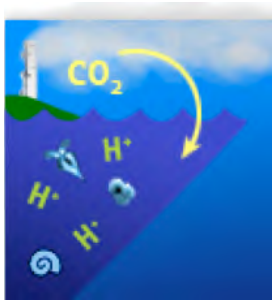
Paleo, Proxies, and Modeling Synthesis of Projects

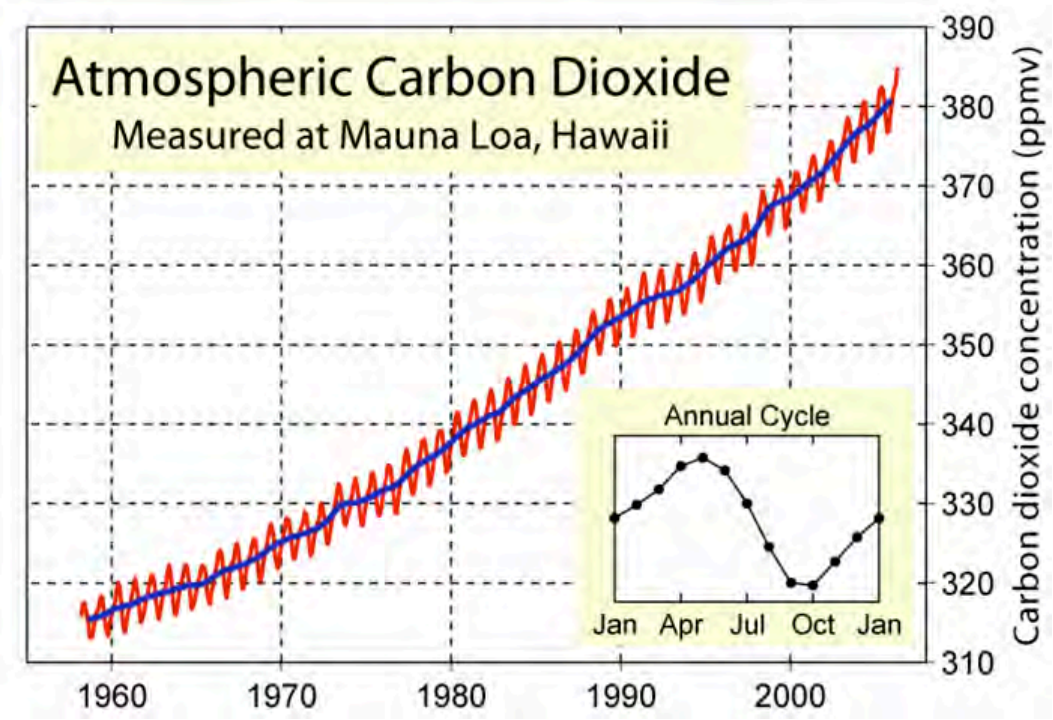
OCB Ocean Acidification PI Meeting

March 22-24, 2011 (Woods Hole, MA)

Presenter: Heather Benway (WHOI/OCB)



Proxy Development and Validation



- Real time assessment of ocean acidification proxies and their incorporation in the sediment record (Thunell/Scher)
- Validation of the B/Ca proxy for surface seawater pH and application to measure anthropogenic ocean acidification (**Hönisch**)
- Development of geochemical proxies to evaluate larval pH-exposure history (Levin/Anbar/**Tanner**)

Field Study

Real time assessment of ocean acidification proxies and their incorporation in the sediment record (Thunell, Scher)

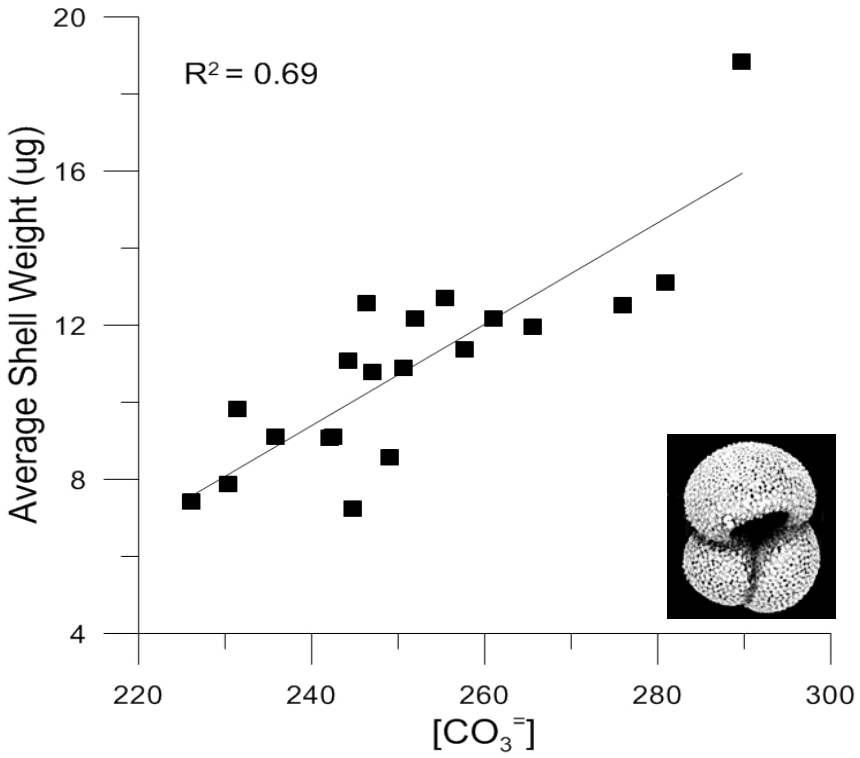


Figure 5. Comparison of G. ruber average shell weight and surface water carbonate ion concentration for the Cariaco Basin for the period January 2003 to May 2005.

Location:

Cariaco Basin (water column, sediment trap, and sediment core samples)

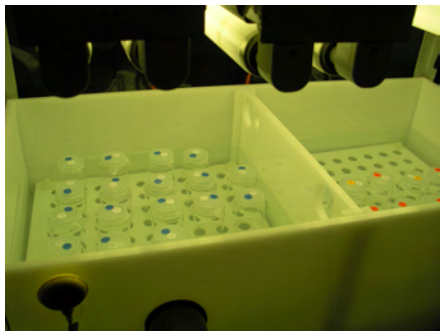
Goals and Methods:

- Calibrate and refine **foraminiferal proxies ($\delta^{11}B$, B/Ca, shell weight)** used to reconstruct surface water pH and $[CO_3^{2-}]$ (sediment trap vs. water column measurements)

- Compare downcore (varved, near-annual resolution) foraminiferal records with past 15 years of sediment trap records, as well as past 2 centuries of atmospheric CO_2

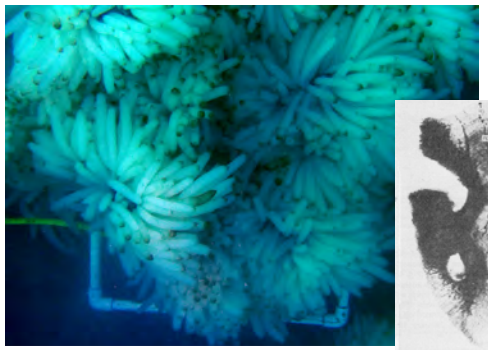
Laboratory Culturing

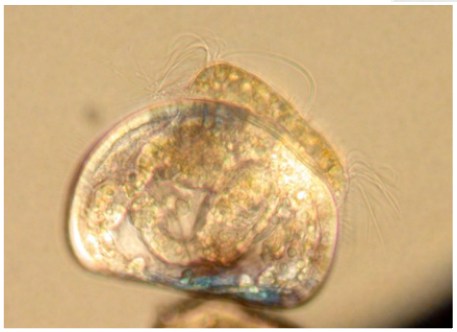
Validation of the B/Ca proxy for surface seawater pH and application to measure anthropogenic ocean acidification (Hönisch)



Goal: B/Ca proxy validation in planktonic foraminifera to evaluate potential for Pleistocene paleo-pH reconstructions

Methods: Controlled (pH, T, S) lab experiments with cultured **planktonic foraminifera**





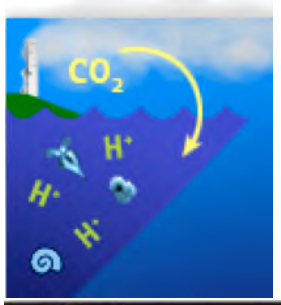
Development of geochemical proxies to evaluate larval pH-exposure history (Levin et al.)

Goal: To develop proxies to determine pH exposure history for living organisms in their larval state.

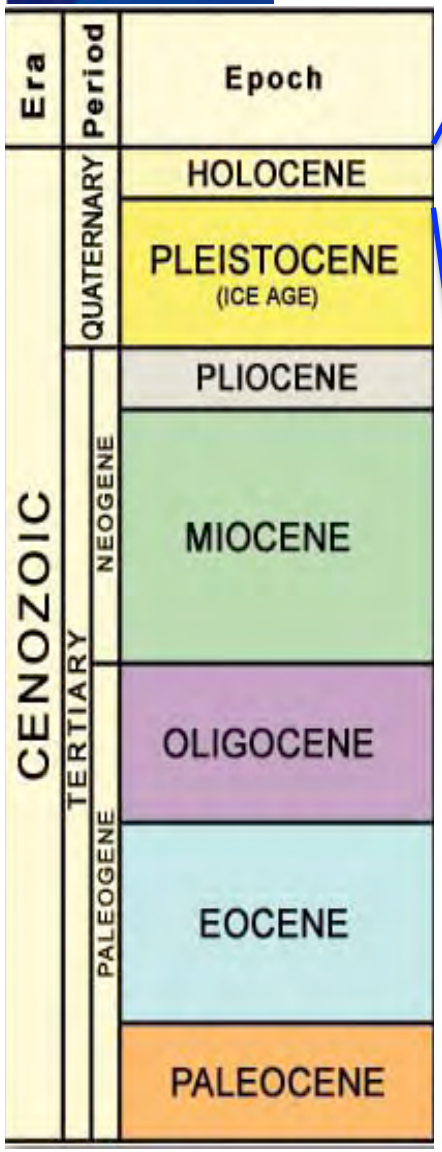
Methods: Controlled (pH, O_2) lab experiments on:

- *statoliths of market **squid embryos**
- *prodissoconch of **mussel larvae**

• SIMS (**$\delta^{11}B$**), multicollector ($\delta^{238}U$, $\delta^{44}Ca$), and LA-ICPMS (B, Cu, U, Pb, Mo)



Holocene to Late Pleistocene (10-10^4 yrs BP)

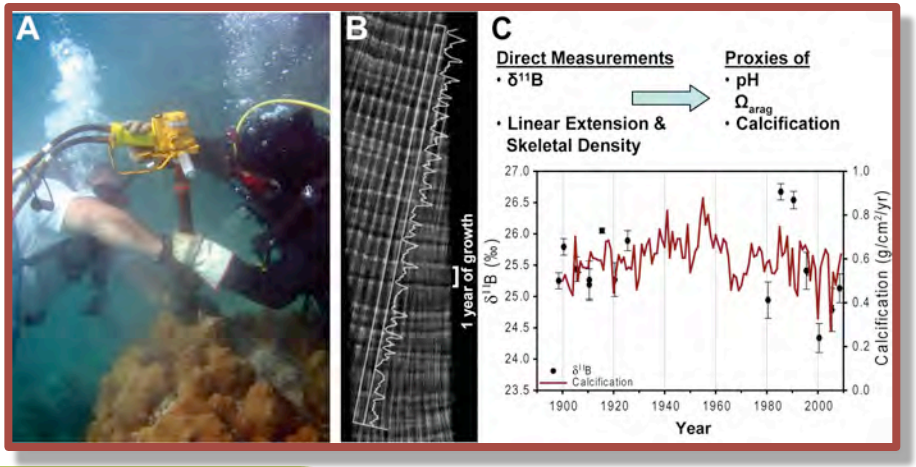


- Reconstructing the impact of thermo-chemical changes in Caribbean seawater on coral extension rates over the past century (**Ries**, Castillo)
- Coral reef calcification: Past, present, future (**Yates**, Moyer)
- Recent spatial and temporal historical patterns of calcification of corals across the Pacific Islands (**Brainard**, **Cohen**, Young)
- Calibration and application of the boron isotope seawater-pH indicator in deep-water corals (**Hönisch**)
- Acidification of California coastal waters: A geologic record of natural and anthropogenic pH variability (**Paytan**, Russell, Hill)
- Historical context of rapid pH decline (**Wootton**, Pfister, Colman, Martin)

Corals

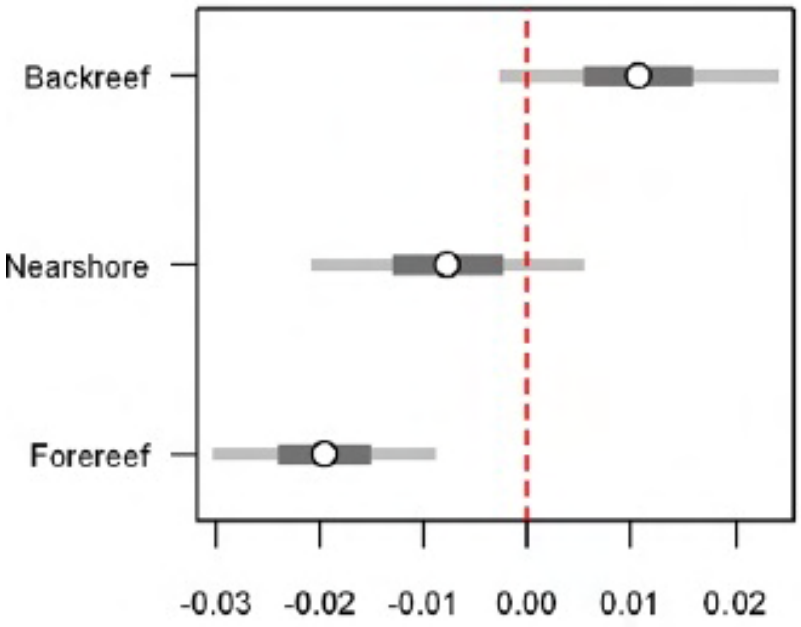
Reconstructing the impact of thermo-chemical changes in Caribbean seawater on coral extension rates over the past century (Ries, Castillo)

Goal: Reconstruct paleo-T, paleo-pH, and coral extension rates in *S. siderea* over the past century



Coral reef calcification: Past, present, future (Yates, Moyer)

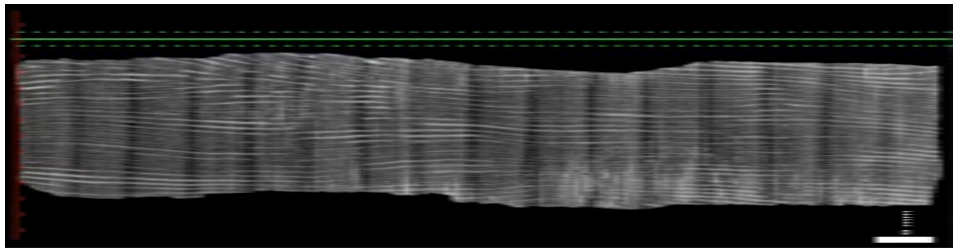
Goal: Measure modern and historical rates of coral calcification (linear growth rate, density) and reconstruct past changes in seawater pH ($\delta^{11}B$)



Rates of change in annual extension (mm yr-1/year) (Castillo et al., 2011)

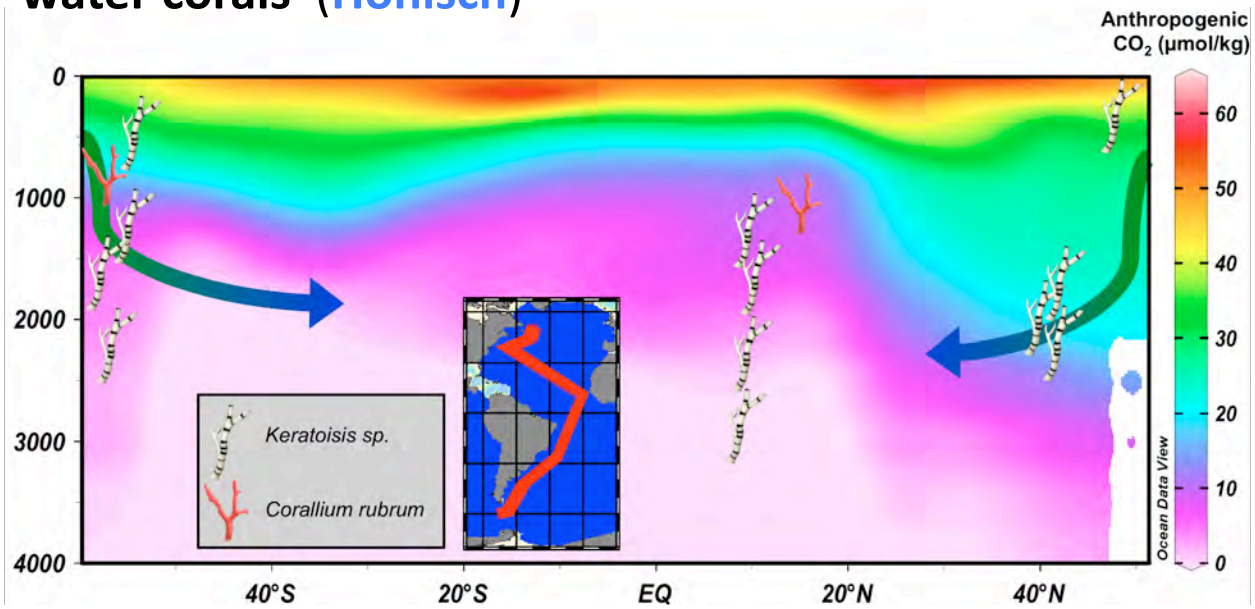
Corals (cont'd)

Recent spatial and temporal historical patterns of calcification of corals across the Pacific Islands (Brainard, Cohen, Young)



Goal: To determine recent history of coral calcification rates across the Pacific Islands using CT scan to examine 3-D internal structure of corals and determine calcification/extension rates

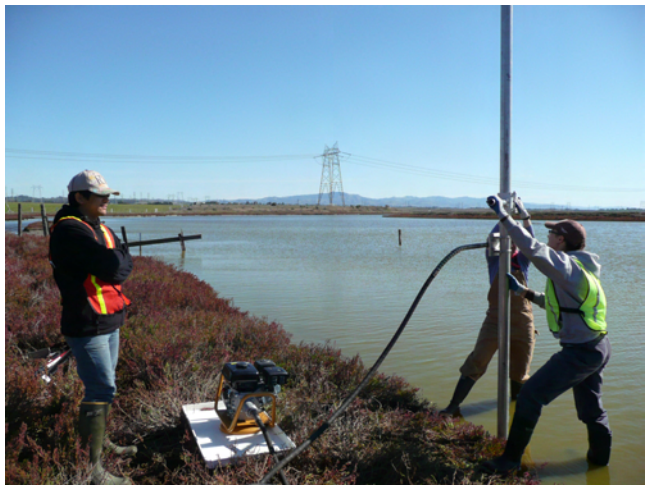
Calibration and application of the boron isotope seawater-pH indicator in deep-water corals (Hönisch)



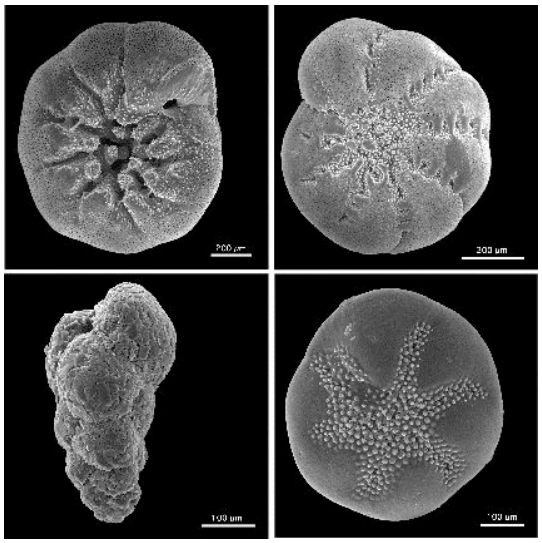
Goal: Collect live deep-sea bamboo corals to calibrate boron isotope and B/Ca proxies and document anthropogenic CO_2 invasion (N. Atlantic, Southern Ocean); and use fossil specimens to extend reconstruction through last deglaciation

Foraminifera

Acidification of California coastal waters: A geologic record of natural and anthropogenic pH variability (Paytan, Russell, Hill)

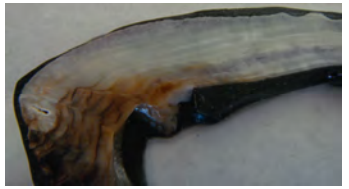


Goal: To reconstruct Holocene paleo-pH (B/Ca) along the California coast (Santa Monica, Santa Barbara, Elkhorn) using planktonic and benthic foraminifera

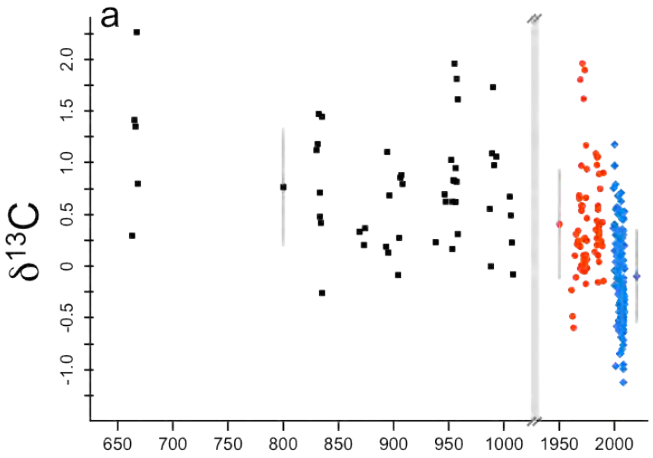


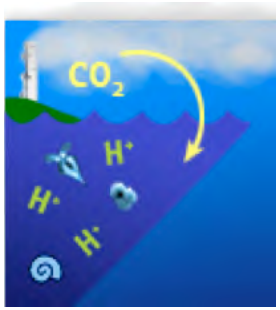
Mollusks

Historical context of rapid pH decline (Wootton, Pfister, Colman, Martin)

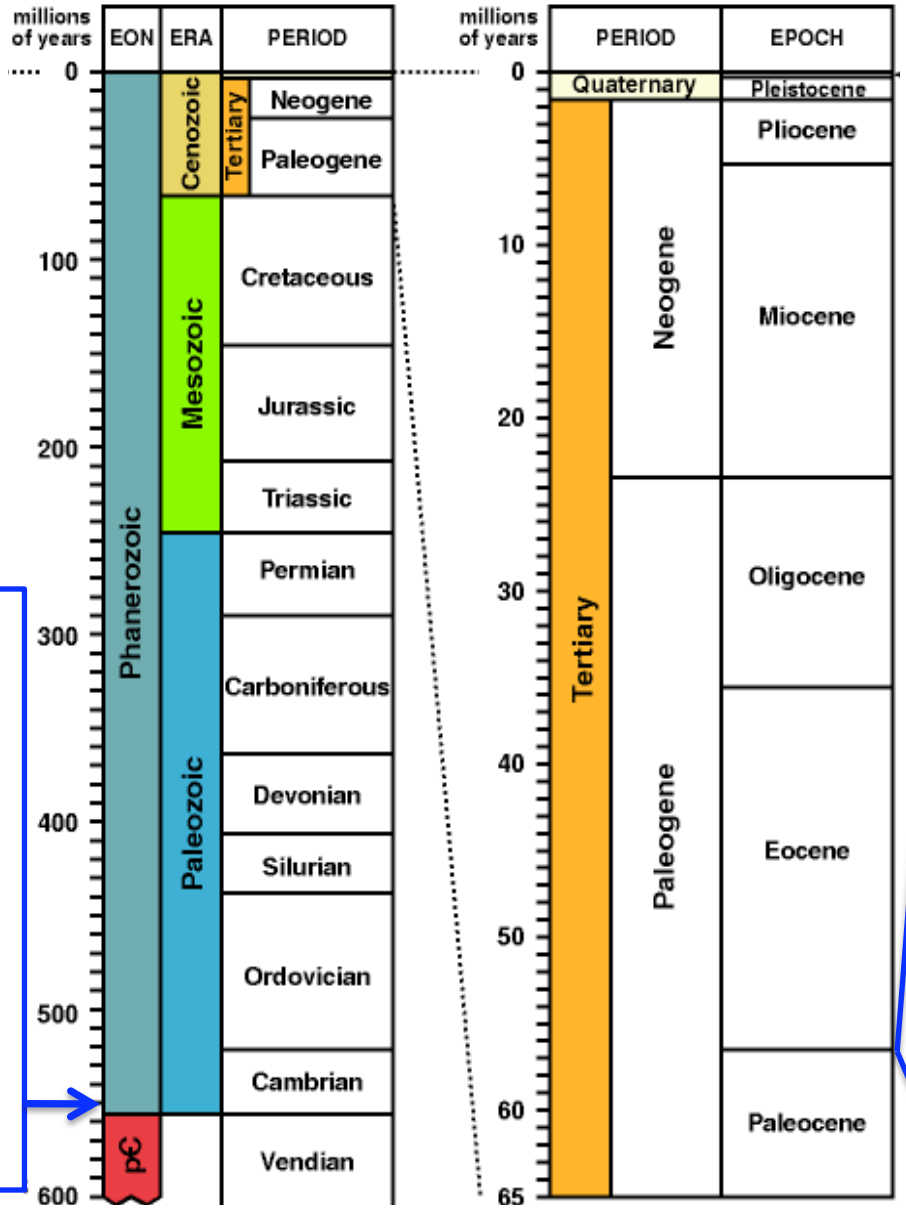


Goal: To use historical and modern shell material (mussels, limpets) from Tatoosh Island, WA to explore whether recently observed pH changes are unusual over the past 2300 yrs ($\delta^{13}C$, trace, and rare earth elements)





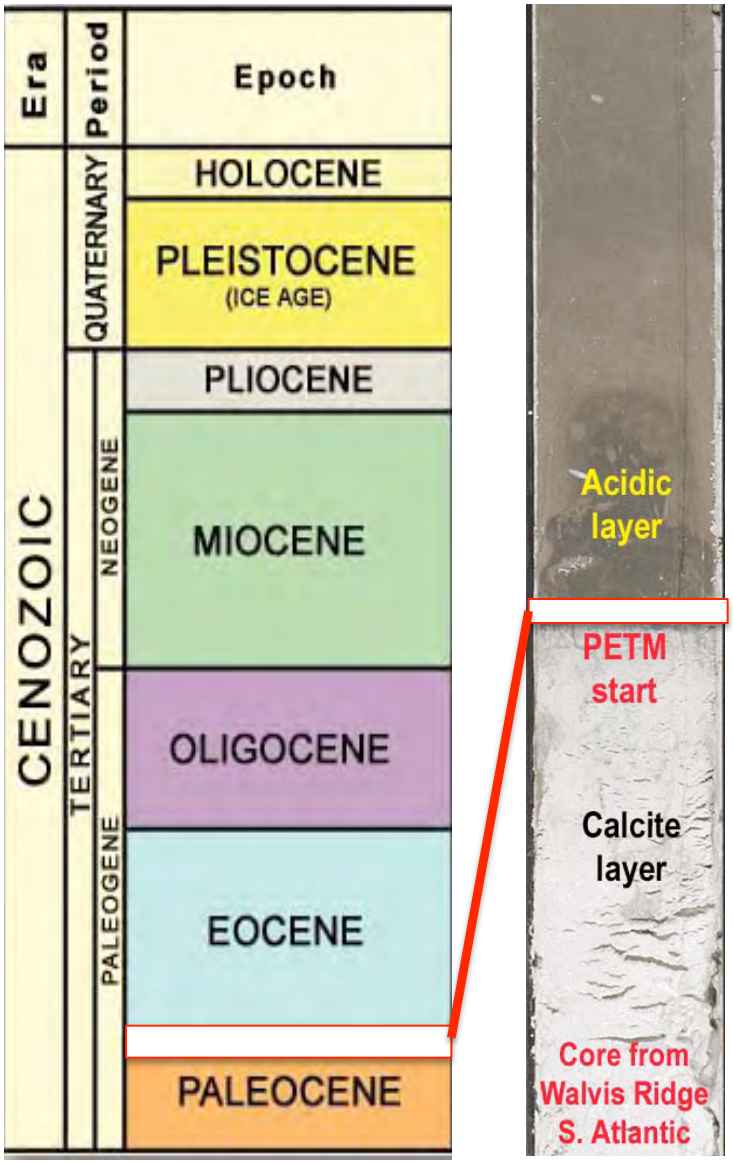
Eocene and beyond (10s-100s My BP)



- Geochemical & petrographic investigation of a novel calcite-aragonite sea transition in terminal Proterozoic time (**Ries**)

- Reconstructing deep-sea acidification during the Paleocene-Eocene Thermal Maximum (**Hönisch,** Thomas**, Zachos, Zeebe**)
- Dynamics of carbon release and sequestration: Case studies of two early Eocene hyperthermals (**Zeebe**, **Zachos**, and 8 others)

Reconstructing deep-sea acidification during the Paleocene-Eocene Thermal Maximum (~55 My BP) (**Hönisch,** Thomas**, Zachos, Zeebe**)

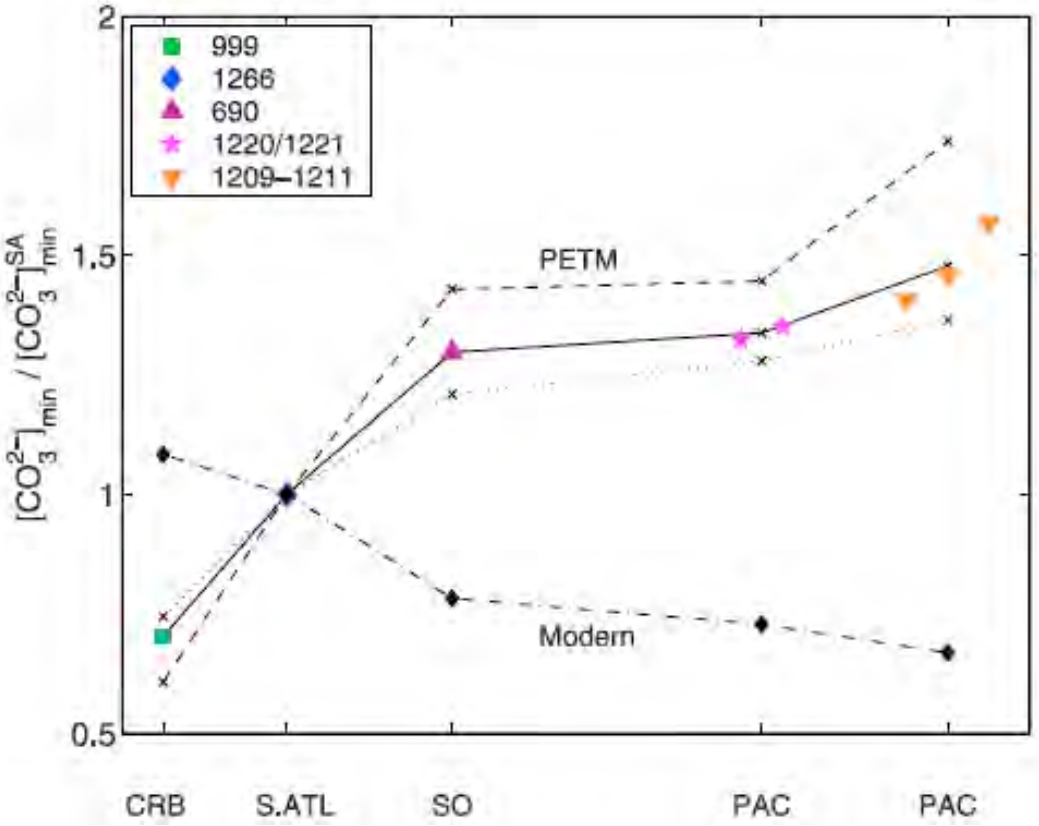


Goal: To reconstruct surface (planktonic forams) and deep (benthic forams) ocean carbonate chemistry changes across the PETM to determine the degree of ocean acidification during a period of high CO_2 and extreme warming

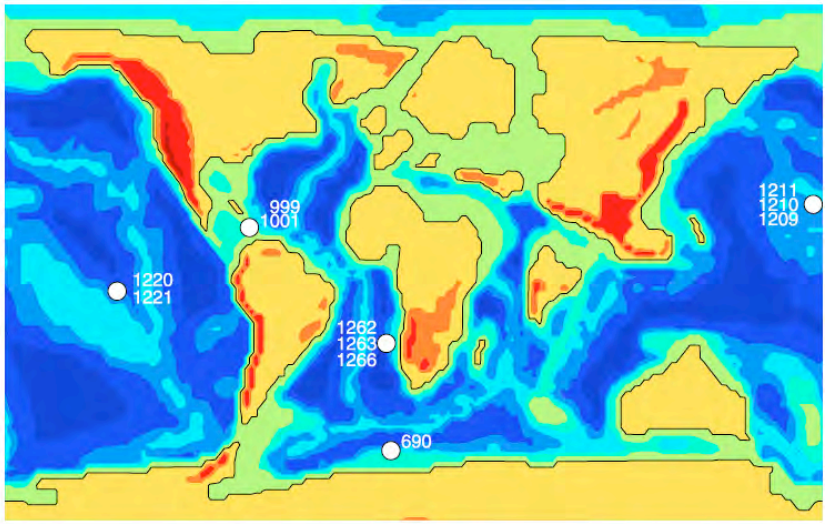
Locations: Walvis Ridge (S Atlantic), Shatsky Rise (NW Pacific)

- **Hönisch**: B isotopes (paleo-pH)
- **Zachos**: B/Ca (modern calibration and paleo-$[CO_3^{2-}]$)
- **Zeebe**: modeling

Dynamics of carbon release and sequestration: Case studies of two early Eocene hyperthermals (Zeebe, Zachos, *et al.*)



Figures from: Zeebe and Zachos (2007) *Paleoceanography*

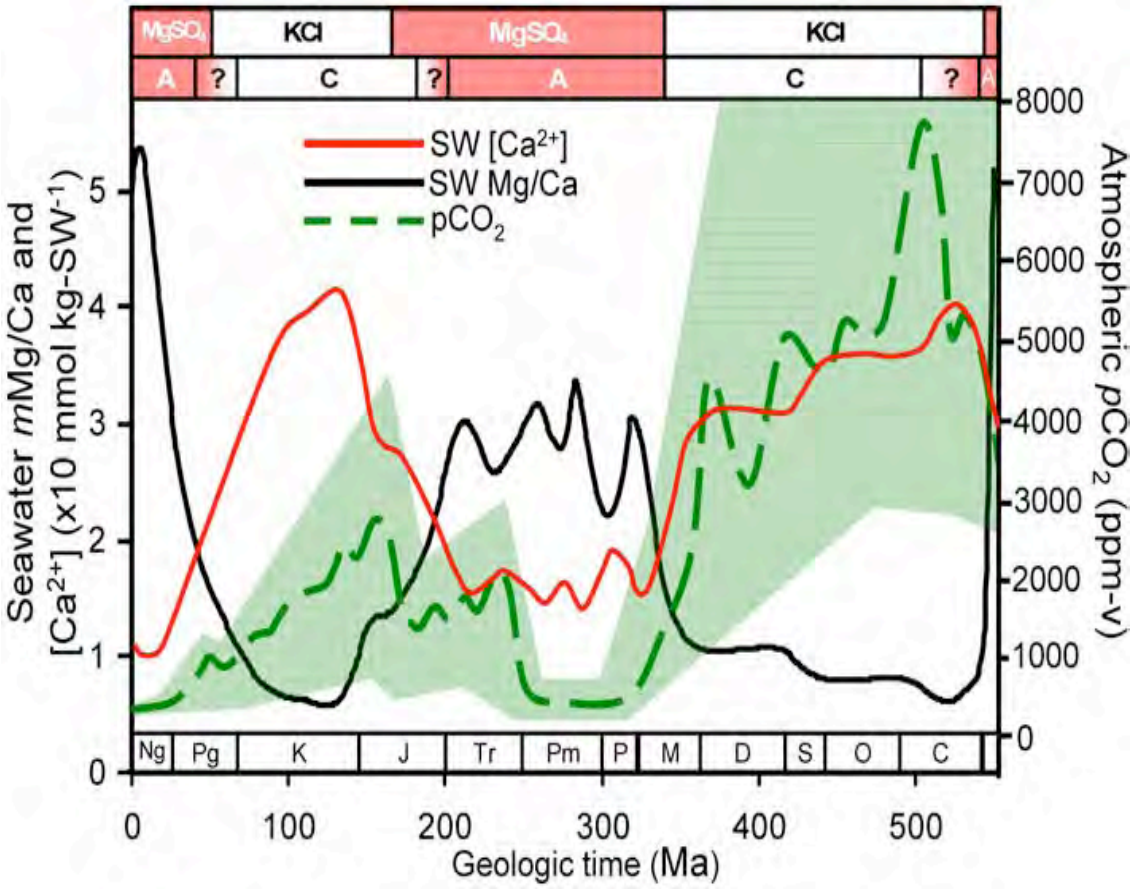


Goal: To integrate paleo-data and numerical models to determine:

- Mass, rate, and origin of carbon released during hyperthermals
- Rates of sequestration and recovery and associated biogeochemical feedbacks
- Effects on planktonic calcifiers

Geochemical and petrographic investigation of a novel calcite-aragonite sea transition in terminal Proterozoic time (American Chemical Society) (Ries)

Goal: To reconstruct **changes in seawater Mg/Ca** and associated **impacts on the early marine calcifiers** (*Namacalathus* and *Cloudina*) using geochemical and petrographic information from limestones of terminal Proterozoic age **(549-548 Ma)**



Ries (2010) *Biogeosciences*

Paleo, Proxies, and Modeling

Community Activities and Resources

- Workshop on Paleo-Ocean Acidification and Carbon Cycle Perturbation Events (**Hönisch,** Schmidt, Barker, **Zachos**, Kiefer)
- Ocean Acidification Data Sets at the World Data Center for Paleoclimatology (Anderson)
- Enhancing opportunities for ocean acidification research and education at the University of California, Santa Cruz (**Paytan**)

Workshop on Paleo-Ocean Acidification and Carbon Cycle Perturbation Events

B. Hönisch, D. Schmidt, S. Barker, J. Zachos, T. Kiefer

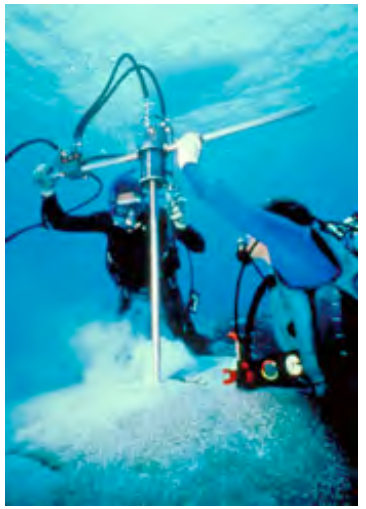
(August 2010, Catalina Island, CA)

Key Questions Addressed:

- What defines a paleo-OA event?
- Proxy evidence
- Biological consequences

Ocean Acidification Data Sets
World Data Center for Paleoclimatology

David Anderson, NOAA National Climatic Data Center



About the data sets:

- Derived from many proxies, including:
  - -trace metals in $CaCO_3$ (carbonate ion concentration)
  - -boron isotopes $\delta^{11}B$ (pH)
  - -carbon stable isotope ratio (aqueous CO_2)
- Time scales range from interannual to millions of years

Questions that can be addressed with paleo-OA data:

- What is the magnitude of natural variability in ocean pH, saturation state?
- How does the ocean compensate for carbon entering and leaving during Ice Age transitions?
- What changes in calcification (coral extension rate, plankton shell weight) accompany changes in ocean environment?

Paleo, Proxies, and Modeling Panel Discussion

Panelists

Bärbel Hönisch (LDEO), **Adina Paytan** (UC Santa Cruz), **Justin Ries** (UNC), **Jim Zachos** (UC Santa Cruz), **Richard Zeebe** (U Hawaii)

Past ocean acidification events – what the paleo-record can tell us

- Establish baseline/natural pH variability over multiple time scales
- Range and rate of observed pH changes (relative to ocean mixing/ overturning)
- Recovery time

Ecosystem response – can we reconstruct?

- Did marine calcifiers respond to the larger events?
- Paleo-evidence exists (i.e. changes in community structure of calcareous plankton), but how can we isolate influence of ocean carbonate chemistry from other influences (e.g., increasing temperatures)?
- Is biotic response more likely to be threshold-driven?

Modeling/predictability challenges

- Steady state (e.g., PETM) vs. transient (Anthropocene)
- Sensitivity of ocean chemistry and atmospheric CO_2 to C-input and how it has evolved throughout earth history; what controls this sensitivity?
- Magnitude and time-scale of carbon input

Proxies

- Boron (paleo-pH)
  - Methods: TIMS vs. MC-ICP-MS (pros and cons of each?)
  - $\delta^{11}B$-pH relationship species-specific?
  - T effect?
  - Do we need to know the $\delta^{11}B_{sw}$ to interpret the proxy? Is this possible?
  - Additional seawater pH proxies?
- Paleo-CCD (paleo-pH and paleo-pCO_2 not enough to constrain carbonate system of the ancient ocean)
- Plans for cross-calibration of different proxies?