Paleocean acidification, proxies & modeling

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OA PI workshop, WHOI, March 2011
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


(Science, 2005)
estimated CO₂ 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. Wilson3

(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 CO₂

Stephen Barker* and Henry Elderfield

Science, 2002
Pagani et al. Nature Geoscience, 2010 (rescaled)
Boron proxies for past seawater-pH

Laboratory calibrations of marine carbonates

- shallow water corals
- planktic foraminifers
- inorganic carbonates

Concentration (µmol kg⁻¹)

- $\text{B(OH)}_3$
- $\text{B(OH)}_4^-$

$\rho K_B = 8.60$

$\epsilon = 27.2\%$

$\delta^{11}\text{B}$ (‰)

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

Jimin Yu *, Henry Elderfield

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. Opdyke3

(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 due 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.