Seasonal variability in sea surface temperature, salinity, and carbonate chemistry during Greenhouse Extremes (e.g., PETM)

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Acknowledgments:

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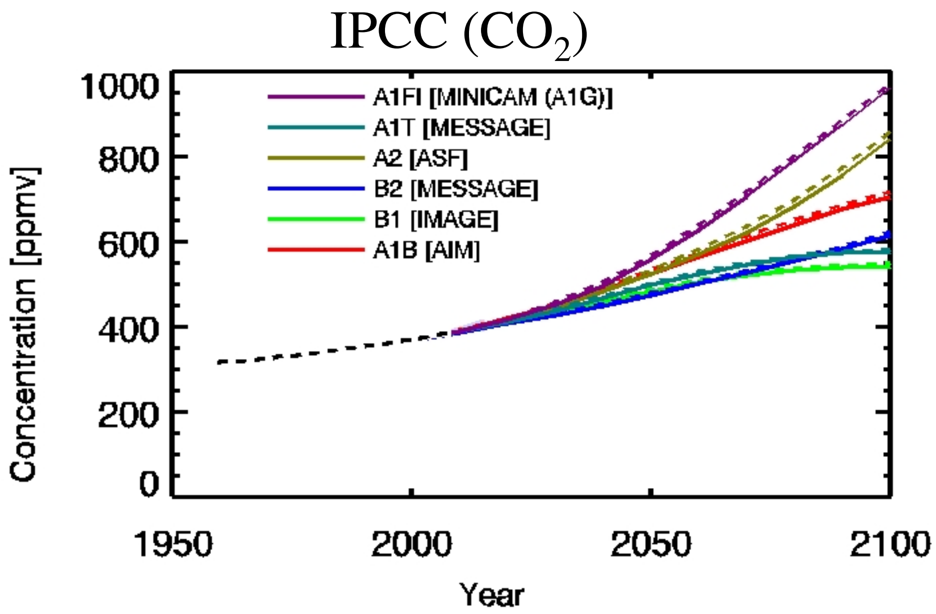
Hydrologic Cycle: Rich get richer,



With rising CO_2 and global warming;

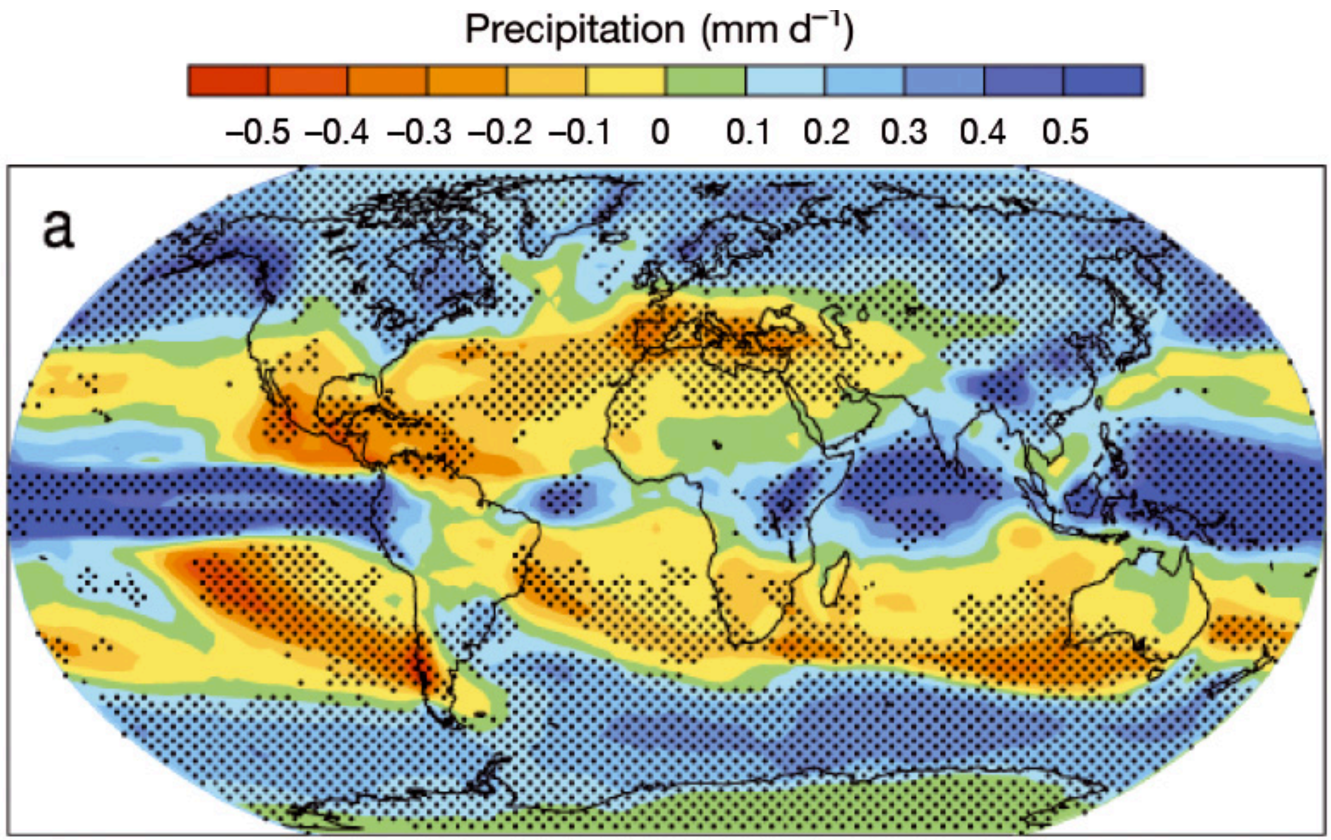
- water holding capacity of air increases by about 7% per 1°C warming
- **convection** - dry regions become drier, wet regions become wetter
- more intense precipitation events
- frequent/longer droughts

Impacts of future GHG Warming

- Global increase in humidity/mean annual precipitation(MAP)

Precip. change from 1980–1999 to 2080–2099

11 CMIP5 models under the RCP4.5 emissions



erth 2011

“the earth has been here before…”

A Case Study in Extreme Greenhouse Warming: Paleocene-Eocene Thermal Maximum (PETM, 55.6 Mya)

1. Transient Global Warming (5-6°C)
   - Relatively uniform over latitude
2. Massive carbon release (4500 to 7000 PgC)
   - Carbon isotope excursion (CIE) of ~**-4.0‰**
   - Ocean acidification
3. Intensification of the hydrologic cycle
   - Overall higher humidity
     - Reduced MAP - low latitudes
     - Increased MAP - mid to high latitudes
   - Significant Δ in Evaporation-Precipitation (E-P)

Abrupt increase in seasonal extreme precipitation at the Paleocene-Eocene boundary

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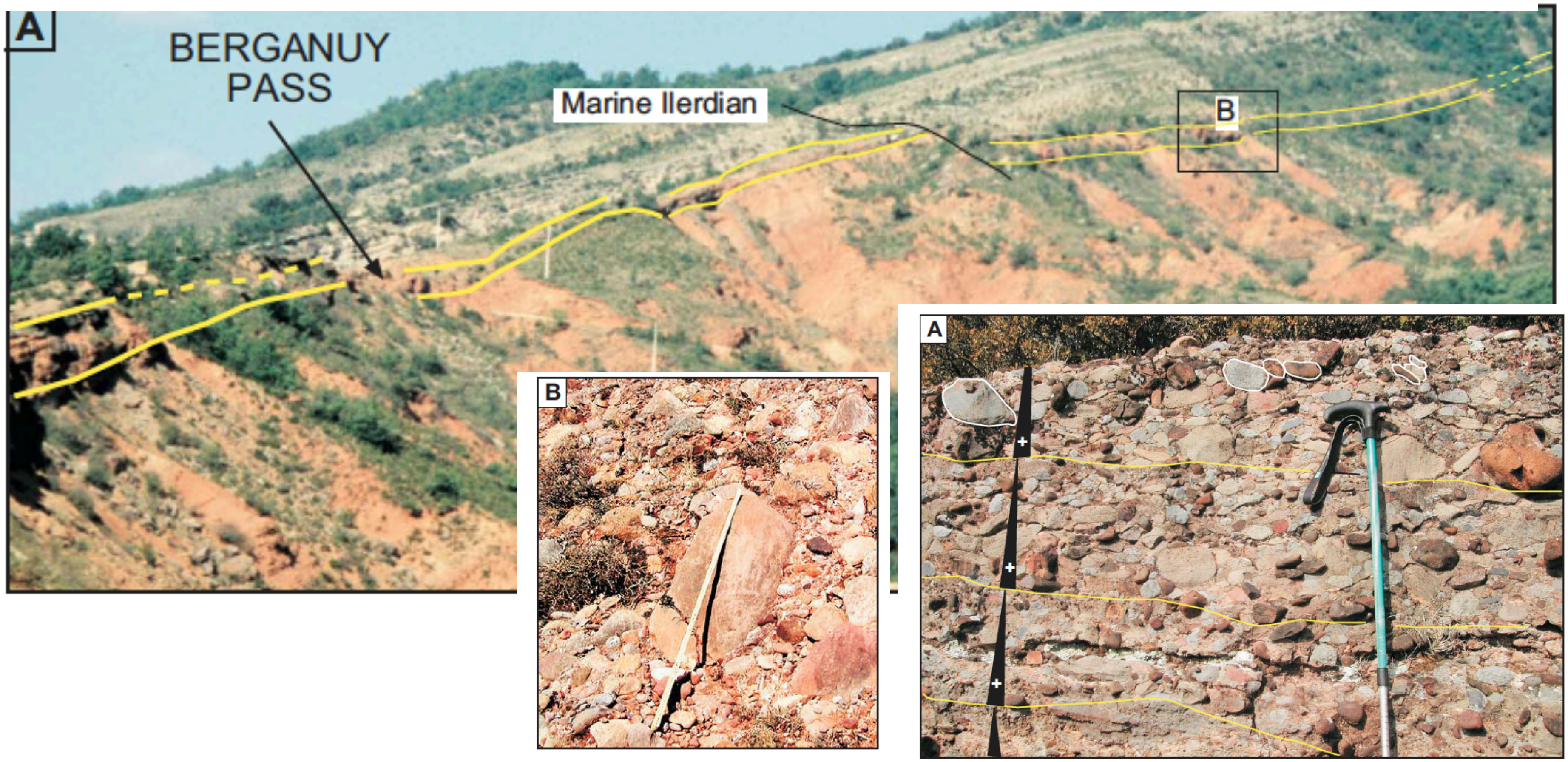
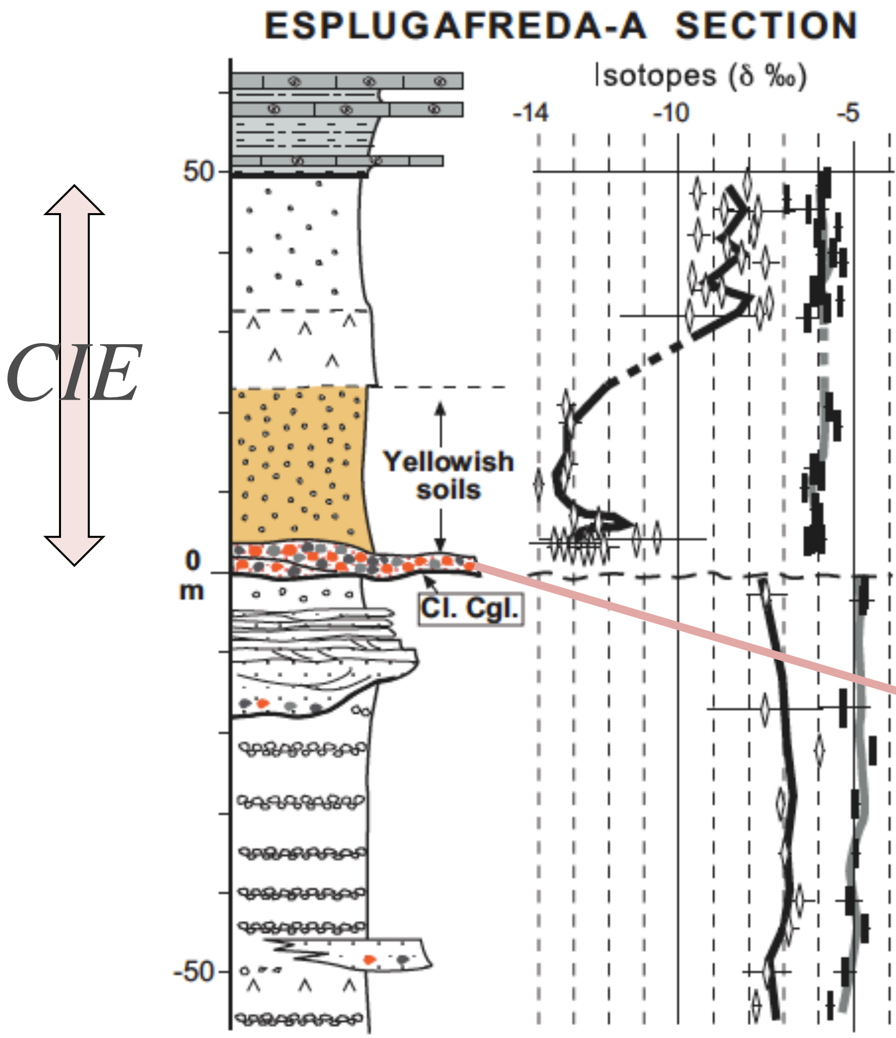
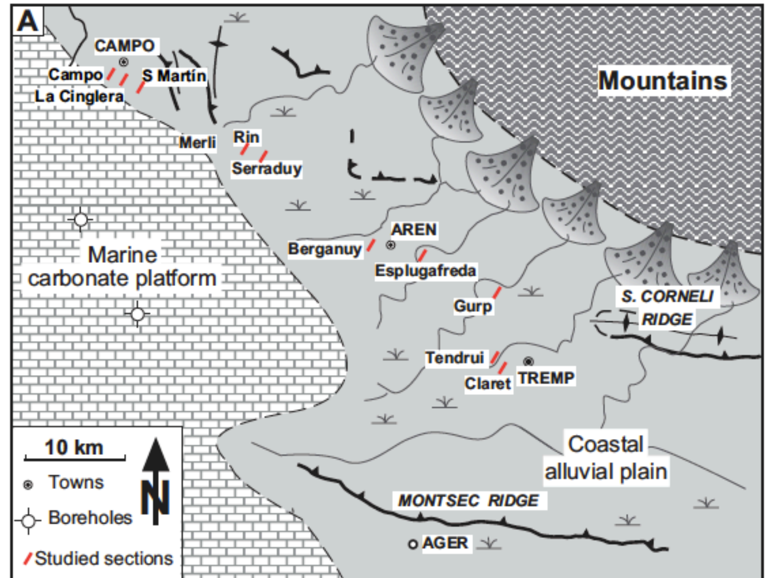


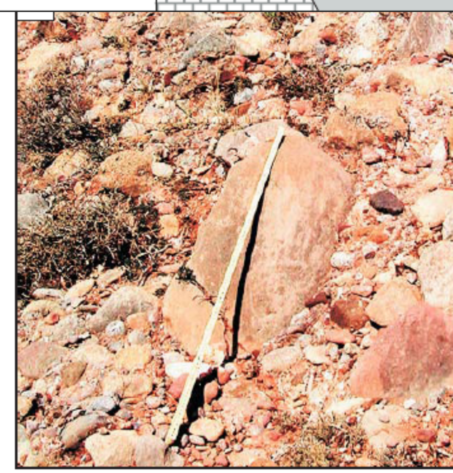
- *Claret Conglomerate* – Alluvial Fan Progradation

P-E Boundary, Pyrenees, Spain

(Schmitz & Puljate, 2007)



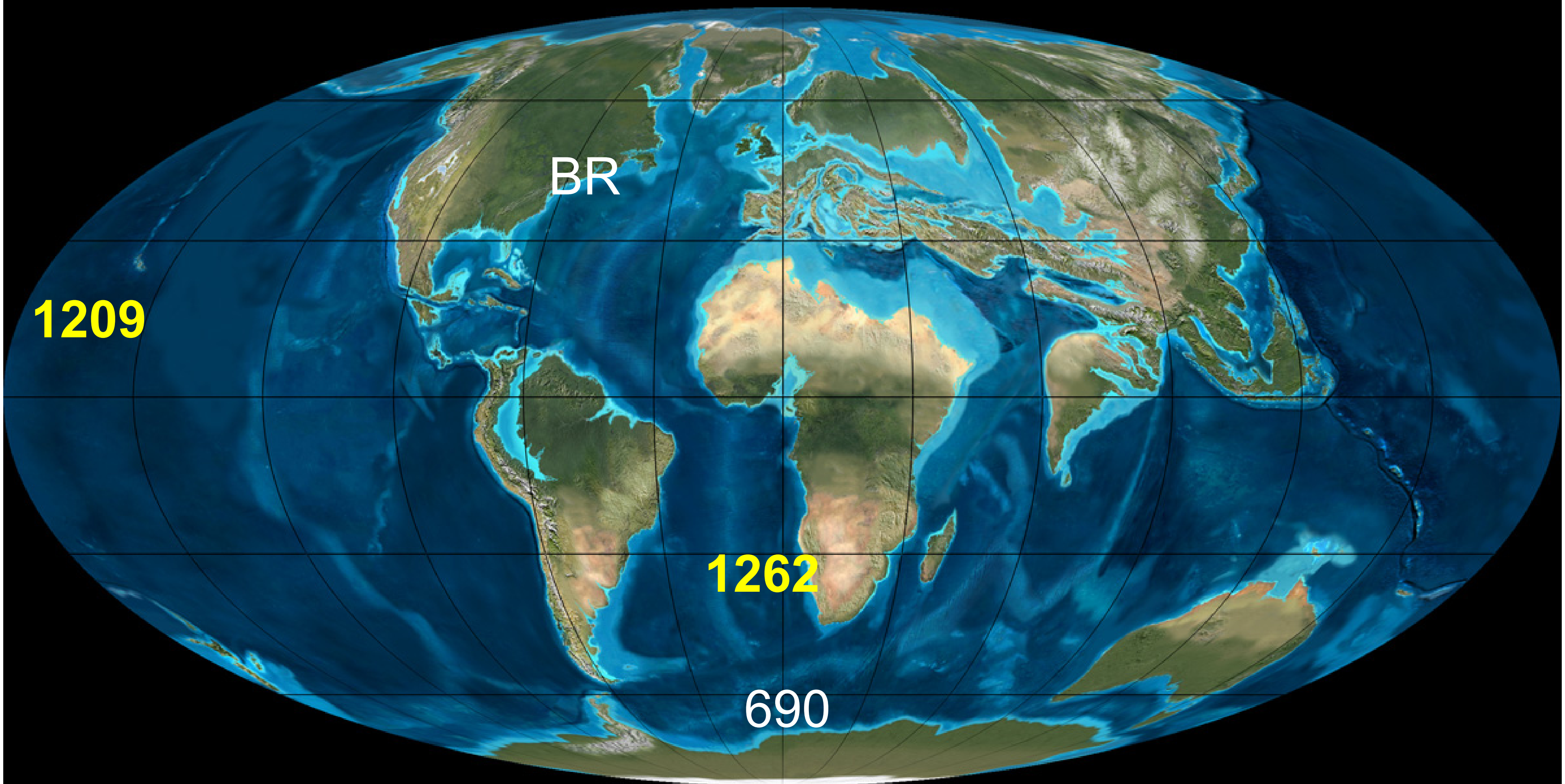




- *Claret Conglomerate* – Rapid Alluvial Fan Progradation (i.e., high energy floods) – Seasonally dry climate, intense wet season

Seasonal Extremes –
More frequent flood events

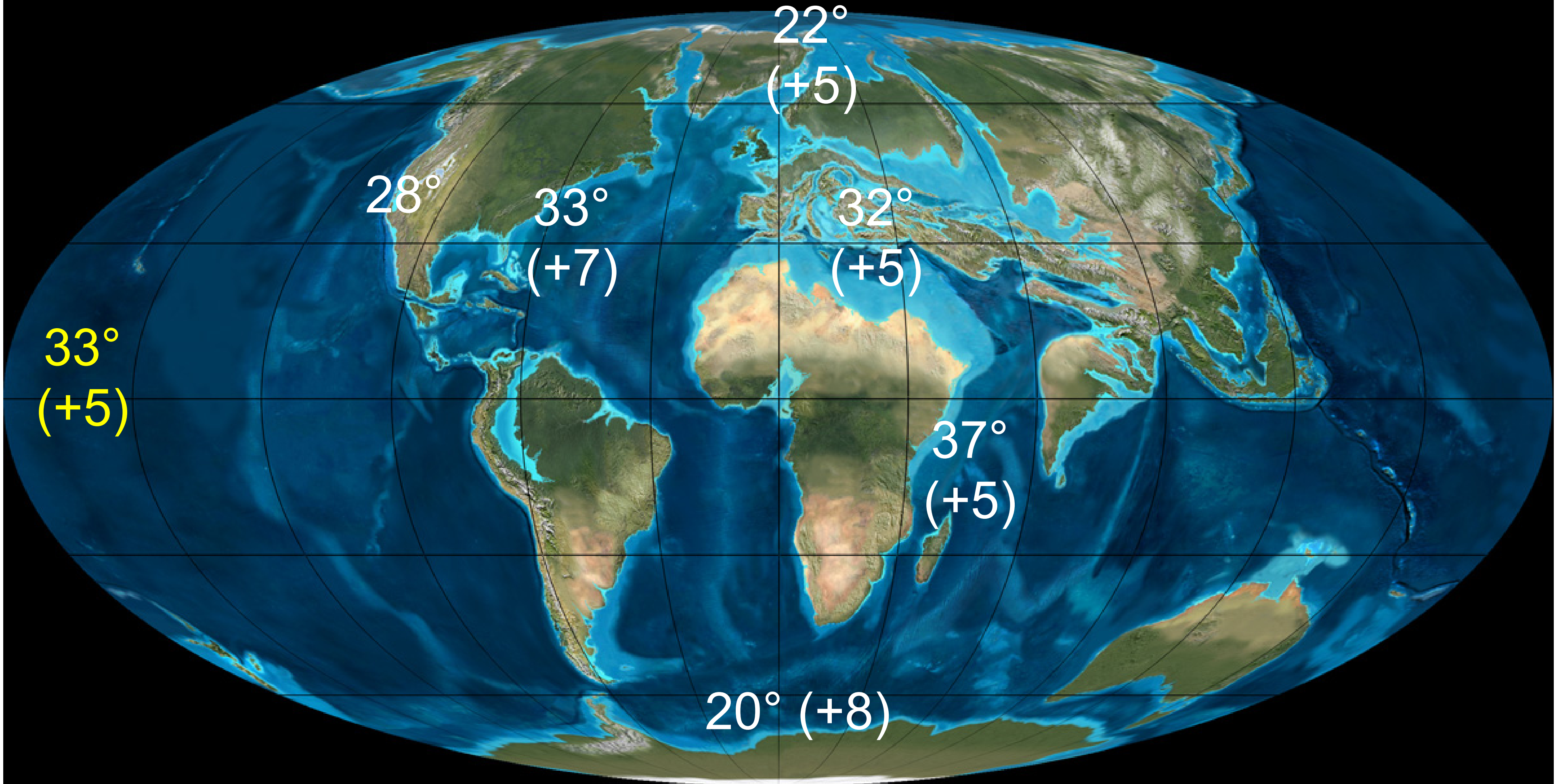
Early Eocene (~56 Mya)



Site 1262 Cores, South Atlantic

•Paleocene-Eocene sediments: ODP Leg 208

Peak SST (ΔSST°C) during the PETM

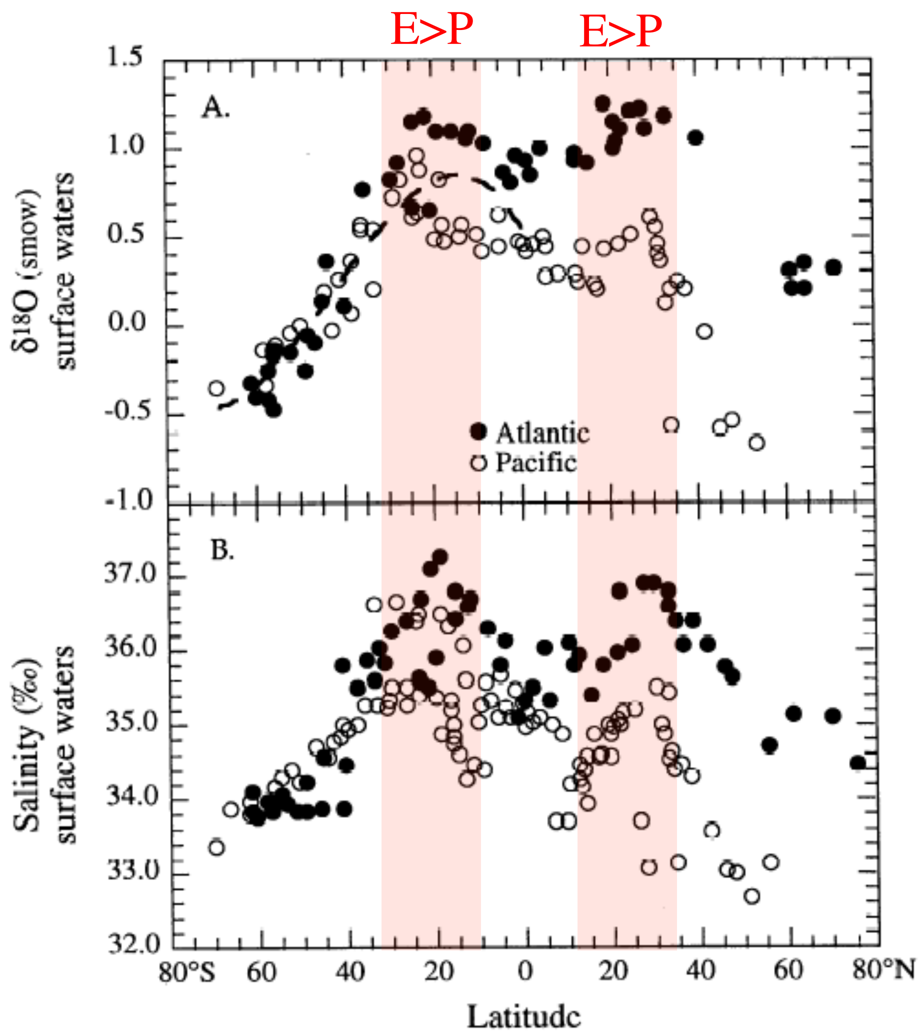


Proxies: $\delta^{18}O$, TEX_{86}, Mg/Ca

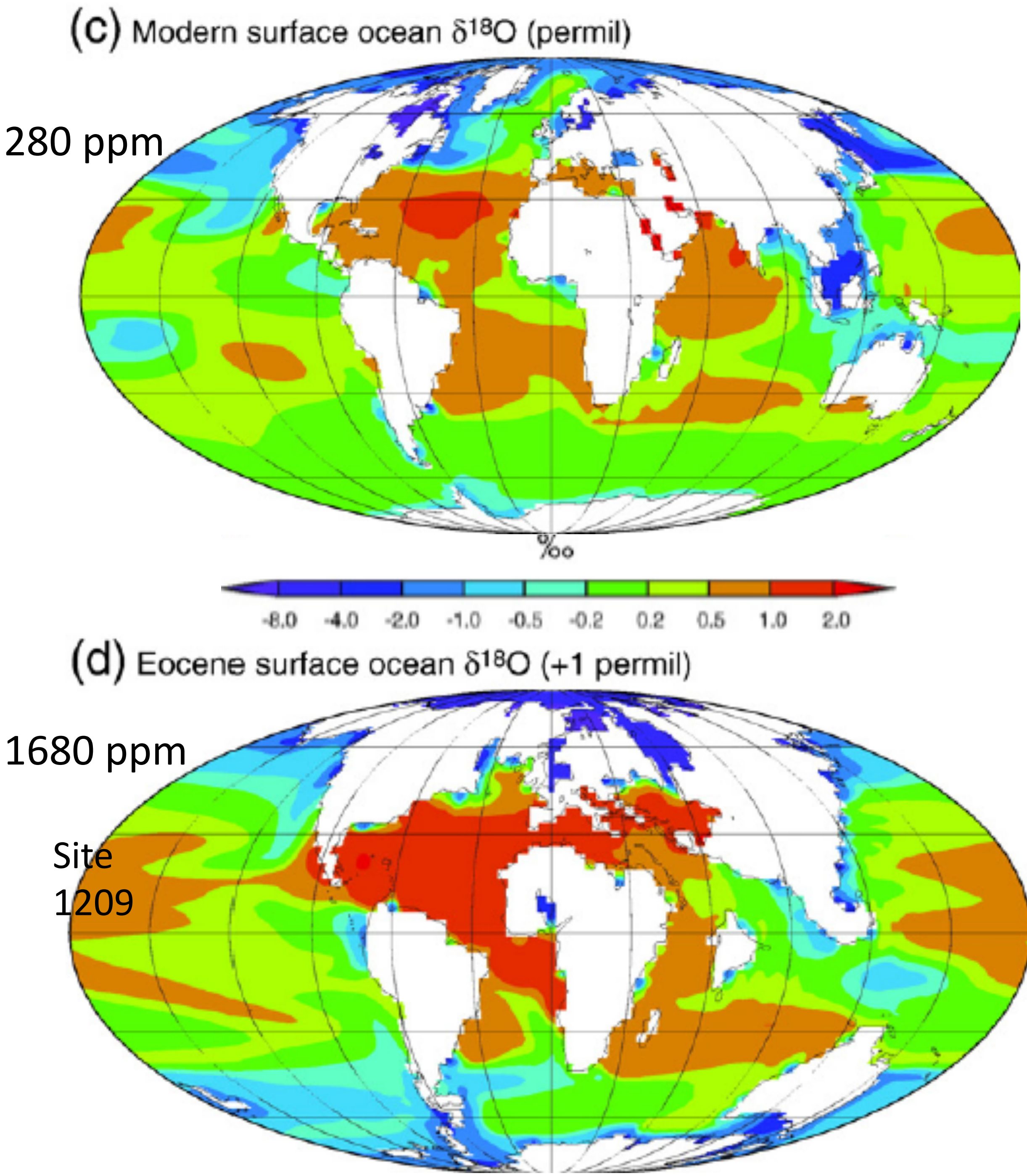
ACEX - Lomonosov Ridge; New Jersey Margin, Bass River; California, Lodo; Maud Rise, Sites 689 and 690; Allison Guyot, Site 865

Paleo SST/ SSS ($\delta^{18}O_{SW}$)

- Spatial SSS and $\delta^{18}O_{SW}$ variations linked to E-P
  - ↑E-P, ↑$\delta^{18}O_{SW}$
- Planktonic foraminifera $\delta^{18}O$
  - SST (Mg/Ca)
  - $\delta^{18}O_{SW}$
- Variables (local)
  - seasonality
    - minor in the open ocean
  - vertical mixing
  - runoff (coastal oceans)



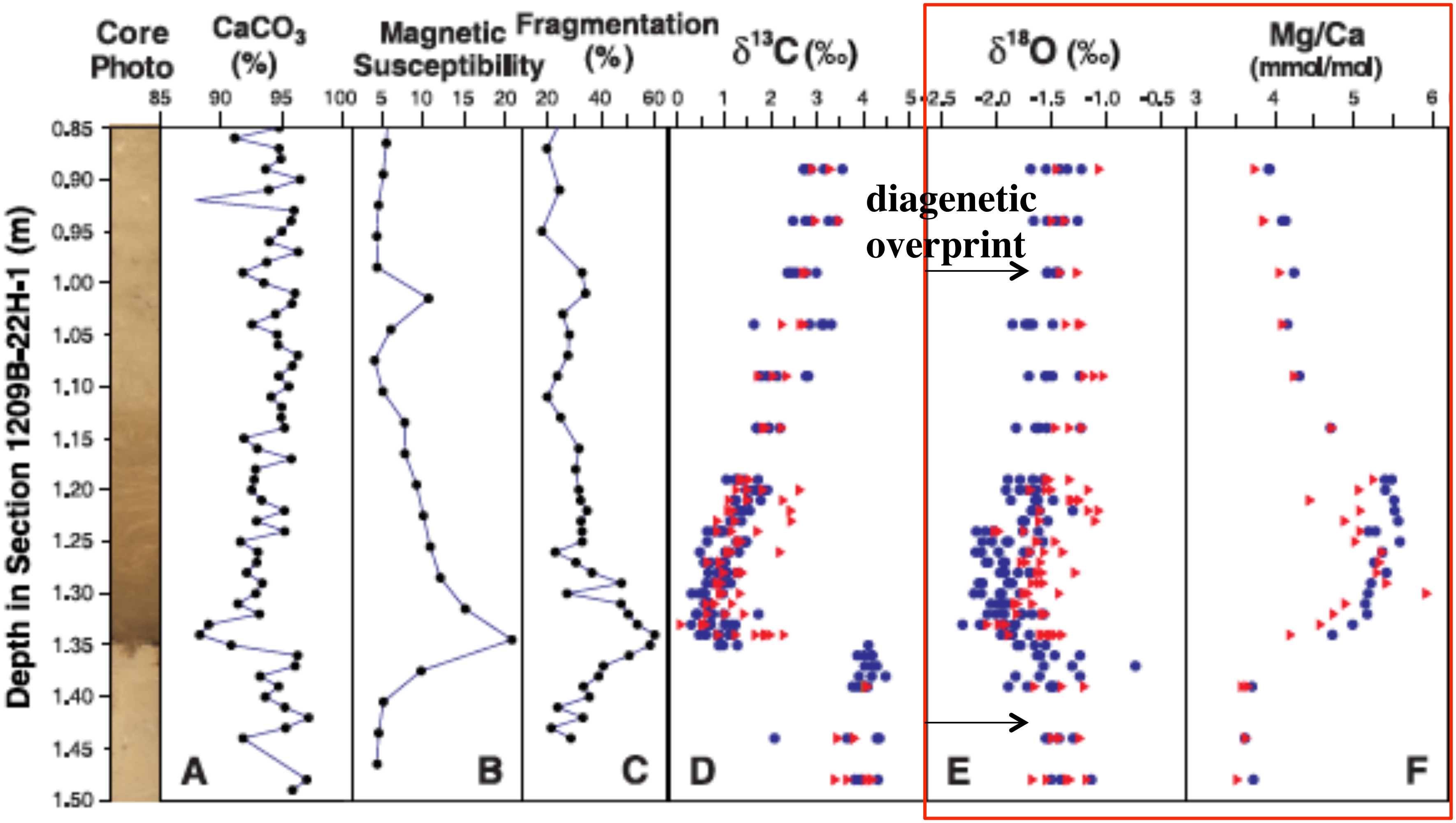
GHG Extremes and $\delta^{18}O_{SW}$



Tindall et al., 2011

- HadCM3
- 280 to 1680 ppm
- Δ sea surface salinity and $\delta^{18}O$
- More energetic hydrologic cycle
- E-P increases in the tropics, decreases in mid-high latitudes (salinity)

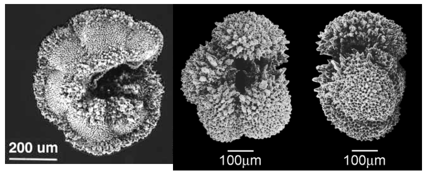
Site 1209 - PETM



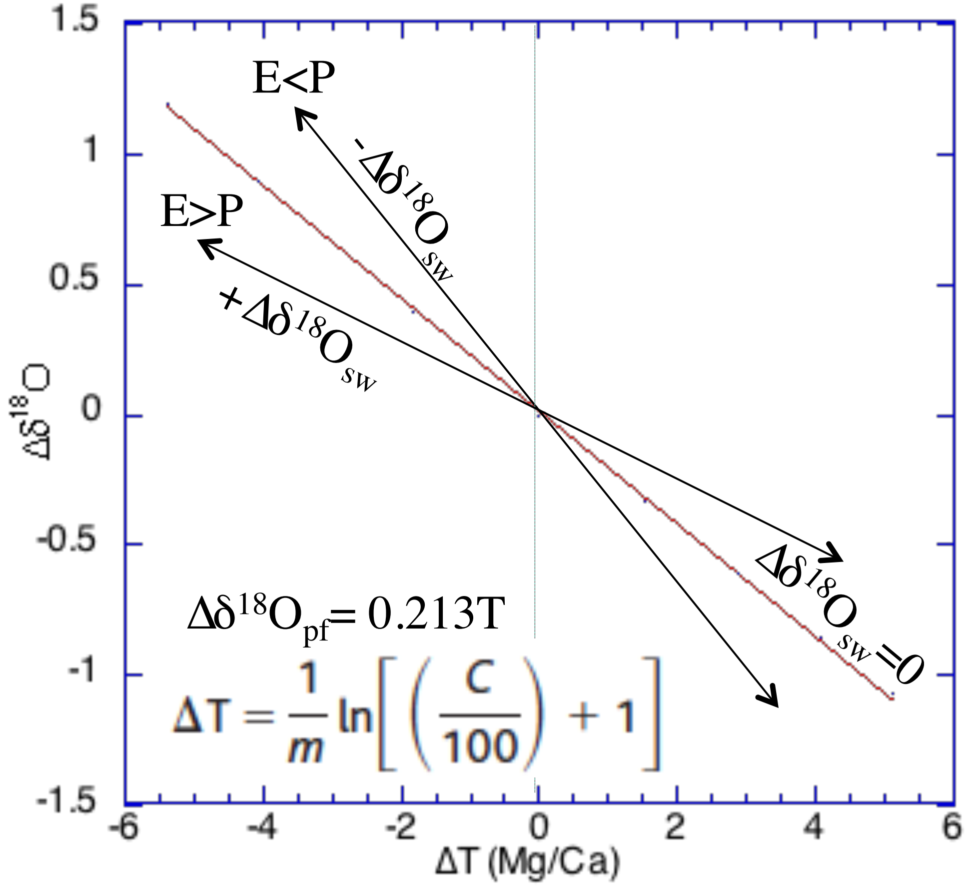
Mixed-layer Planktics record:

Zachos et al., 2003

- 0.7‰ decrease in $\delta^{18}O$
- 50% rise in Mg/Ca



SST/SSS Anomalies
$\Delta Mg/Ca_{pf}$ and $\Delta\delta^{18}O_{pf}$



Increase in sub-tropical SSS (E-P) during the PETM

Site 1209

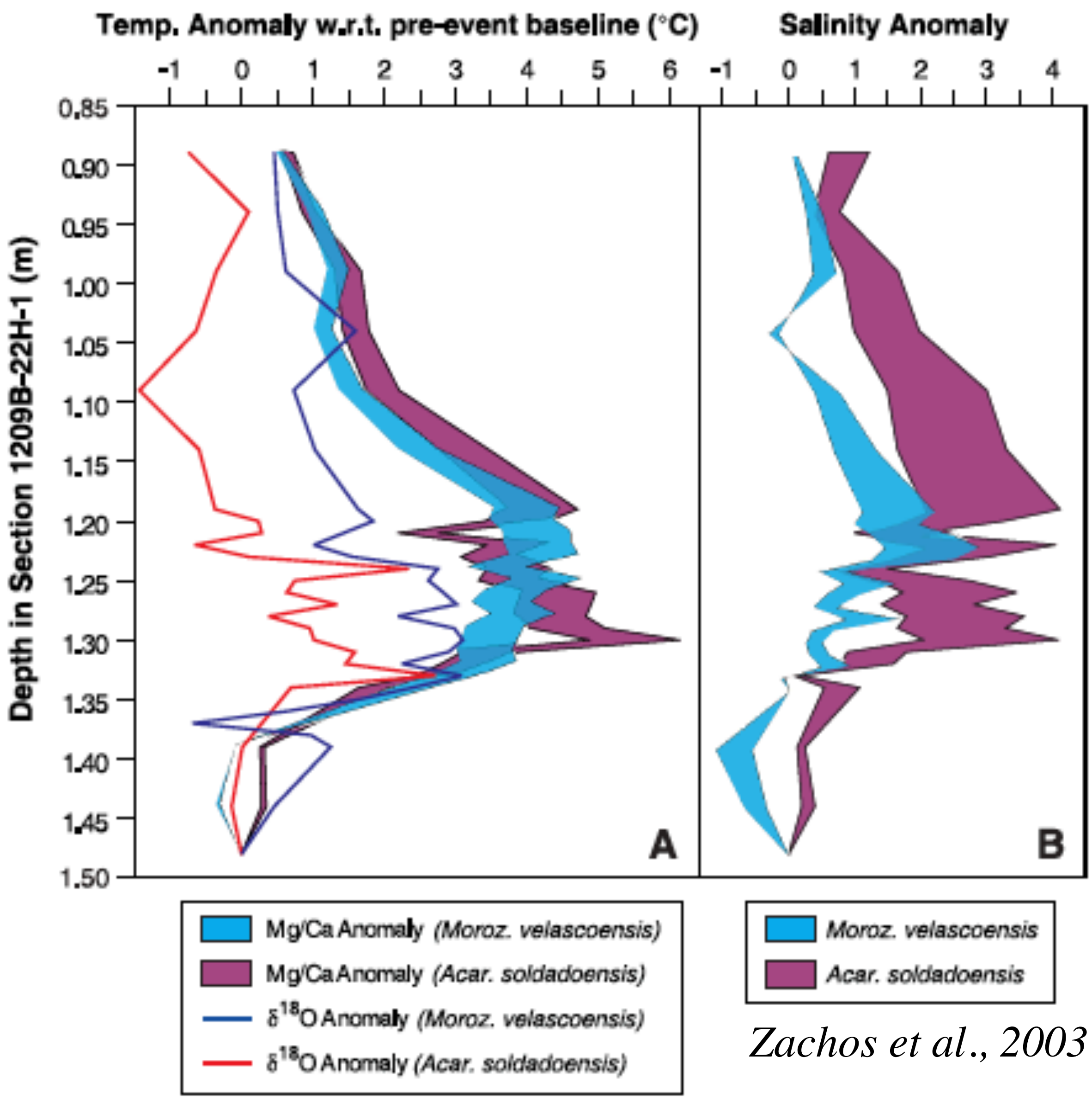
- ΔMg/Ca SST

$$\Delta T = \frac{1}{m}\ln\left[\left(\frac{C}{100}\right)+1\right]$$

m=exp. constant (0.1)
C=%Δ Mg/Ca

$\Delta\delta^{18}O_{sw}/\Delta sal = 0.25$ to 0.50

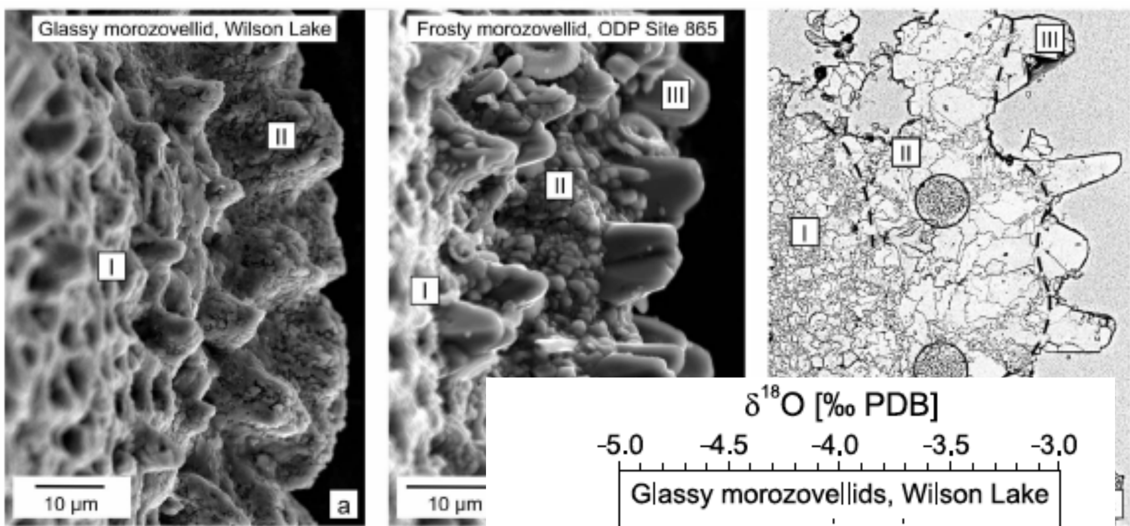
ΔSST= +5 to 6°C
ΔSSS= +2 to 3 ppt

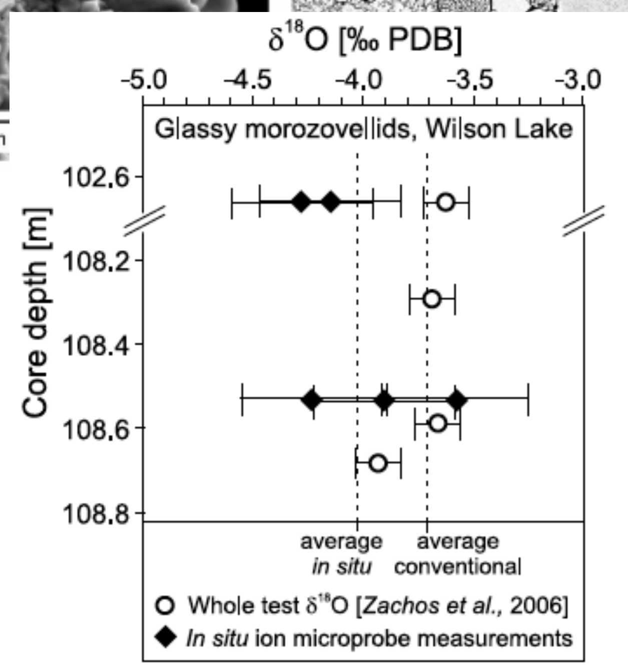


Zachos et al., 2003

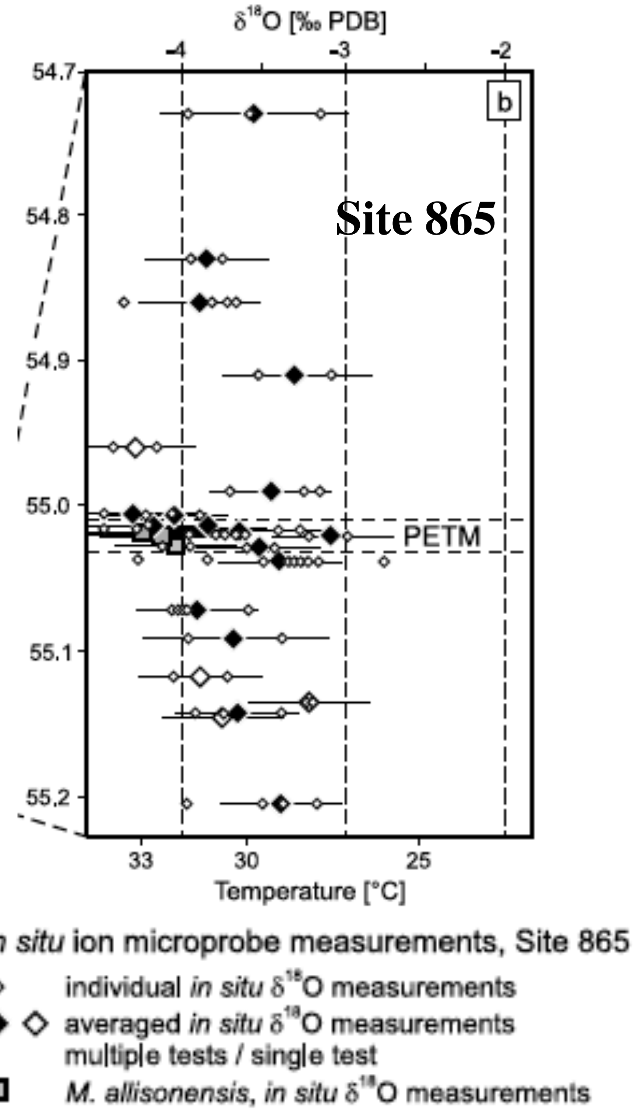
Can the primary ΔMg/Ca and $\Delta\delta^{18}O$ be restored via microprobes?

KOZDON ET AL.: $\delta^{18}O$ IN MURICAE BASES BY ION MICROPROBE

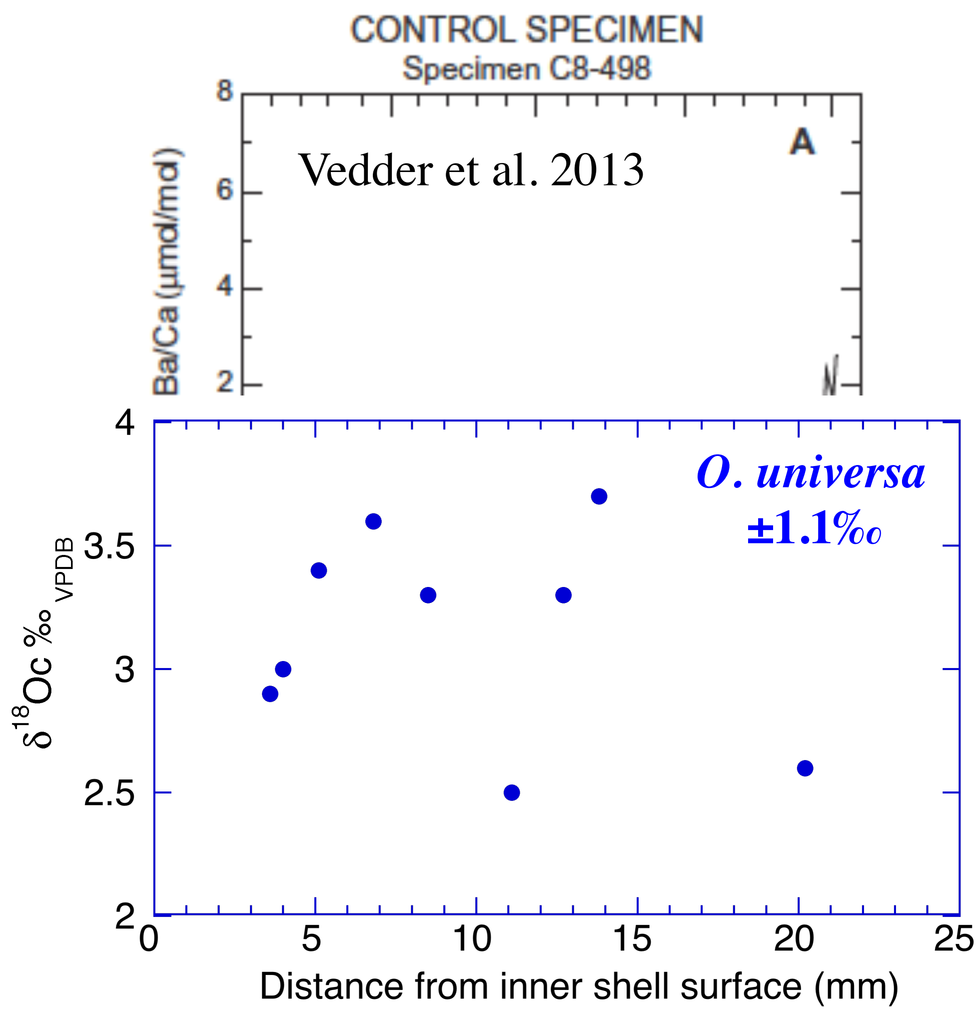




It appears so….



Can the changes in ΔMg/Ca and $\Delta\delta^{18}O$ as influenced by <u>seasonal cycles</u> in SST/SSS be reconstructed using microsampling?

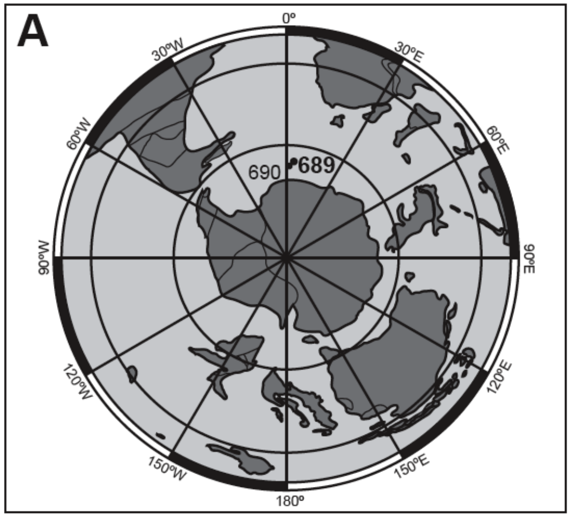


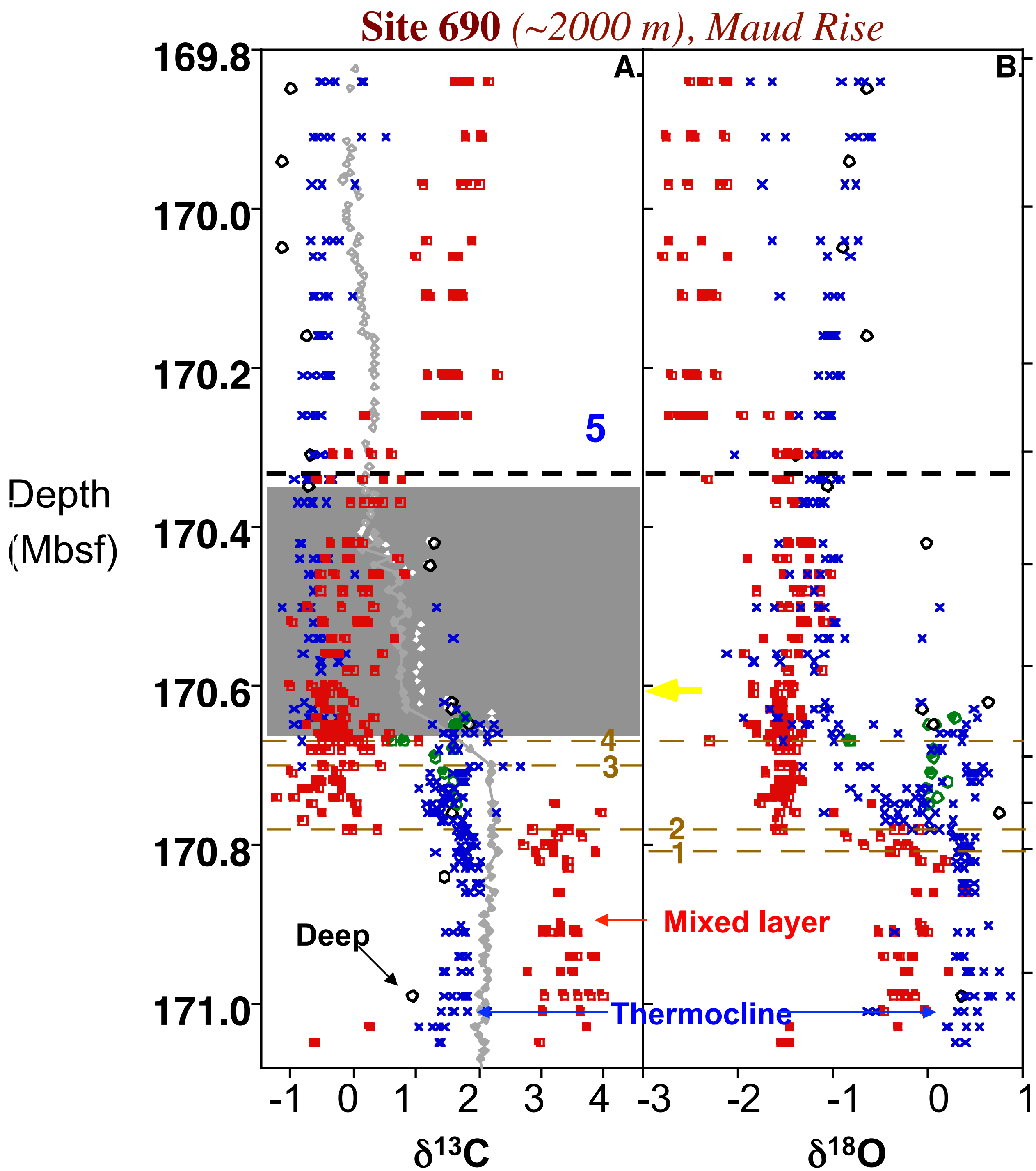
Some basic requirements

<u>Co-eval Mg/Ca & $\delta^{18}O$</u>

<u>Temporal resolution</u>

- weekly/monthly?
- micro-, whole shell, and/or multi-shell sampling
- precision vs. accuracy- statistical requirements





Single shell isotopes

- Mixed Layer Plank.
- Thermocline Plank.
- Benthic Foraminifera

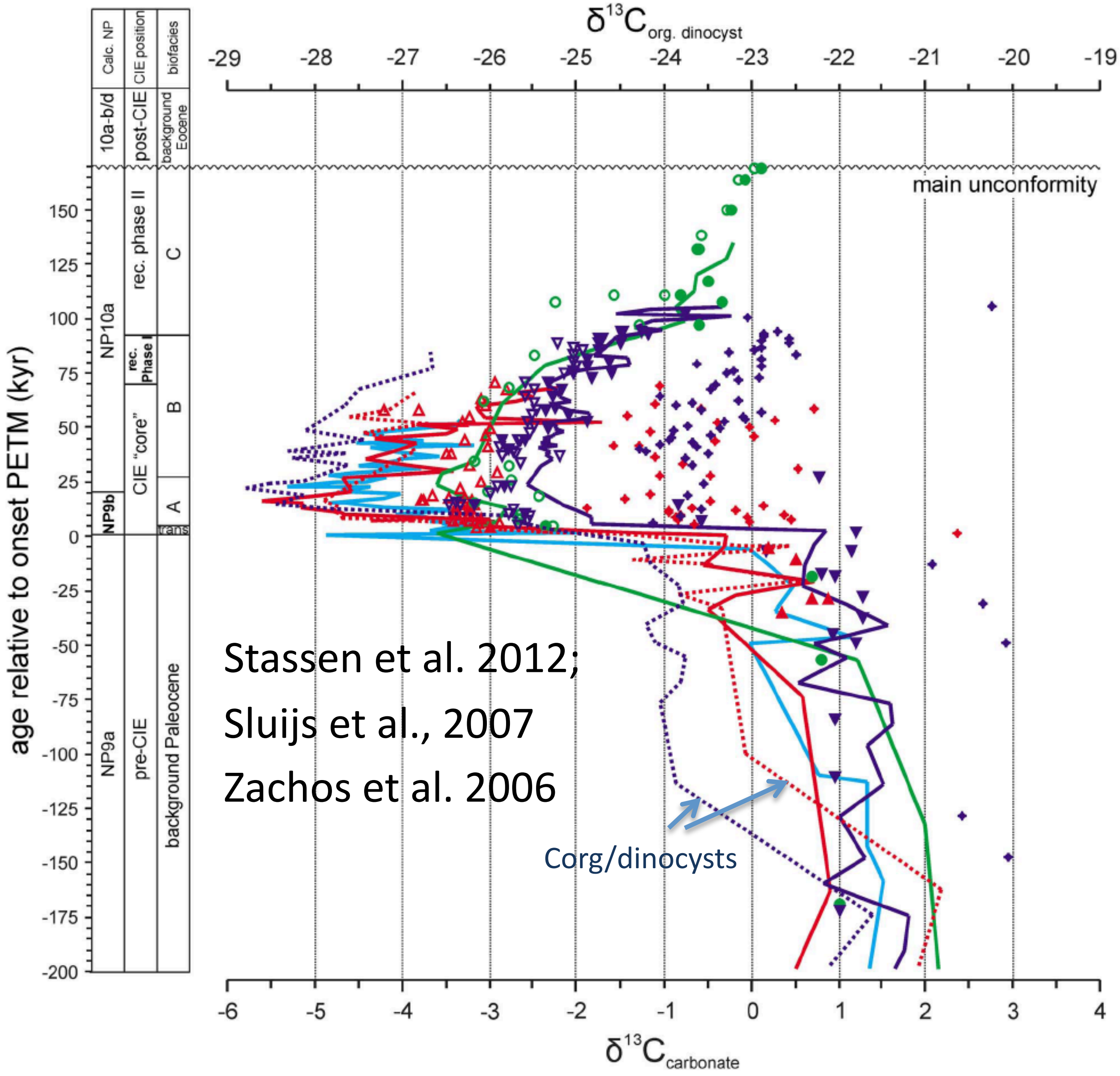
Thomas et al. 2002

$\Delta\delta^{18}O_{pf} = -2.2‰$

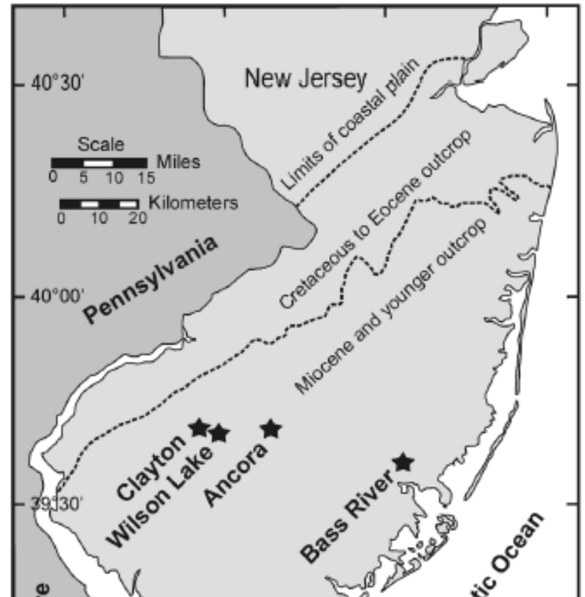
$\Delta T = +5\text{-}6°C$

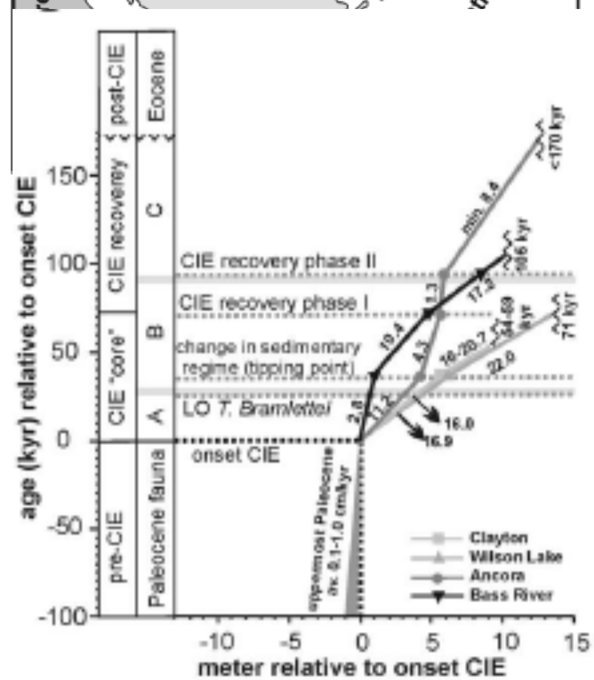
$\Delta\delta^{18}O_{sw} = -0.8‰$

PETM/CIE –NJ coastal sections

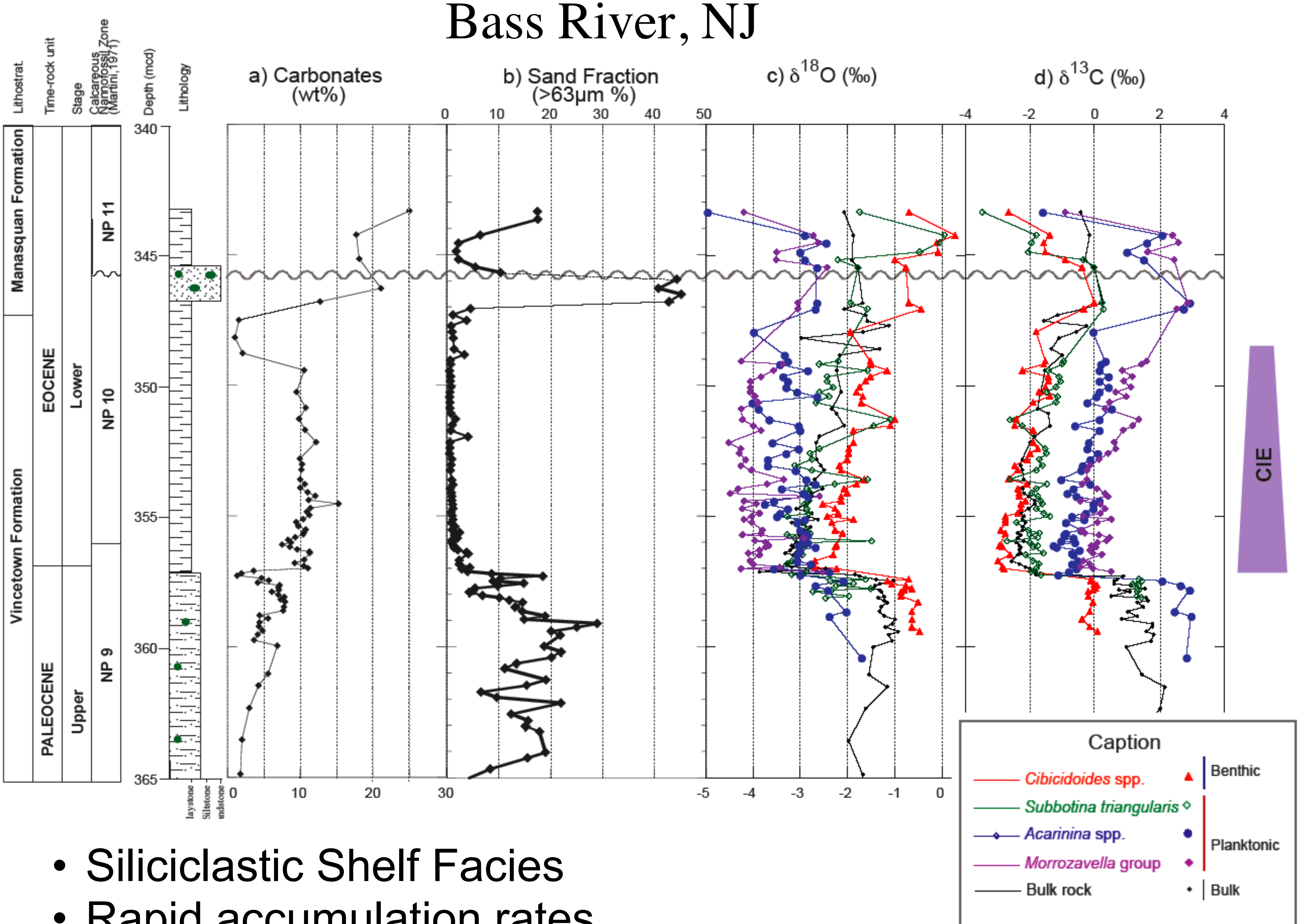


Stassen et al. 2012;
Sluijs et al., 2007
Zachos et al. 2006





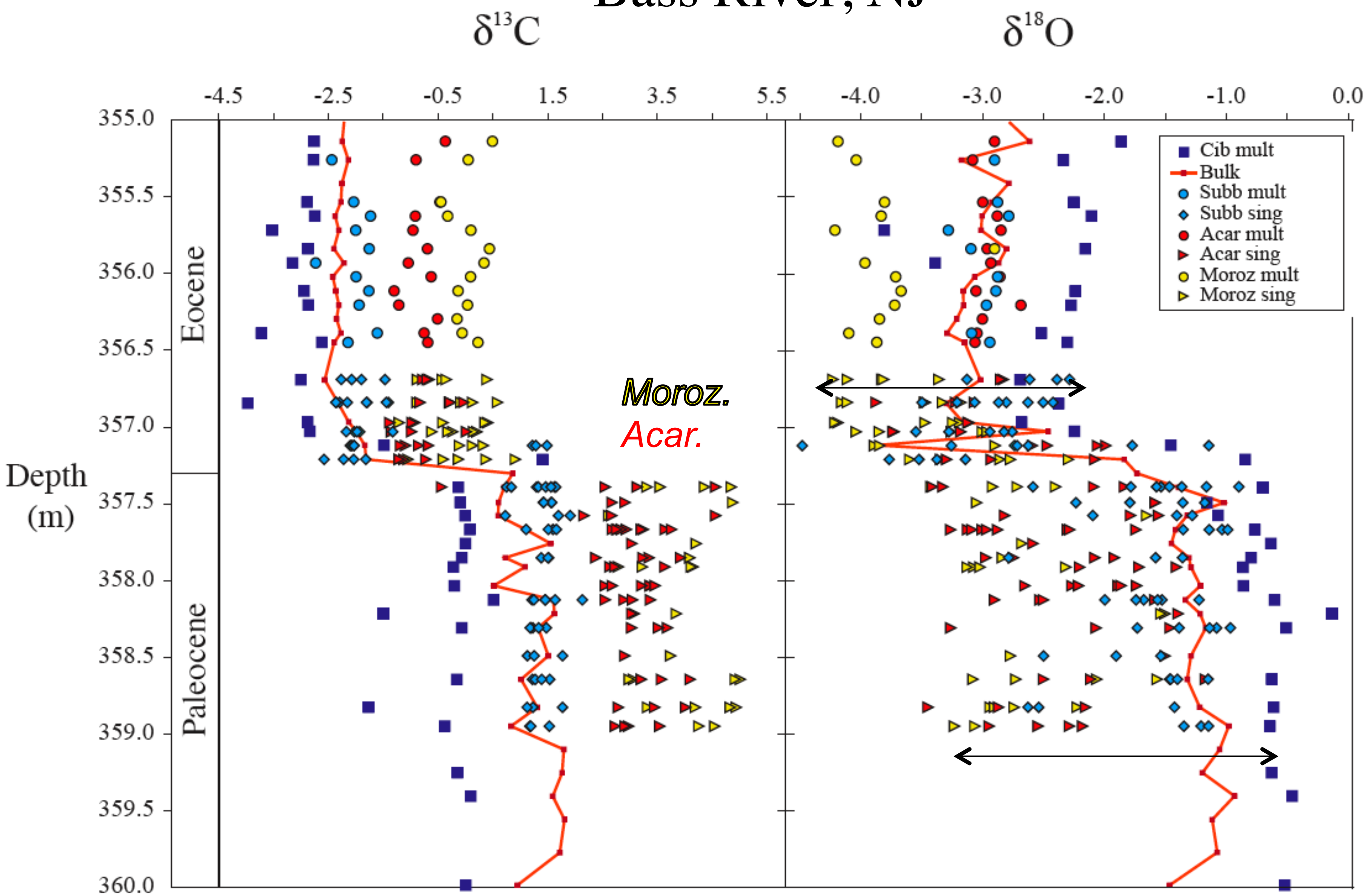
Bass River, NJ



- Siliciclastic Shelf Facies
- Rapid accumulation rates

John et al., 2008

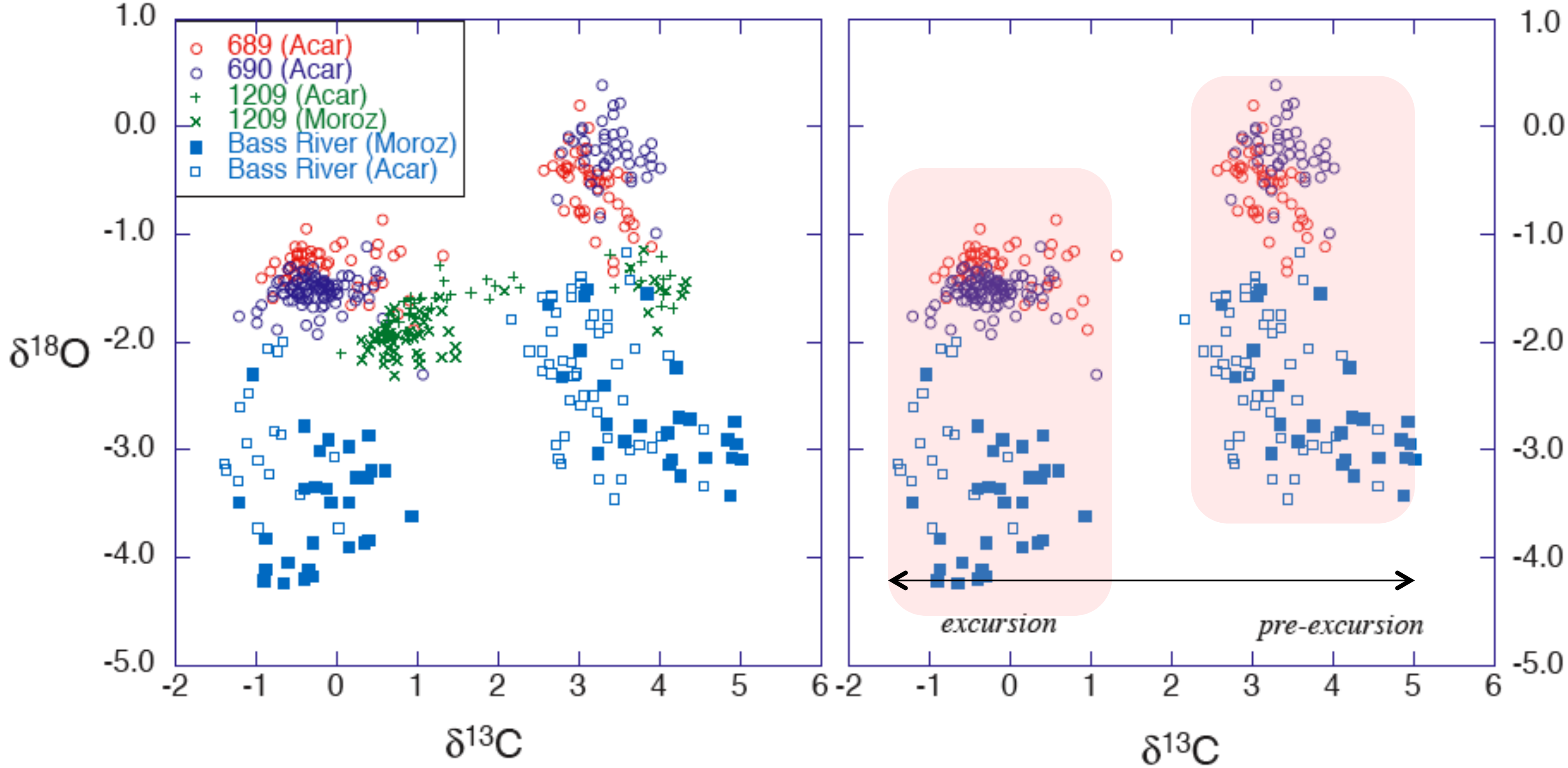
Bass River, NJ



- Multiple/Single Shell Isotope Series
- Δ in seasonal SST/SSS range?

Zachos et al. (2007)

P-E Single Shell Isotope Data: Magnitude of the CIE?



- couple Mg/Ca with $\delta^{18}O$ to constrain relative SST/SSS

Zachos et al. (2007)