

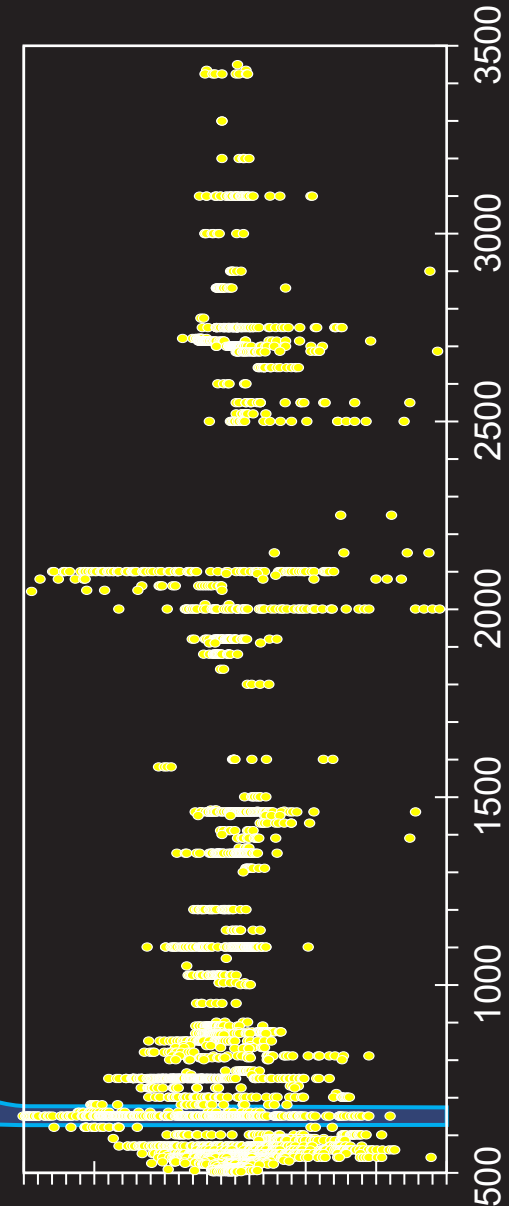
AGU Fall 2016

# What do carbonate $\delta^{13}\text{C}$ variations tell us ?

(about the evolution of the marine environmental conditions vs. life)

Andy Ridgwell

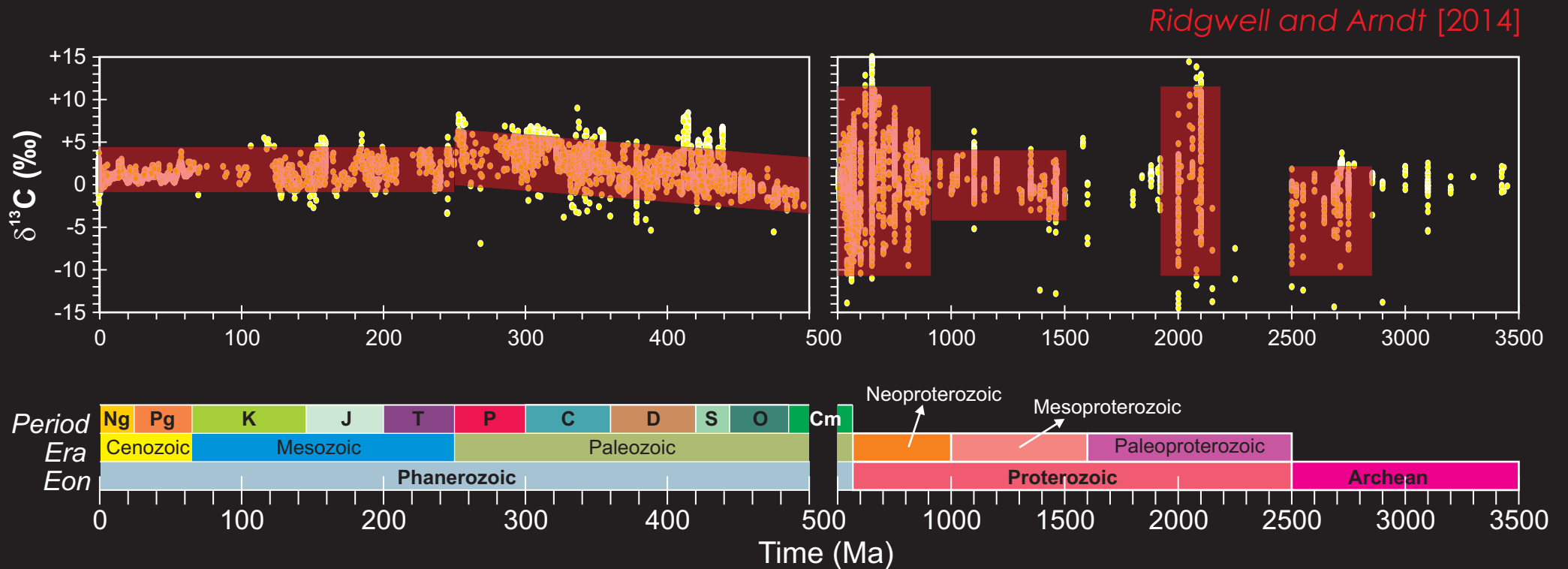
University of California – Riverside  
University of Bristol



# Carbonate $\delta^{13}\text{C}$ variability through time




what exactly does it (temporal changes in  $\delta^{13}\text{C}$ ) mean?







*what exactly does it (temporal changes in  $\delta^{13}\text{C}$ ) mean?*

 Re-partitioning of carbon between surficial reservoirs (cf. LGM)?

 Injection (or removal) of isotopically light carbon?

 Change in  $\text{C}_{\text{org}}$  weathering and/or burial  
(at fixed carbonate weathering / burial)?

 Change in carbonate weathering and/or burial  
(at fixed  $\text{C}_{\text{org}}$  weathering / burial)?

 Carbonate diagenesis and loss of primary  $\delta^{13}\text{C}$  signal, either  
marine sedimentary or sub-aerial.

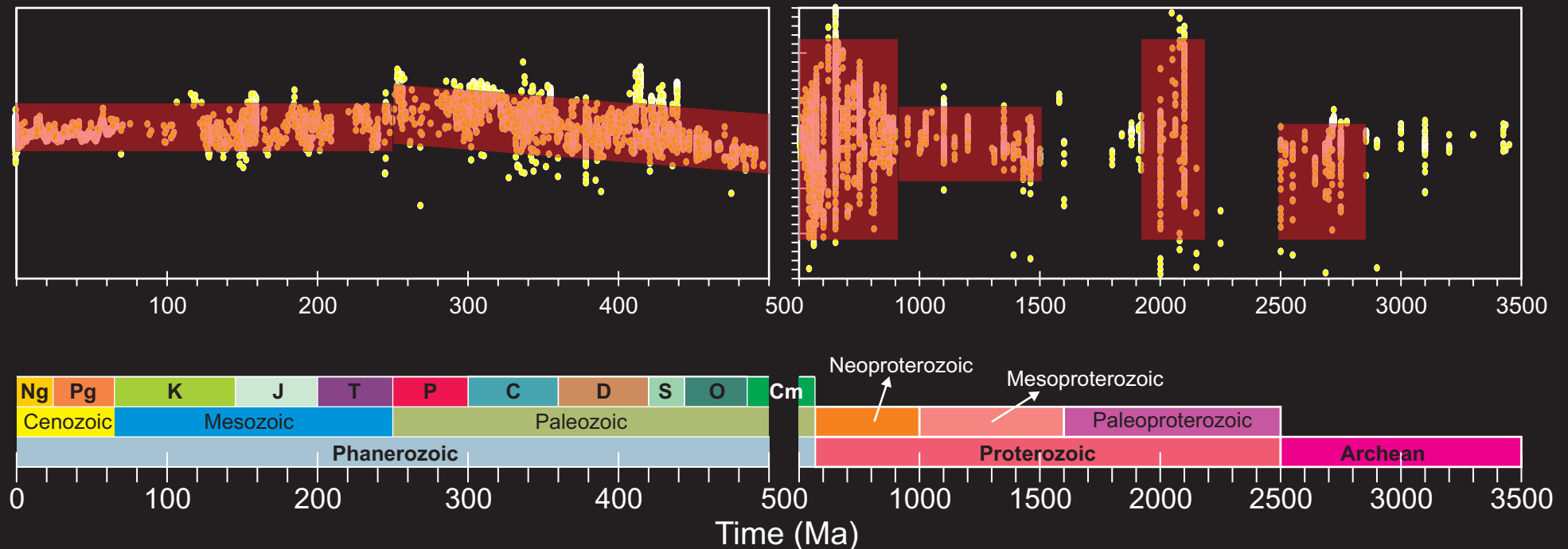
# Carbonate $\delta^{13}\text{C}$ variability through time



what exactly does it (temporal changes in  $\delta^{13}\text{C}$ ) mean?

 Re-partitioning of carbon between surficial reservoirs (cf. LGM)?

*Ridgwell and Arndt [2014]*




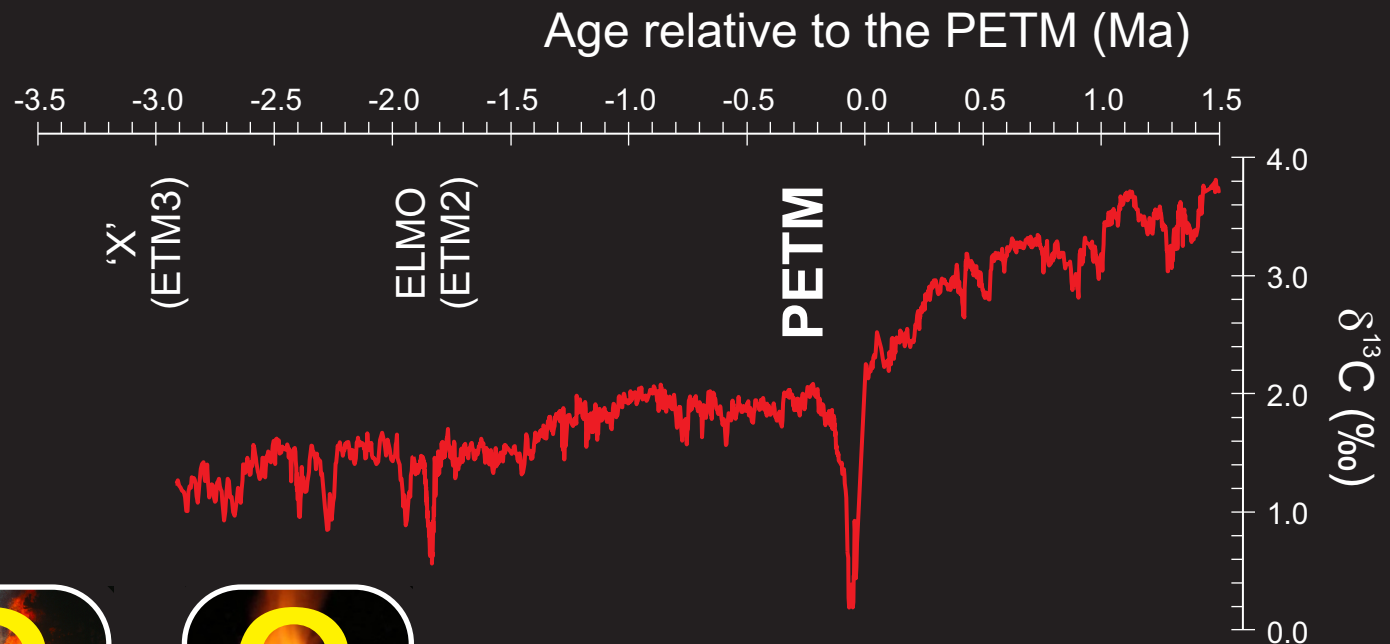
# Carbonate $\delta^{13}\text{C}$ variability through time



what exactly does it (temporal changes in  $\delta^{13}\text{C}$ ) mean?

 Re-partitioning of carbon between surficial reservoirs (cf. LGM)?

 Injection (or removal) of isotopically light carbon?




Zachos et al. [2010]  
Lunt et al. [2011]



*what exactly does it (temporal changes in  $\delta^{13}\text{C}$ ) mean?*

 Re-partitioning of carbon between surficial reservoirs (cf. LGM)?

 Injection (or removal) of isotopically light carbon?

 Change in  $C_{\text{org}}$  weathering and/or burial  
(at fixed carbonate weathering / burial)?

 Change in carbonate weathering and/or burial  
(at fixed  $C_{\text{org}}$  weathering / burial)?

One can write (*Kump and Arthur [1999], Chem. Geol.*):

$$F_{\text{Corg}} / (F_{\text{Corg}} + F_{\text{CaCO}_3}) = \left. \vphantom{F_{\text{Corg}} / (F_{\text{Corg}} + F_{\text{CaCO}_3})} \right\} \text{C burial ratio}$$

$$(\delta^{13}\text{C}_{\text{obs}} - \delta^{13}\text{C}_{\text{input}}) / (\delta^{13}\text{C}_{\text{CaCO}_3} - \delta^{13}\text{C}_{\text{Corg}})$$

observed (recorded) carbonate  $\delta^{13}\text{C}$


-5.0

25.0




*what exactly does it (temporal changes in  $\delta^{13}\text{C}$ ) mean?*

 Re-partitioning of carbon between surficial reservoirs (cf. LGM)?

 Injection (or removal) of isotopically light carbon?

 Change in  $\text{C}_{\text{org}}$  weathering and/or burial  
(at fixed carbonate weathering / burial)?

 Change in carbonate weathering and/or burial  
(at fixed  $\text{C}_{\text{org}}$  weathering / burial)?

 Carbonate diagenesis and loss of primary  $\delta^{13}\text{C}$  signal, either marine sedimentary or sub-arial.





*what exactly does it (temporal changes in  $\delta^{13}\text{C}$ ) mean?*


 Re-partitioning of carbon between surficial reservoirs (cf. LGM)?

 Injection (or removal) of isotopically light carbon?

 Change in  $\text{C}_{\text{org}}$  weathering and/or burial  
(at fixed carbonate weathering / burial)?

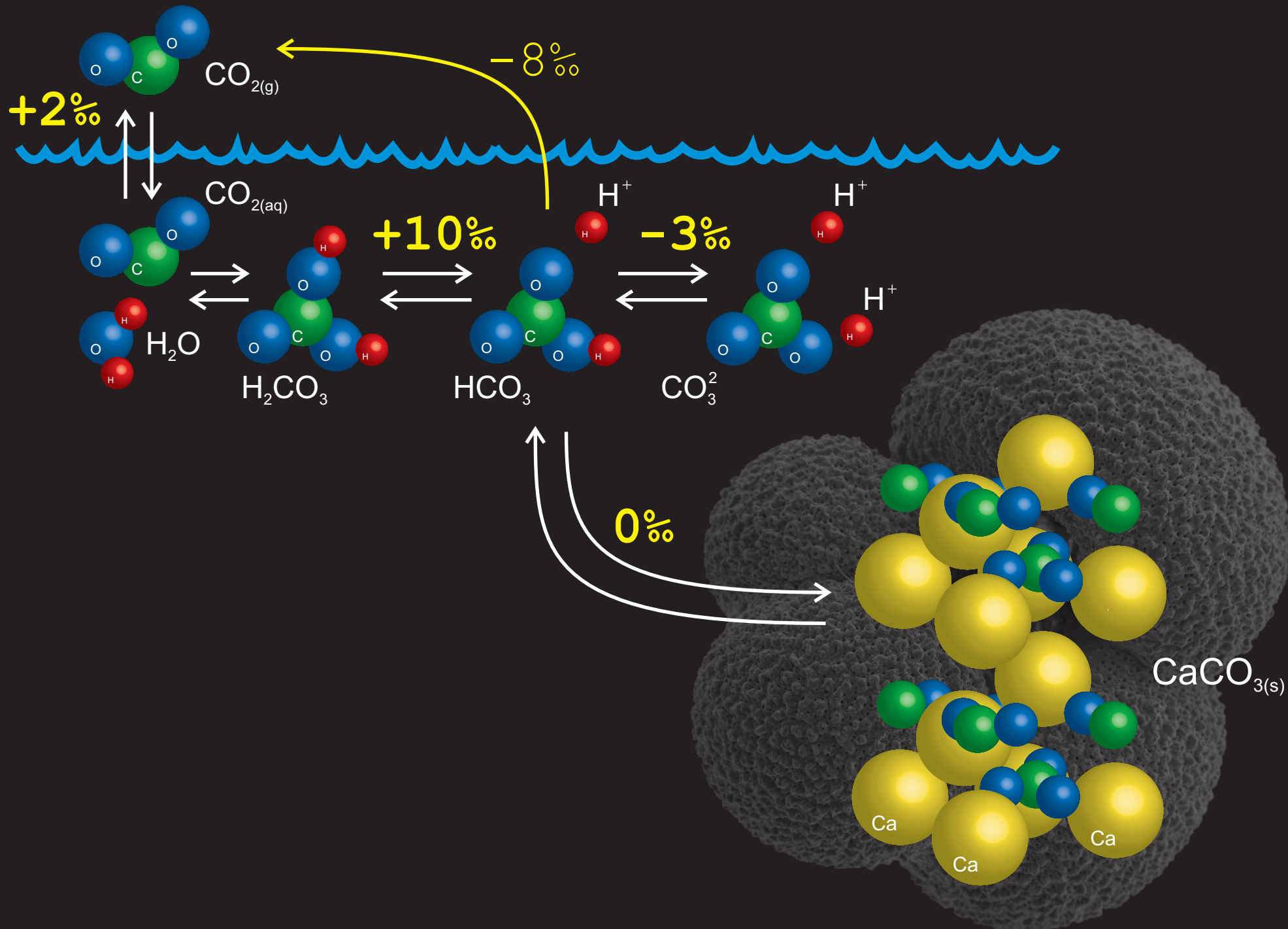
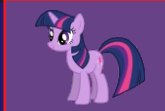
 Change in carbonate weathering and/or burial  
(at fixed  $\text{C}_{\text{org}}$  weathering / burial)?

 Carbonate diagenesis and loss of primary  $\delta^{13}\text{C}$  signal, either  
marine sedimentary or sub-arial.

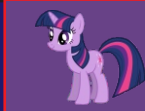
 pH-driven re-partitioning of the where the isotopic composition  
of the mean surficial reservoir is held  
(and what carbonate samples)



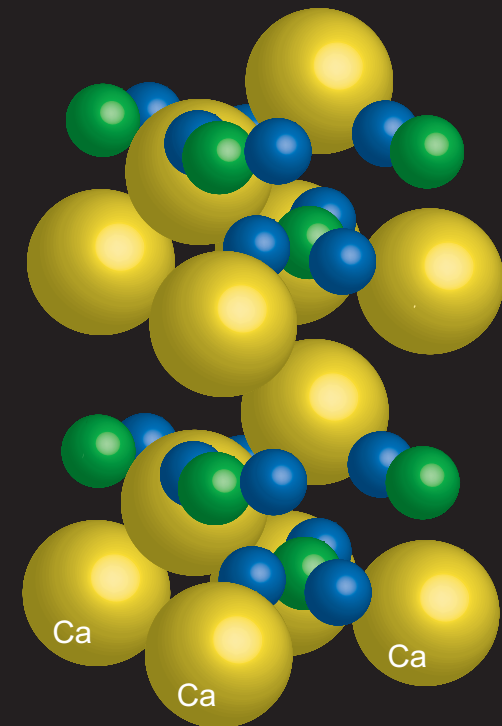
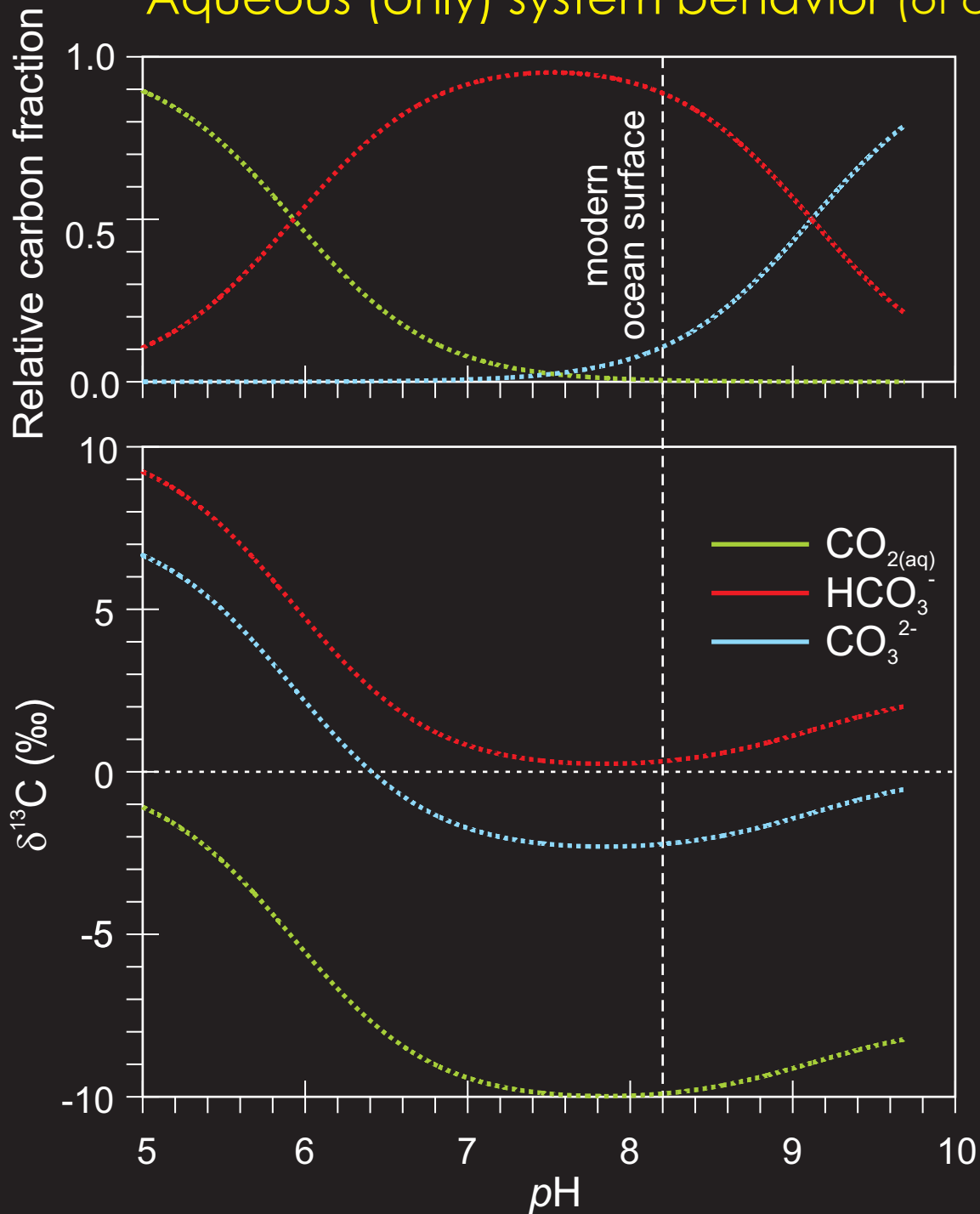
# A new paleo Pokémon appears – The pH control on carbonate $\delta^{13}\text{C}$

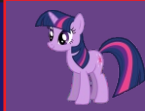


Adapted from: *Barker and Ridgwell [2012]*

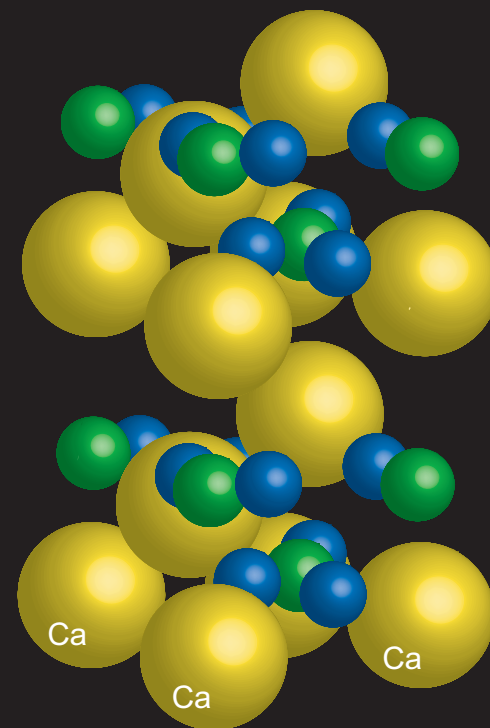
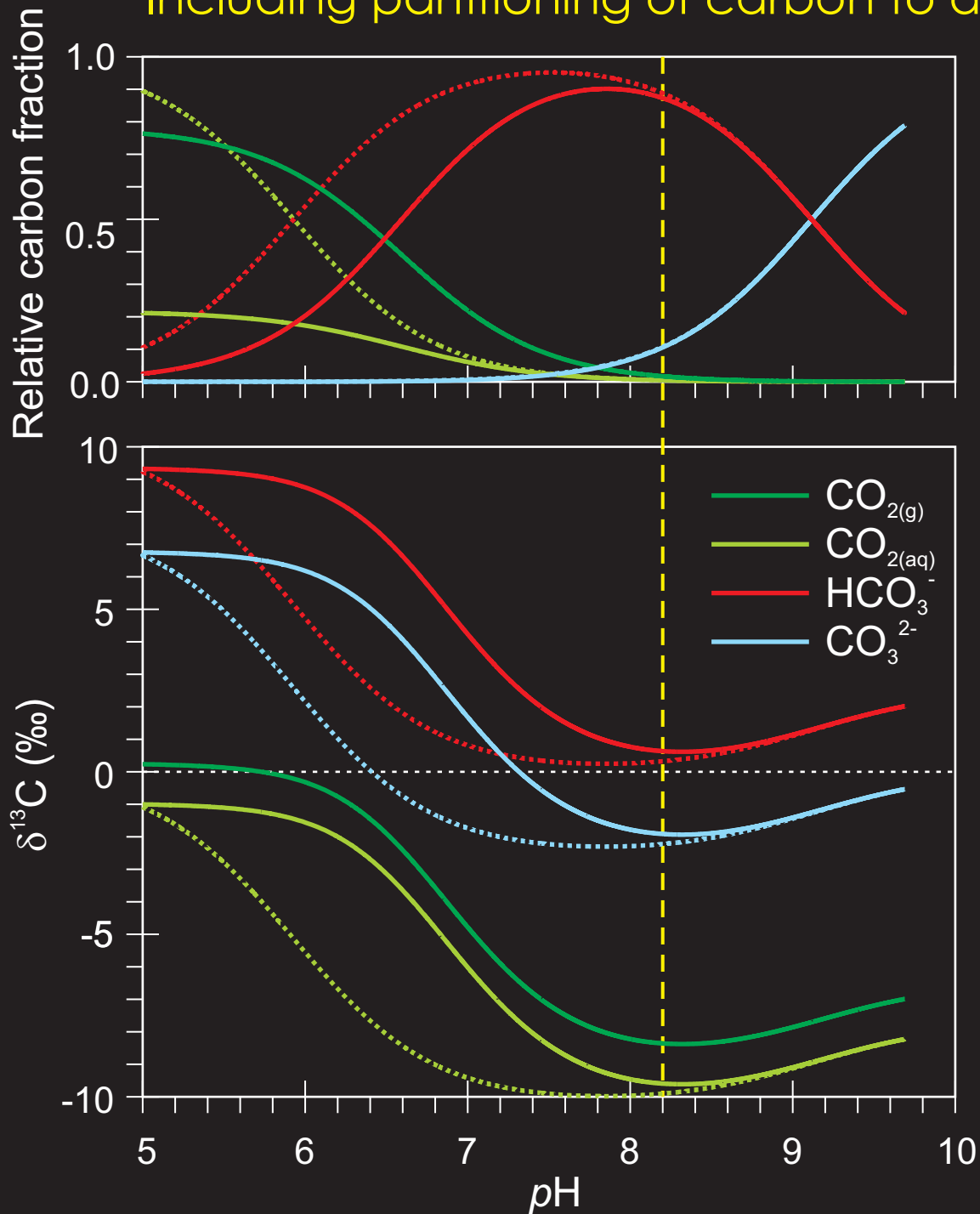


Aqueous (only) system behavior (of carbon partitioning between reservoirs)



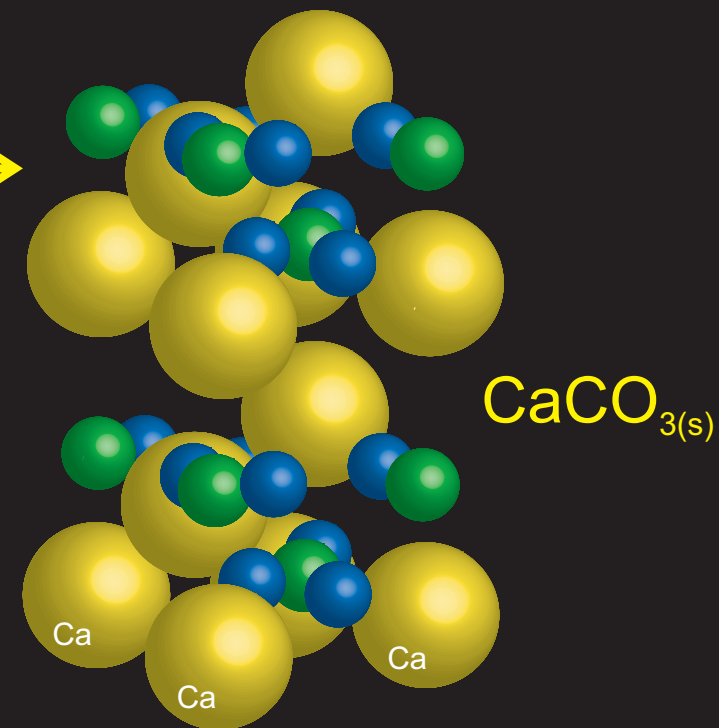
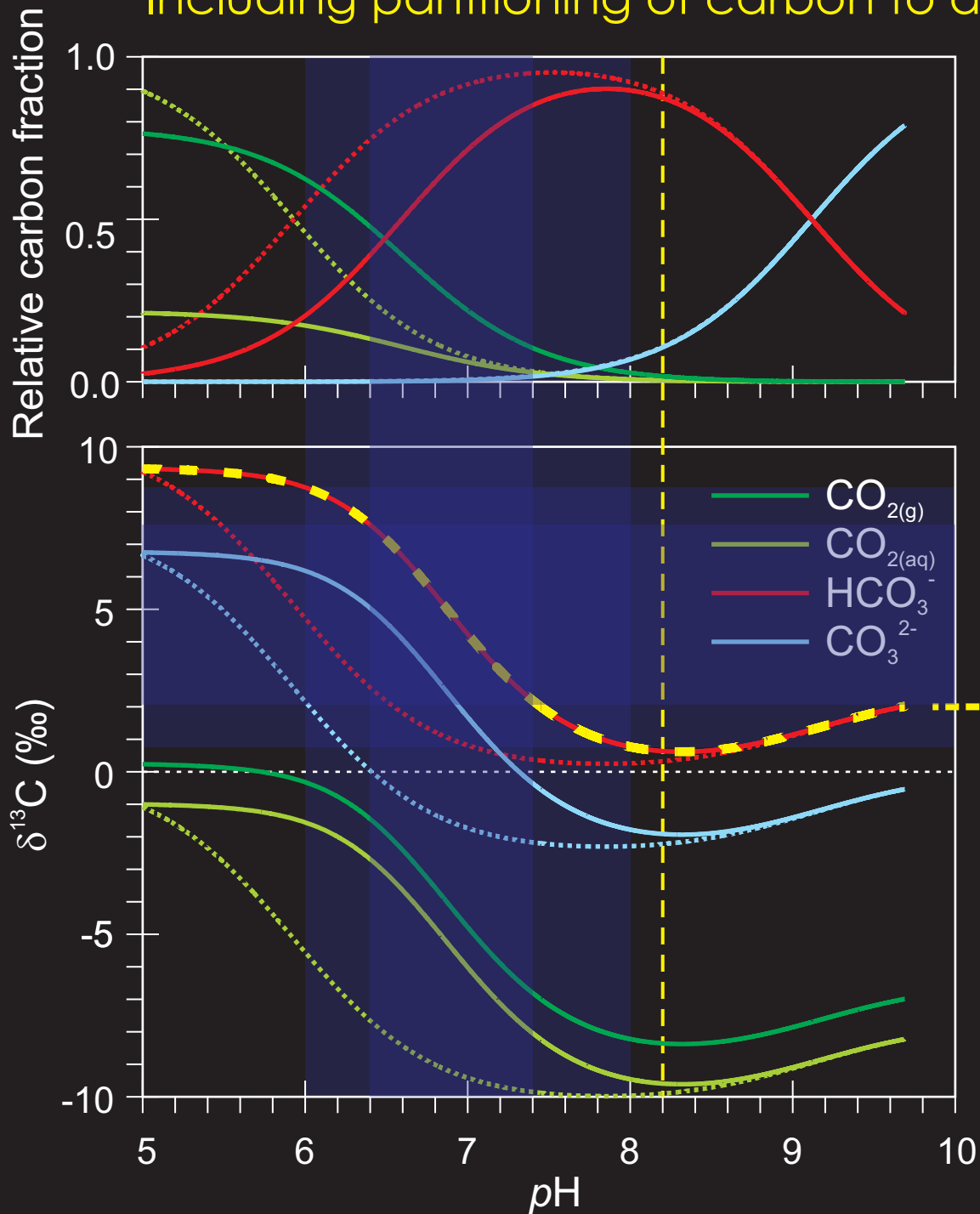


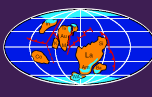
Including partitioning of carbon to atmosphere



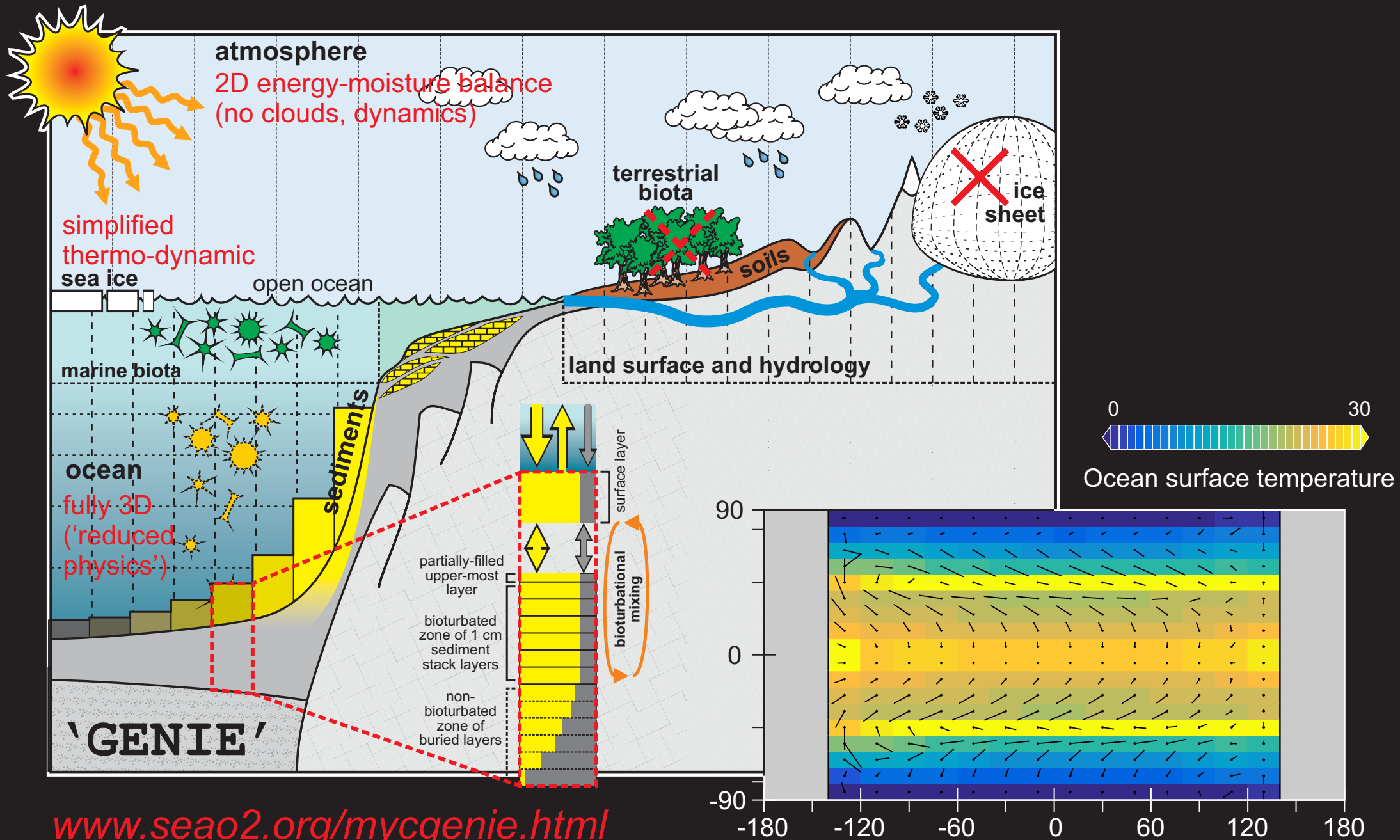


Including partitioning of carbon to atmosphere



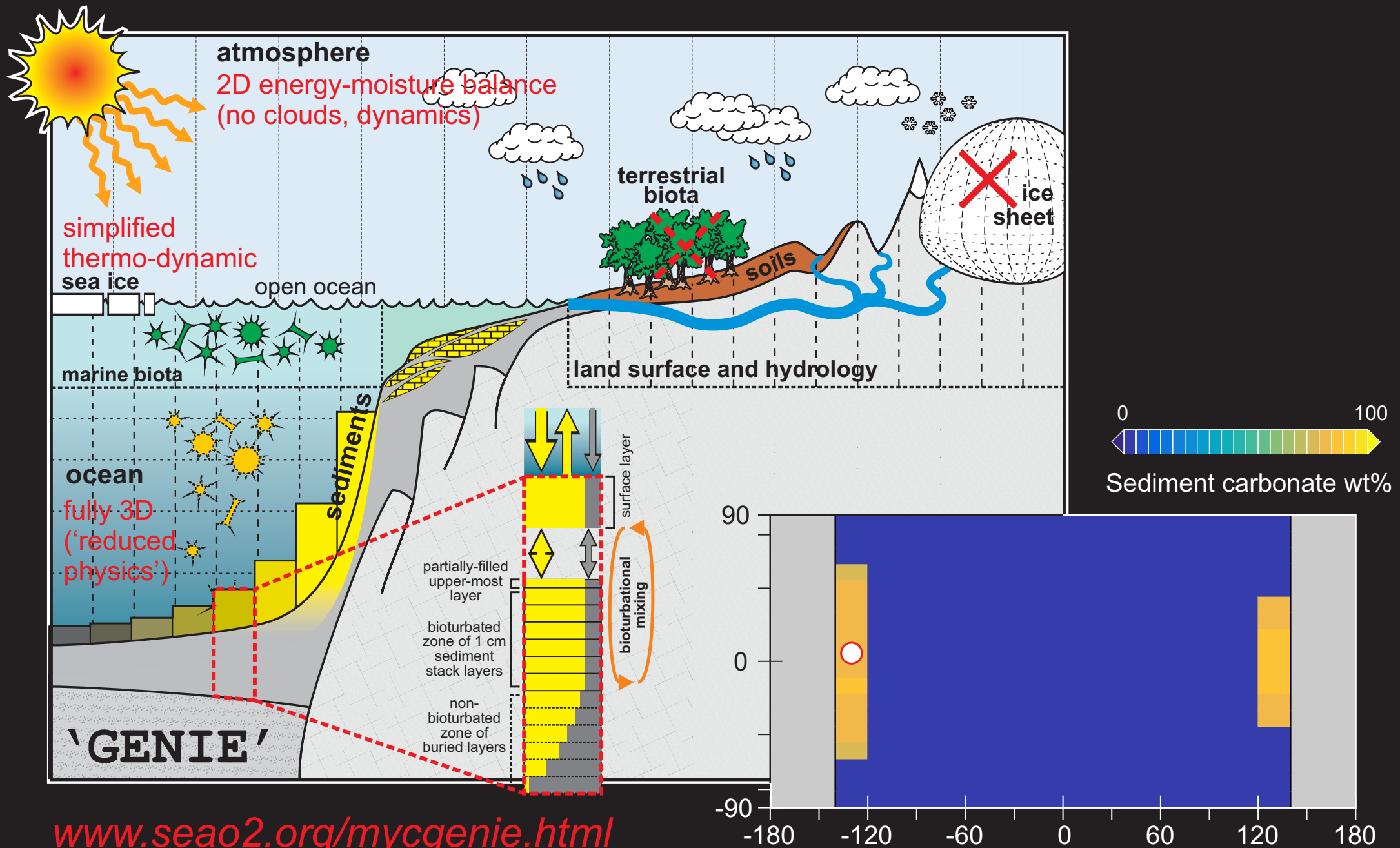


## Earth system model – physical configuration



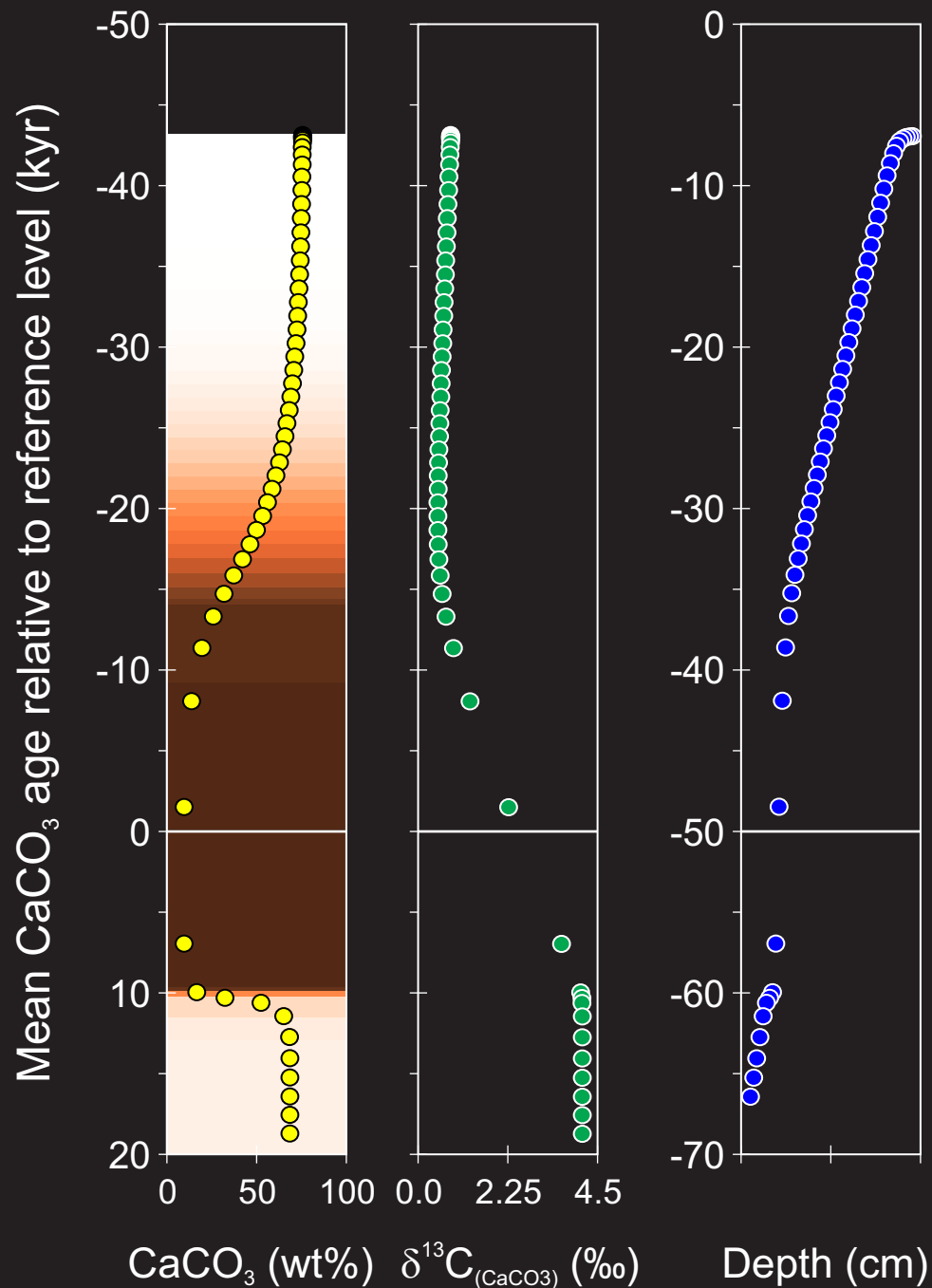


## Earth system model – carbon cycle (sedimentary) configuration

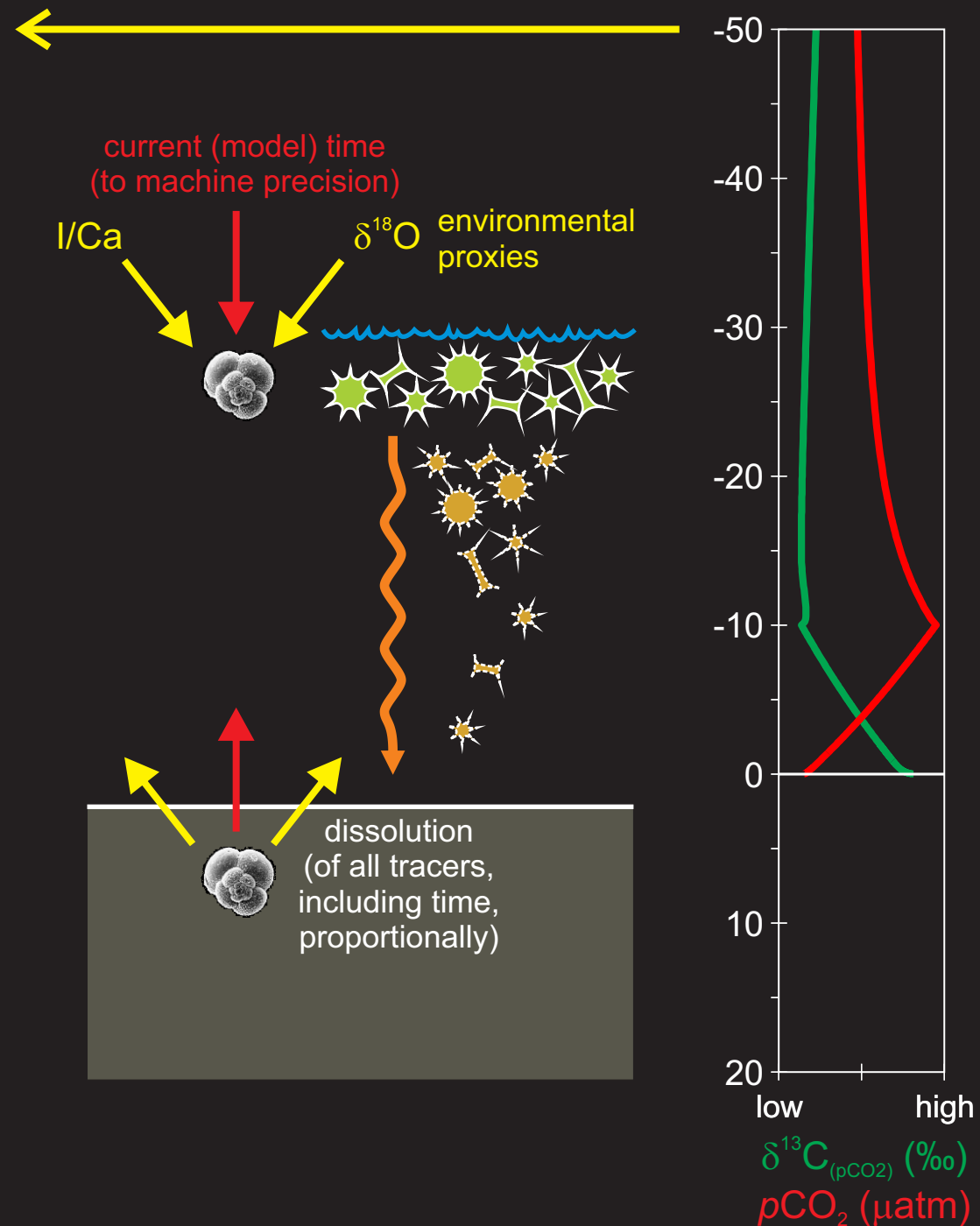




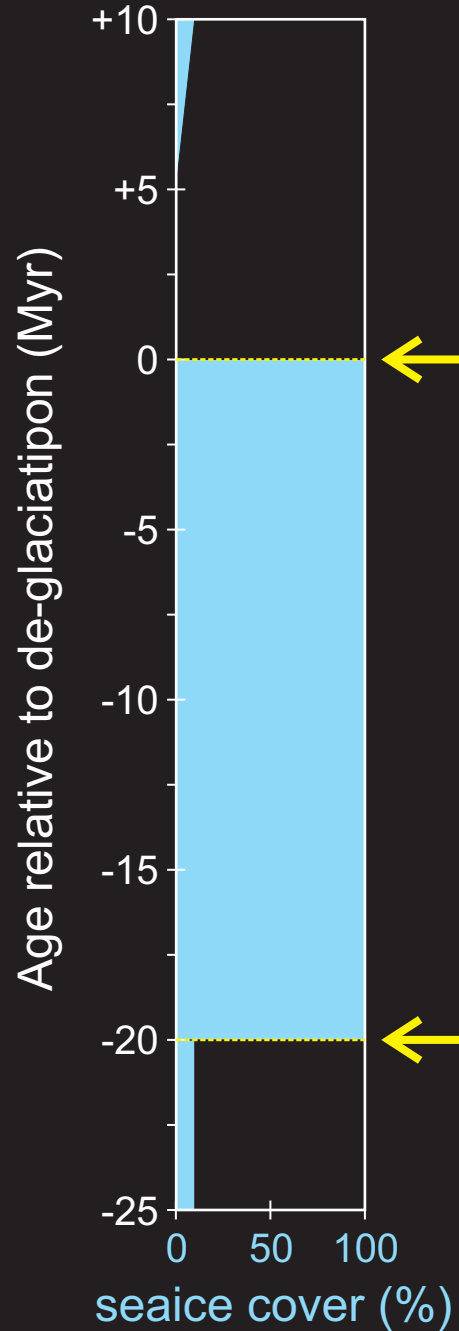
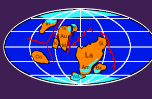
## realized (model) sediment record



## (model) environment



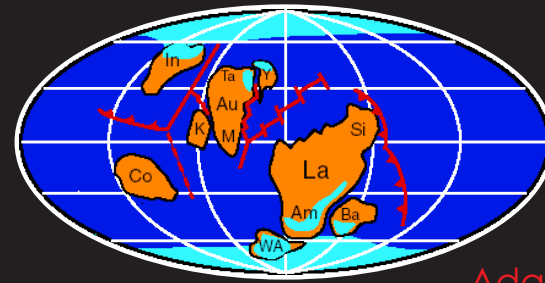
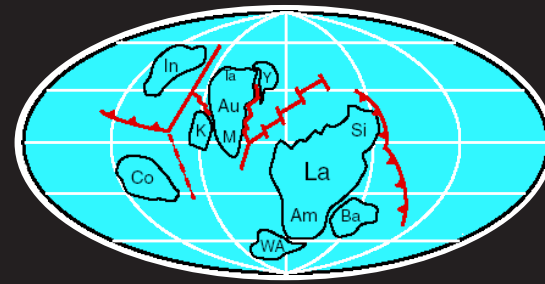
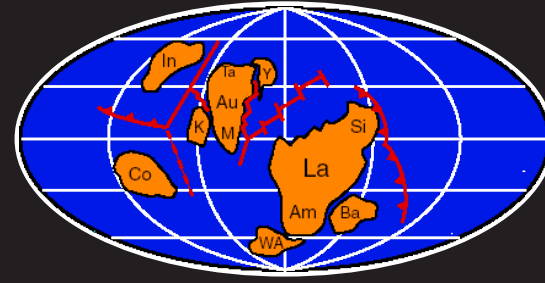
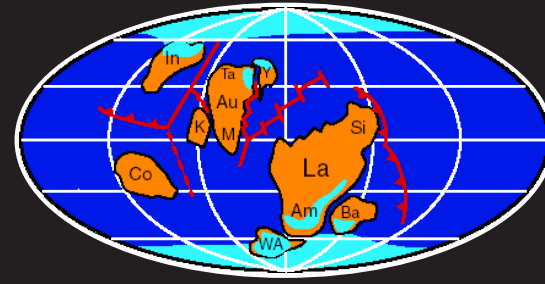
# Numerical modelling – Approach



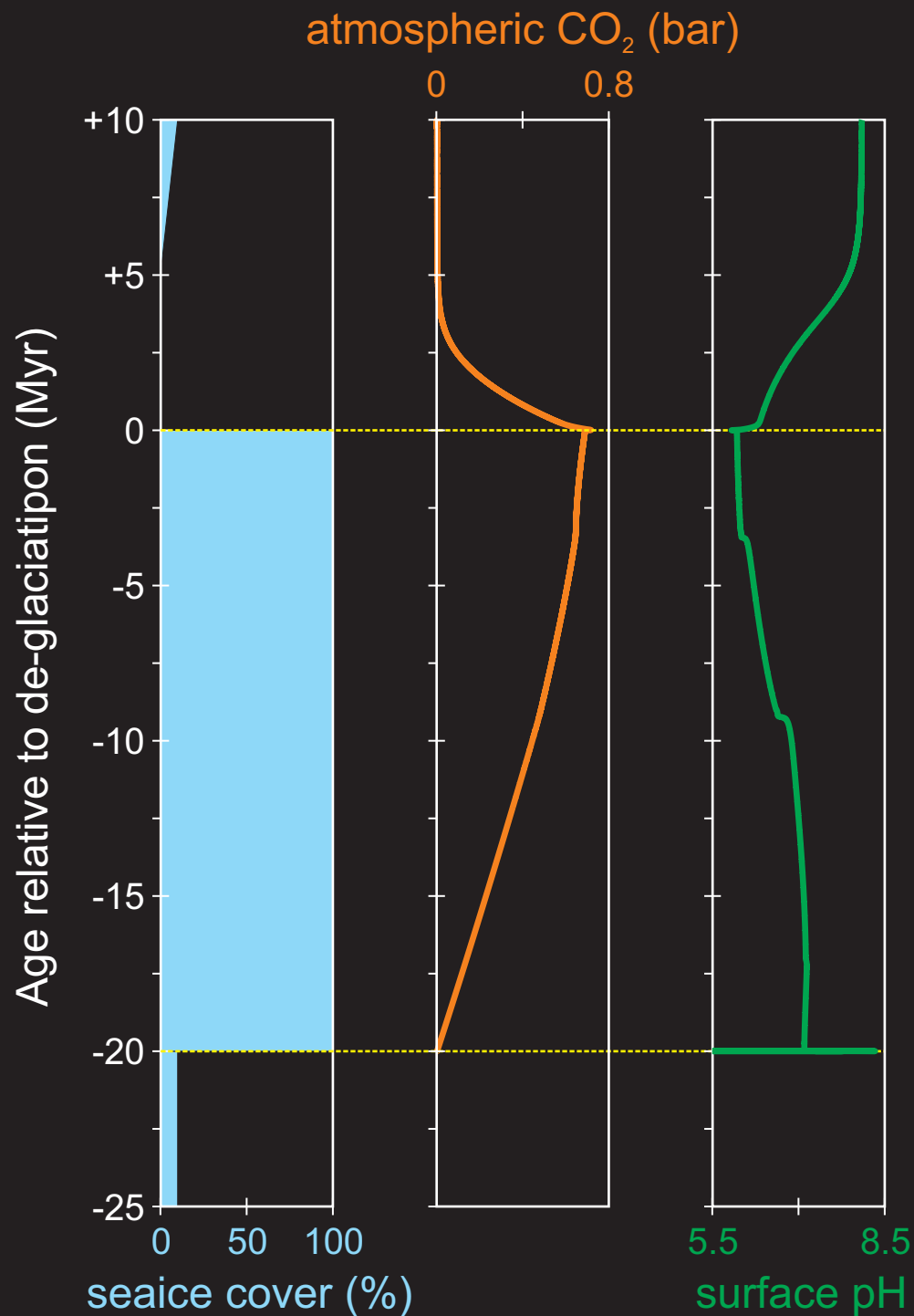
← de-glaciation

← glaciation

time ↑

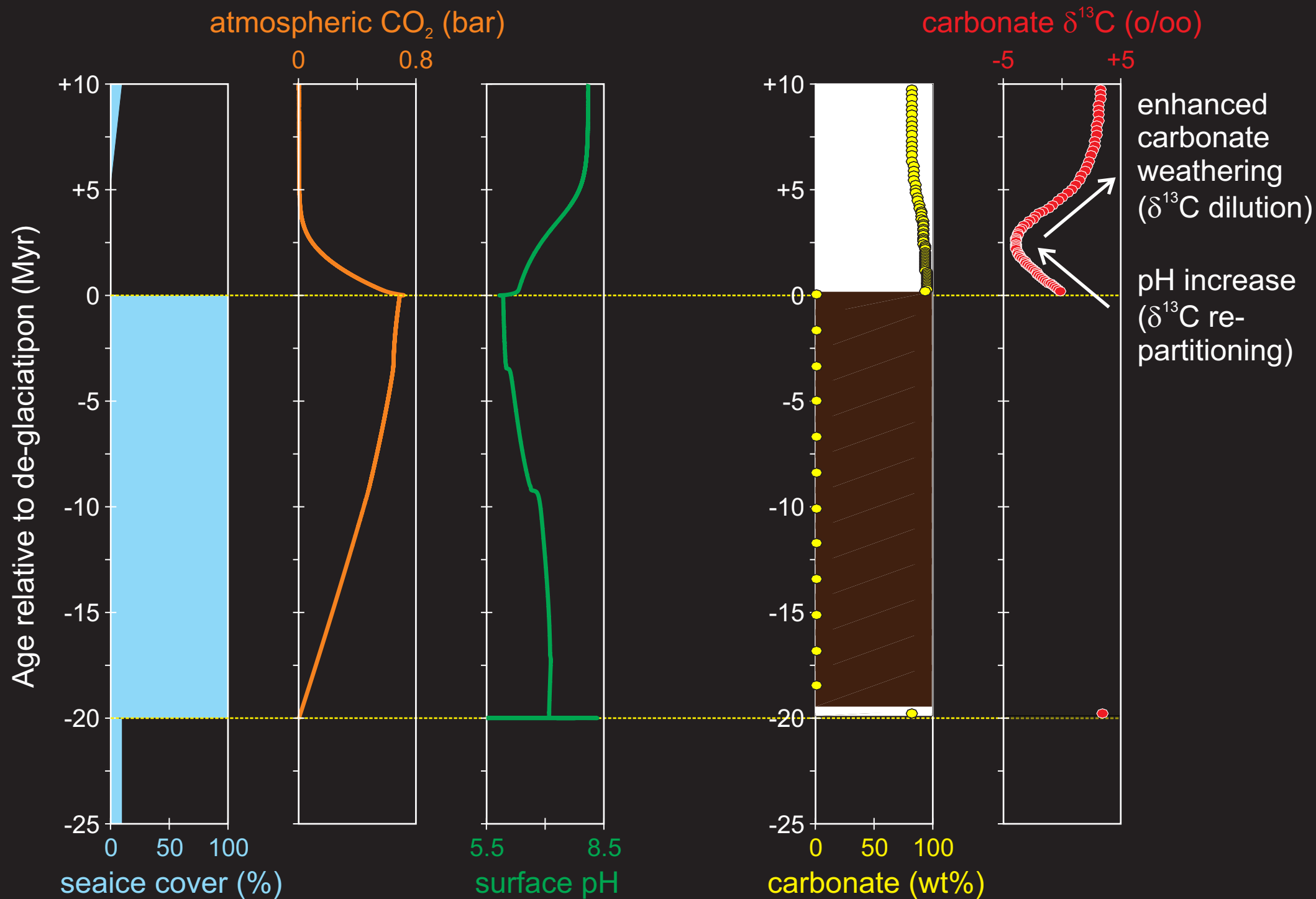






Enhanced weathering  
⇒ CO<sub>2</sub> draw-down  
and pH increase

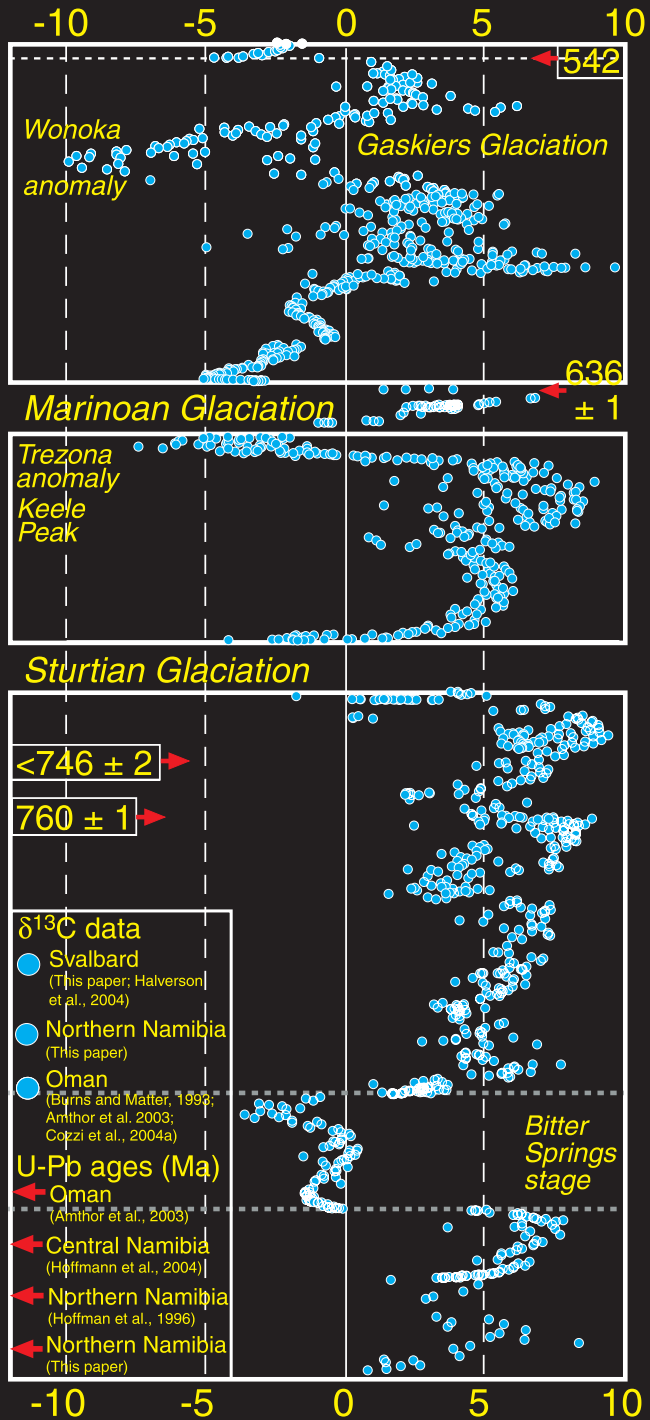
Continued CO<sub>2</sub> out-gassing  
but ... minimal weathering  
⇒ CO<sub>2</sub> buildup @ -6 o/oo  
and ocean pH decline



# Deep-time inferences (aka 'speculation')



## Neoproterozoic composite $\delta^{13}\text{C}$ record



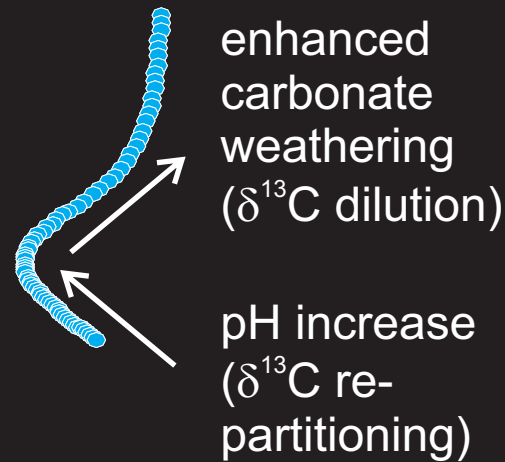
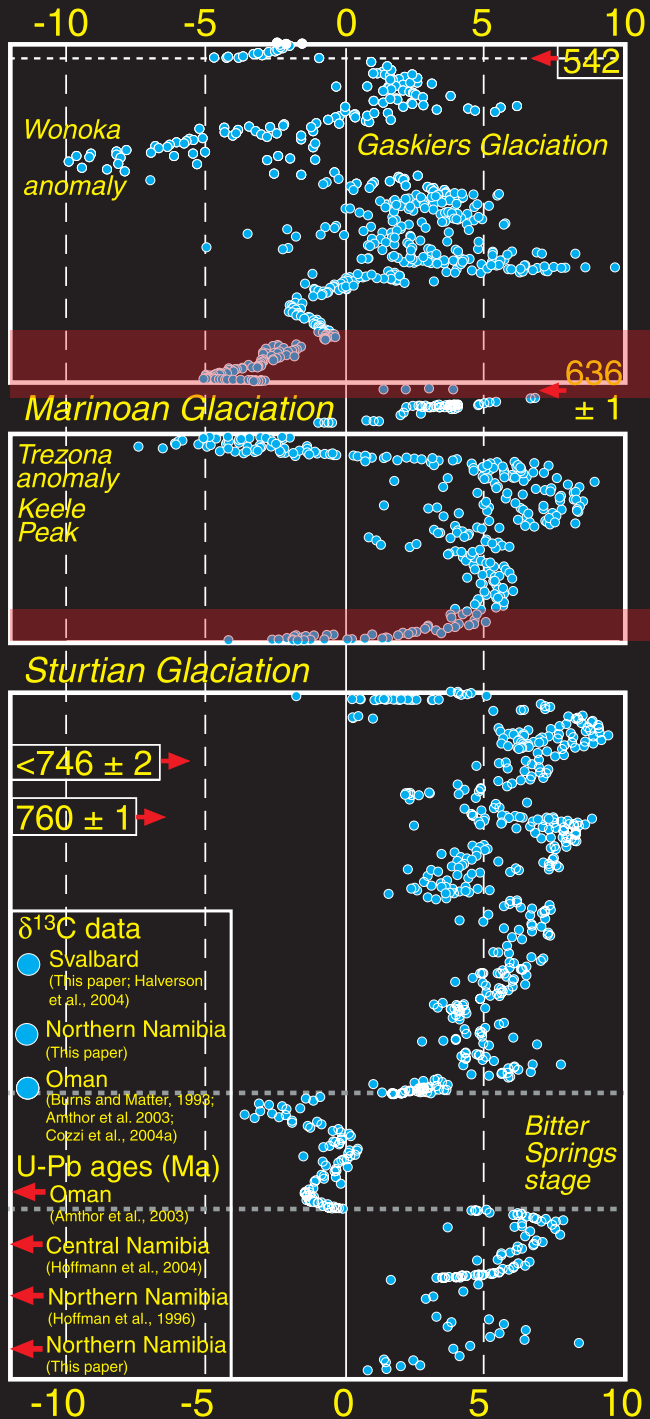
Adapted from: Halverson et al [2005]

time

# Deep-time inferences (aka 'speculation')



## Neoproterozoic composite $\delta^{13}\text{C}$ record



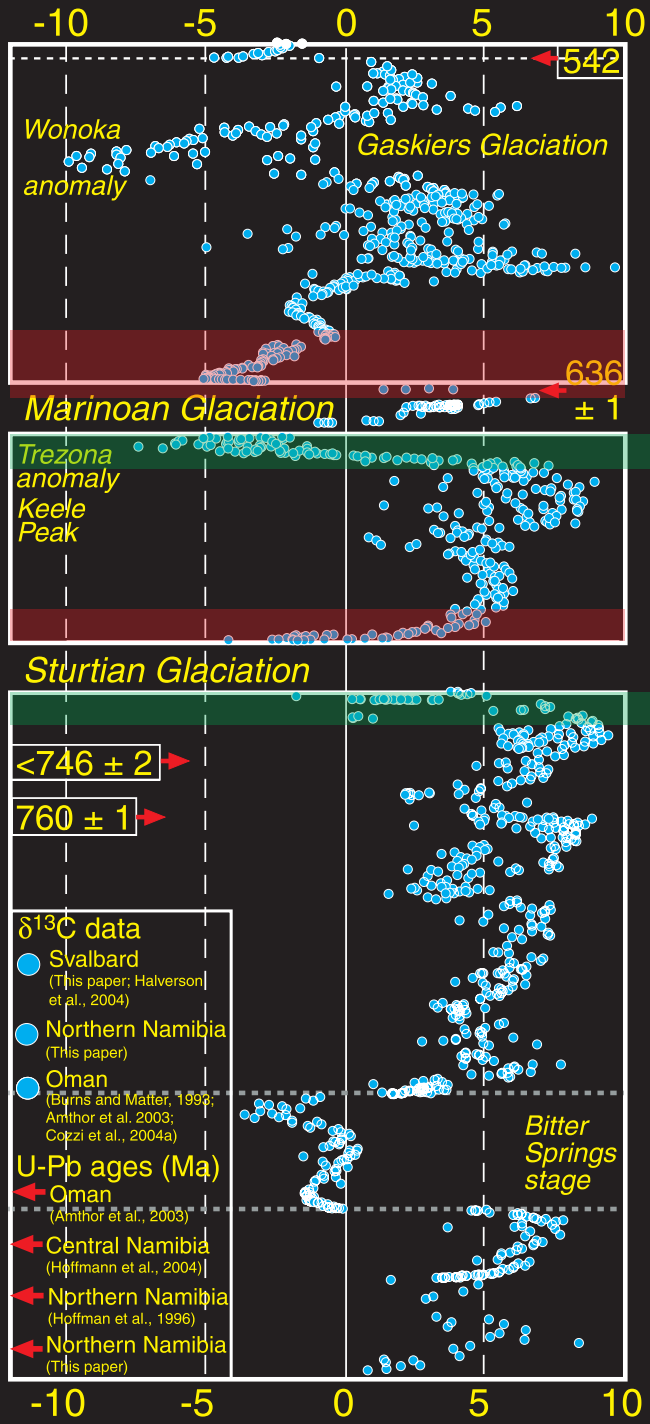
(model simulation on a very different x/y scale)

Adapted from: Halverson et al [2005]

# Deep-time inferences (aka 'speculation')



Neoproterozoic composite  $\delta^{13}\text{C}$  record



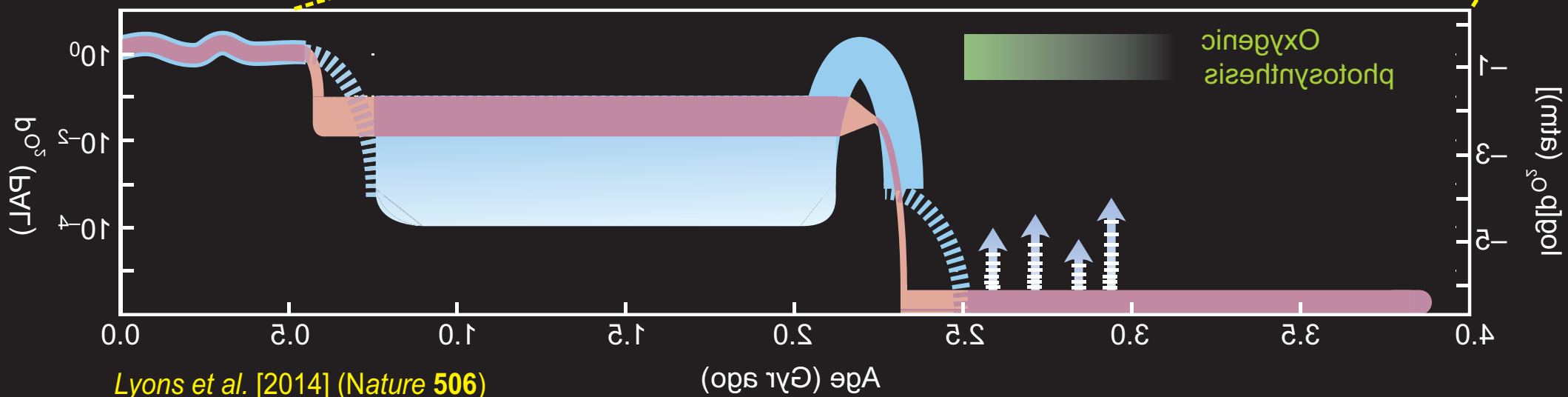
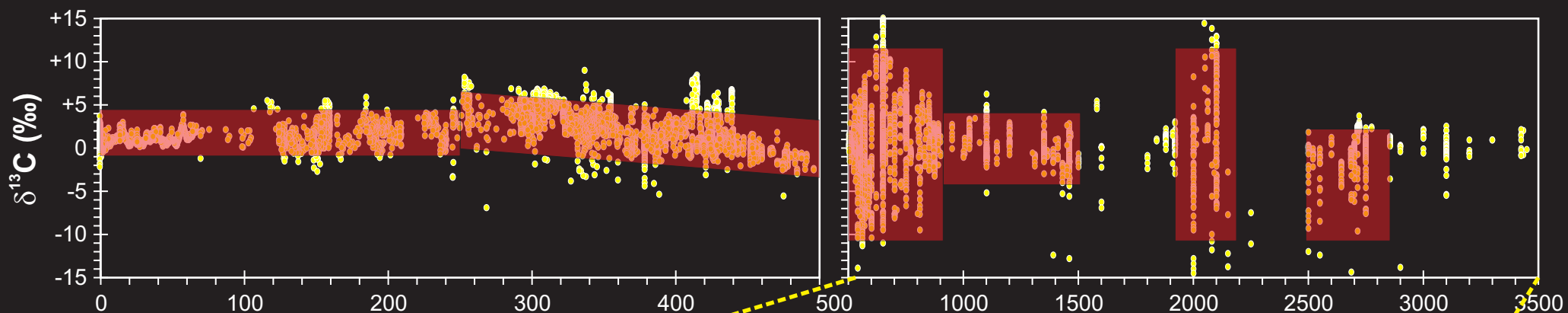
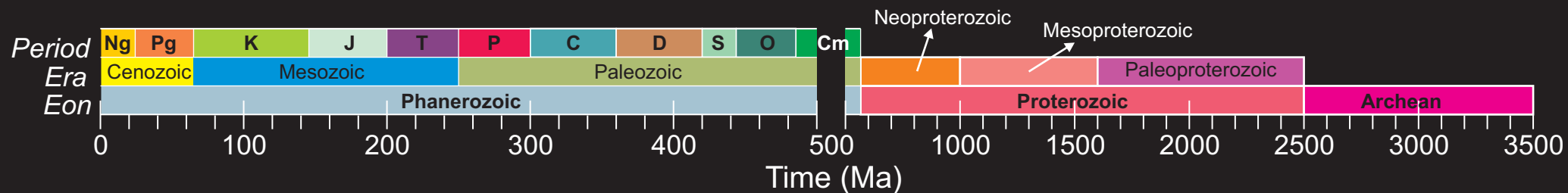
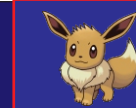
Adapted from: Halverson et al [2005]

Prominent declines (and partial recovery) in  $\delta^{13}\text{C}$  prior to glacial inception.

This would be consistent with a pH increase. How?

Perhaps enhanced basaltic weathering and  $\text{CO}_2$  drawdown (from a state of low pH and high  $\text{CO}_2$  @  $-6$  ‰)??

# Deep-time inferences (aka 'speculation')



Lyons et al. [2014] (Nature 506)

(ops rvg) epA

Thanks to:

*Philip Pogge Von Strandmann* [UCL, UK]

*Mathis Hain* [NOCS, UK]

The European Research Council

Heising-Simons Foundation



vs.

