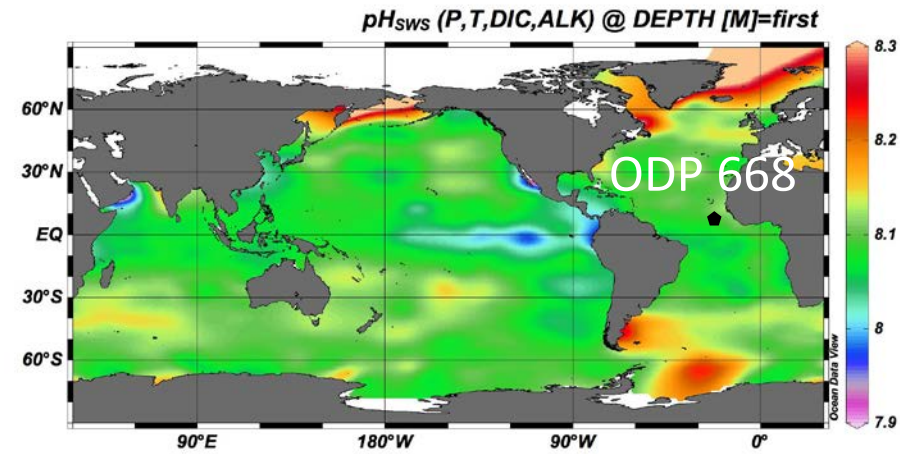


$\delta^{11}\text{B}$



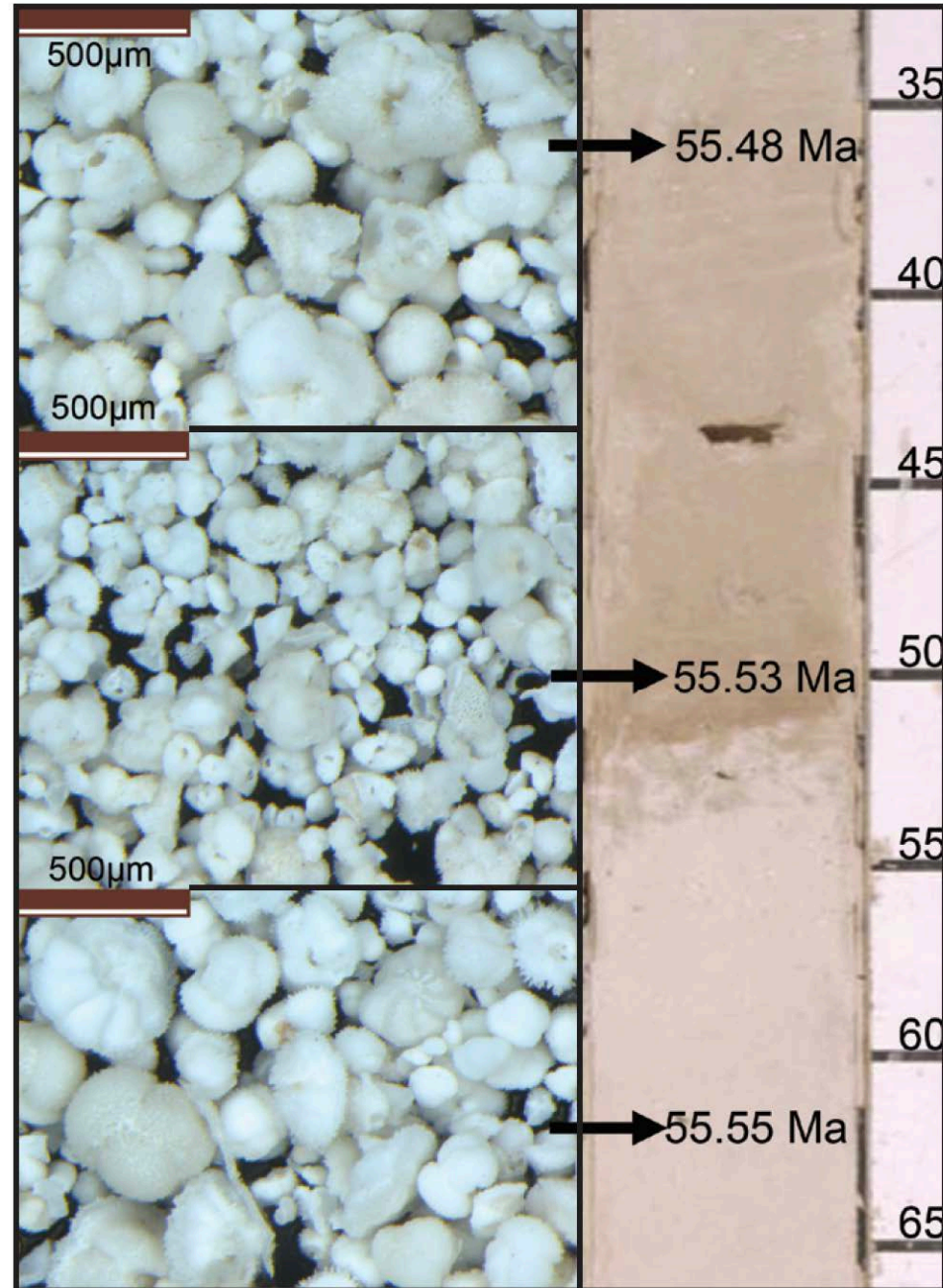
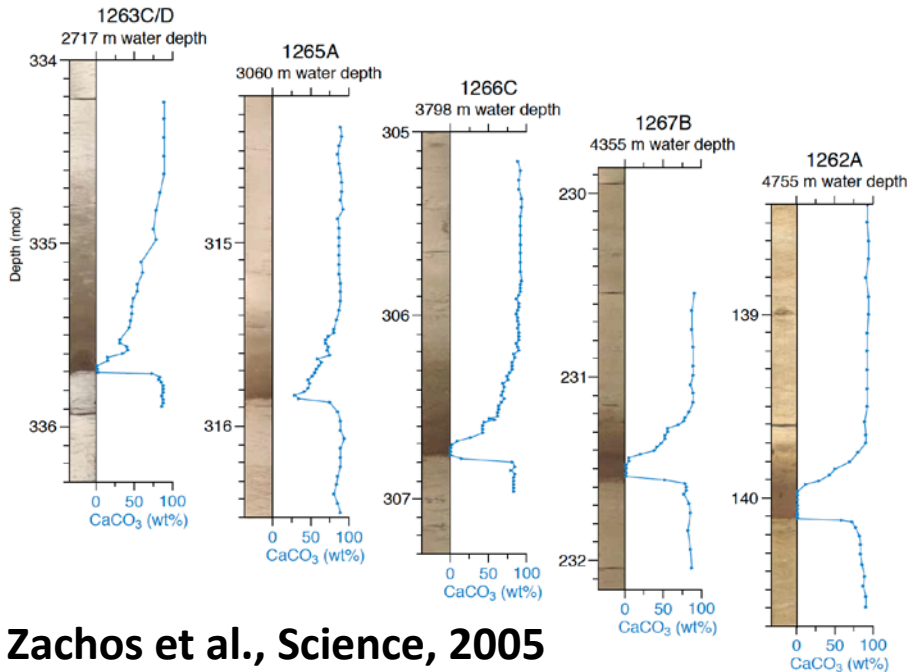
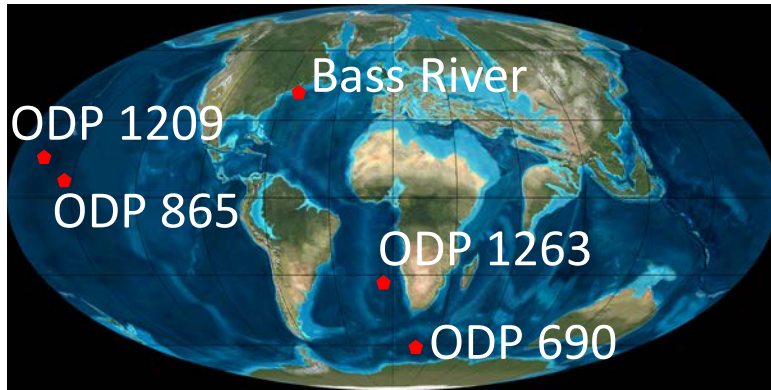
$\text{pH} + \text{pCO}_2$





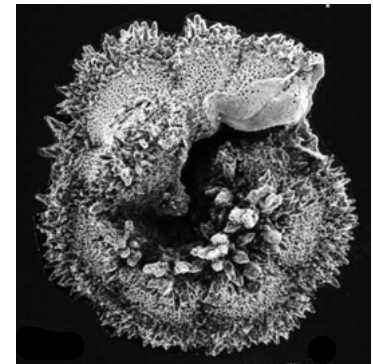
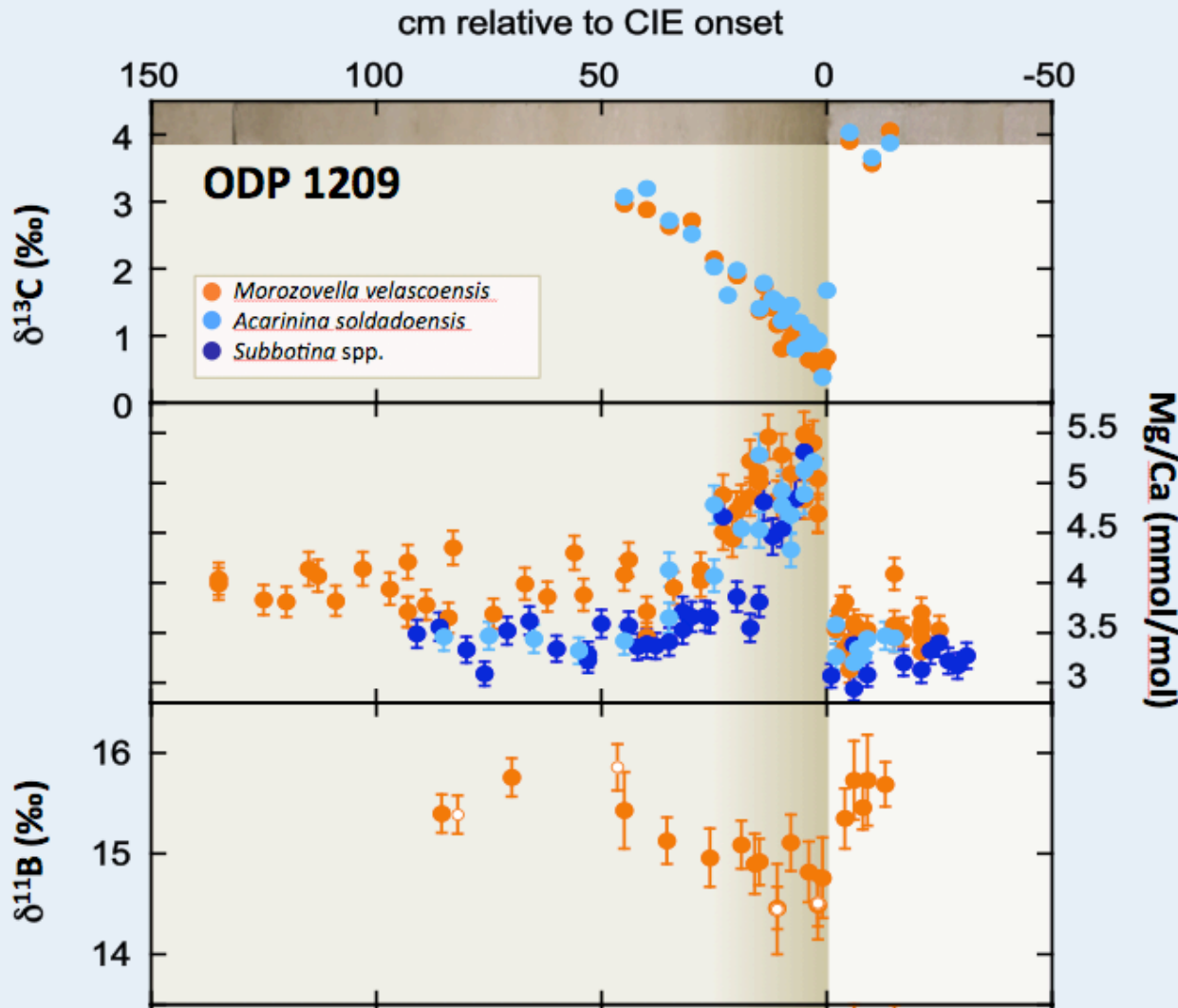
temperature: +2-3°C
 pH: -0.15 units
 Ω: -2
 calcification changes: ✓
 duration: 6.2 ky
 pH change = 0.002 units/century

CaCO₃ dissolution, dwarfism, excursion taxa and extinction at the Paleocene-Eocene Thermal Maximum (56 Ma)



photos: L. Foster

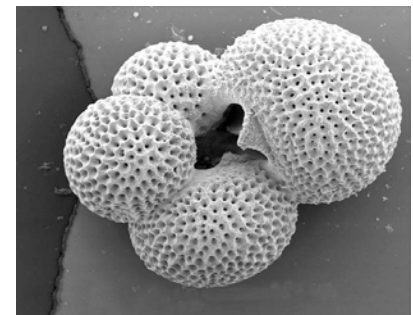
Ocean acidification at the PETM (56 million years ago)



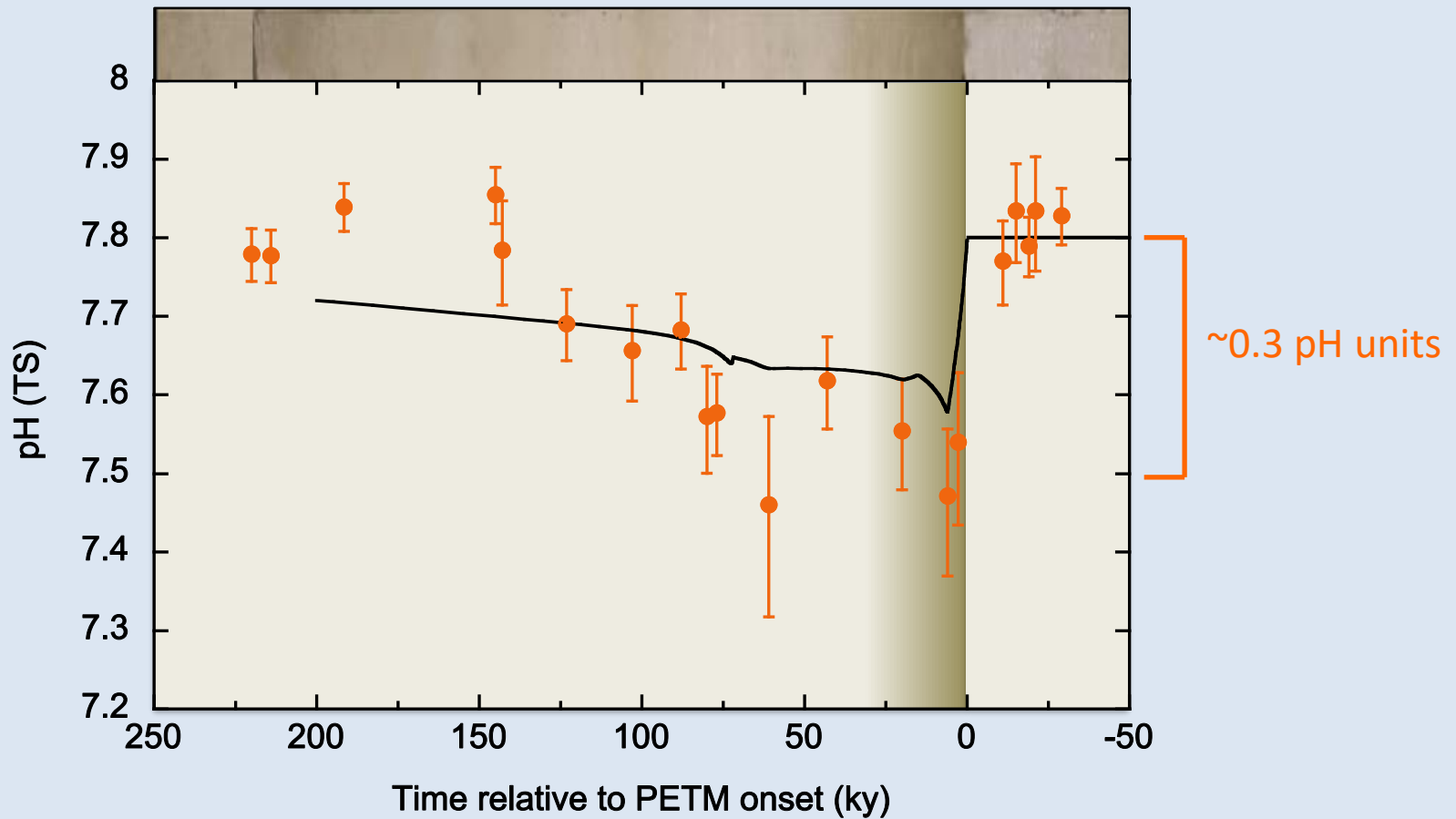
Morozovella velascoensis



Acarinina soldadoensis

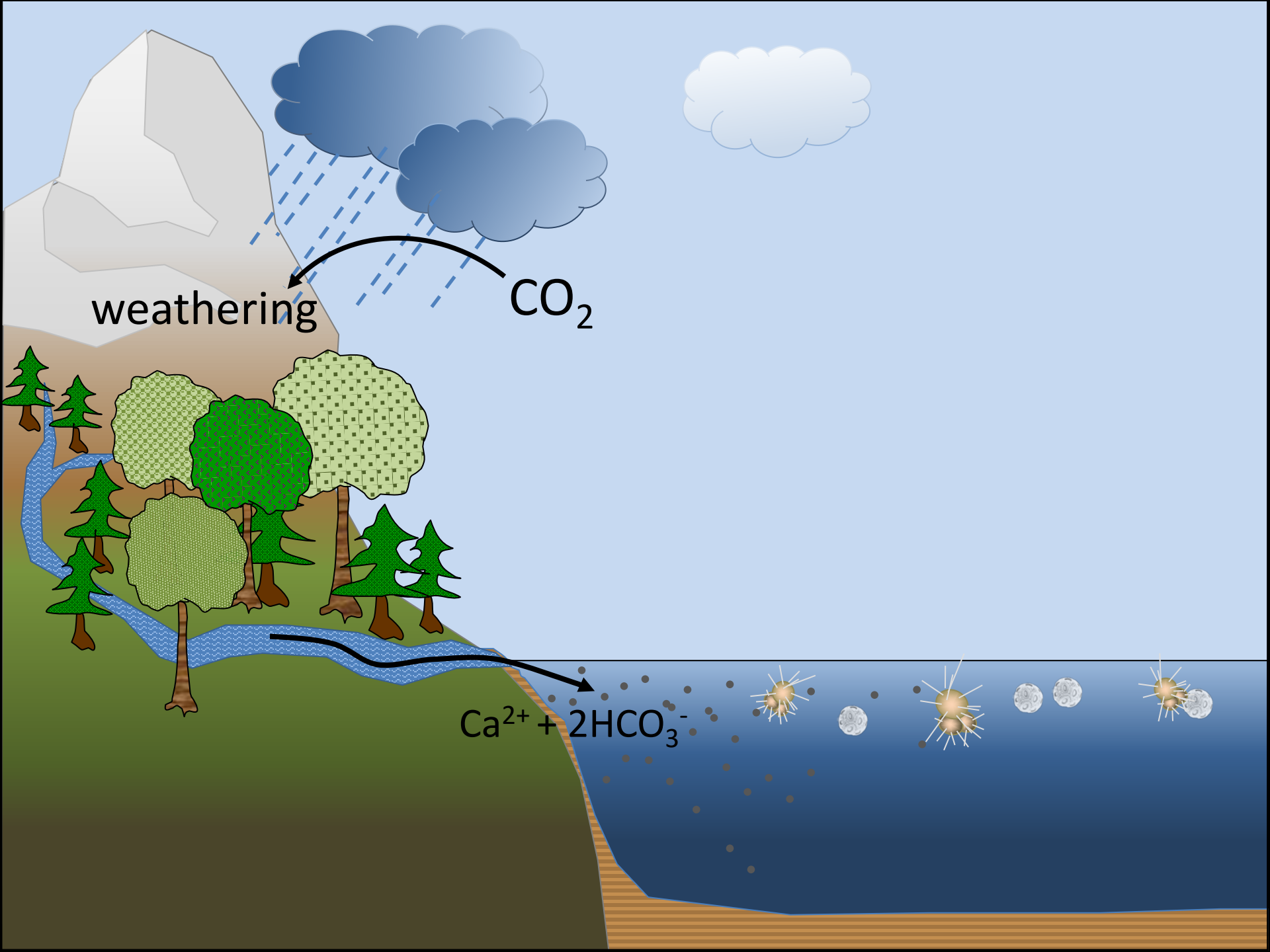


Subbotina spp.



temperature: +5-9°C
 pH: -0.3 units
 ecosystem changes: ✓
 duration: ~3,000-5,000 years
 pH change = 0.01 units/century





weathering

CO_2

$\text{Ca}^{2+} + 2\text{HCO}_3^-$

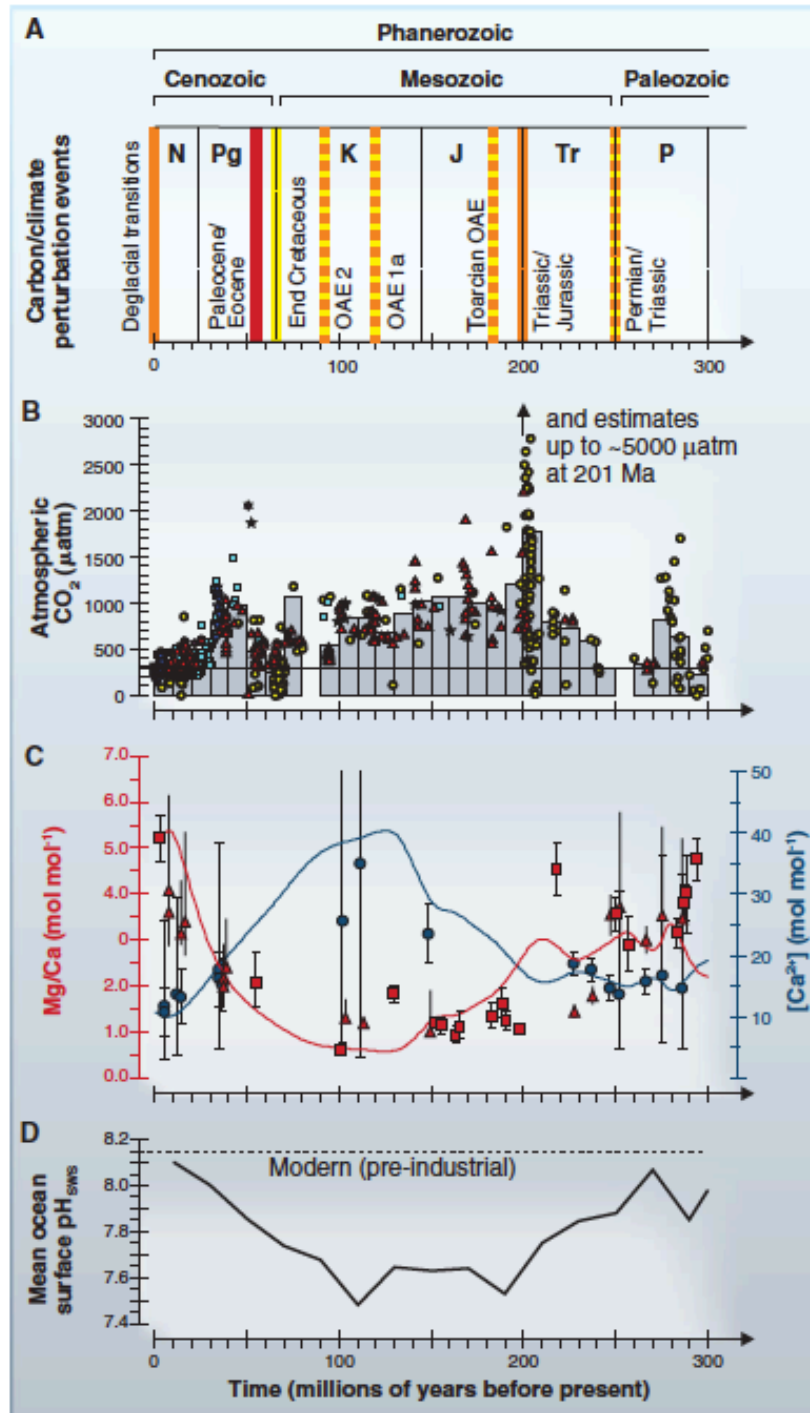
The background is a dark blue gradient. It features several glowing yellow-green spheres with thin white lines radiating from them, resembling stylized organisms or particles. There are also several grey, textured spheres that look like fossilized shells or microfossils. The overall aesthetic is scientific and marine-themed.

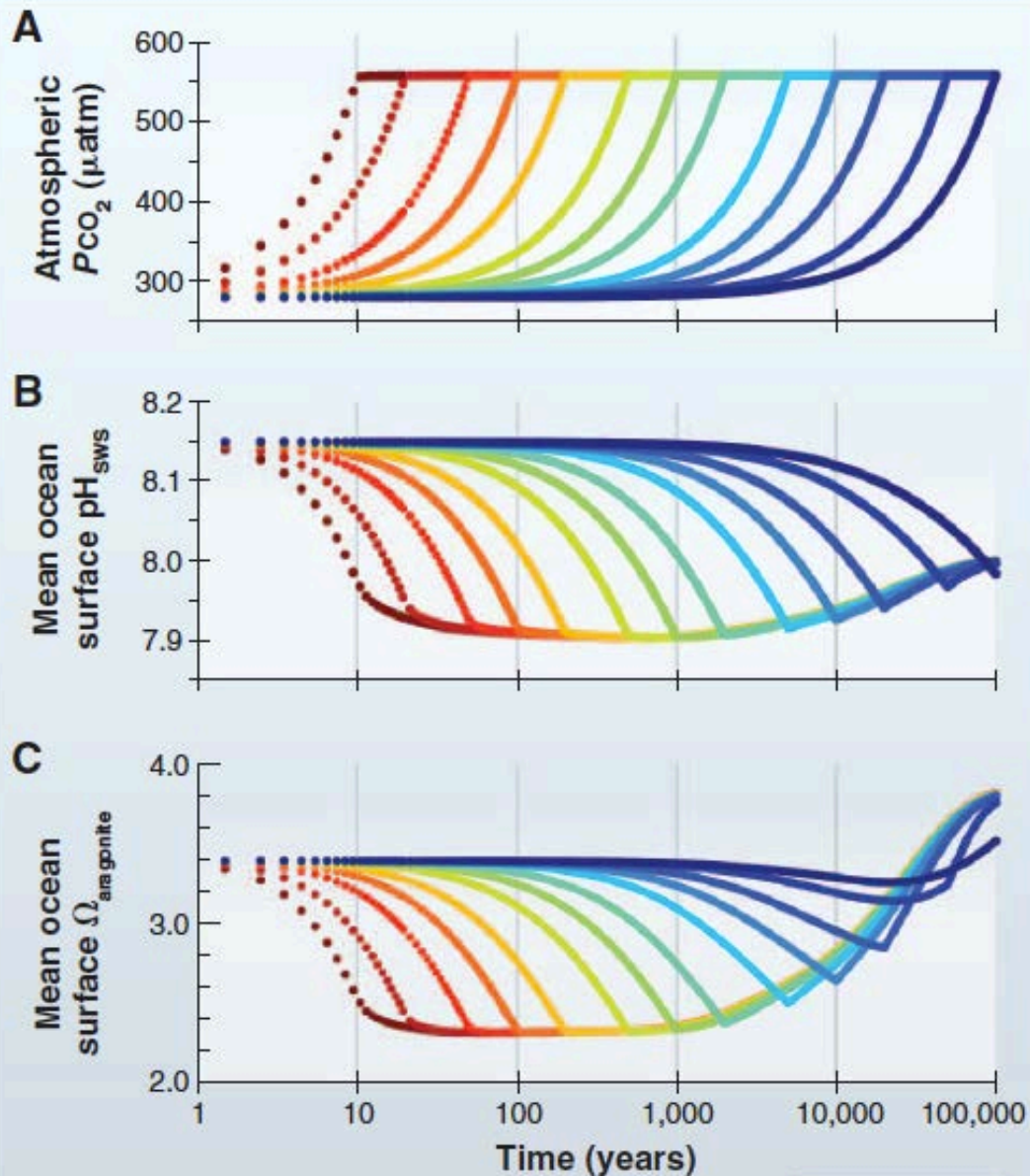
Ocean acidification in Earth history

- Ocean acidification has occurred in Earth history and left evidence in the form of interrupted carbonate deposition, reef crises and extinction among marine calcifiers.
- Modern OA goes together with warming and changes in dissolved oxygen concentrations and nutrients – these consequences are also shared by past OA events, which makes them so useful to estimate future changes
- The current rate of CO₂ release and the ocean's response appear unparalleled in Earth history.

Geological or geochemical proxy evidence for	Future & "Anthropocene"	Deglacial Transition	Oligocene - Pliocene	PETM	End Cretaceous	OAEs	Triassic/Jurassic	Permian/Triassic
$p\text{CO}_2$ change								
pH change					?	?	?	
Saturation Change			-			?	?	?
Temperature Change								
Carbon Release								
Ocean Acidification Score	/3	2	1	3	1	1.5	2	1.5

updated after Hönisch et al., 2012





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.

$$\Omega = \frac{[\text{Ca}^{2+}]_{\text{sw}} \times [\text{CO}_3^{2-}]_{\text{sw}}}{[\text{Ca}^{2+}]_{\text{sat}} \times [\text{CO}_3^{2-}]_{\text{sat}}}$$