

Precambrian $\delta^{13}\text{C}$ variability -- The ghost of the rise (and fall) of atmospheric oxygen?



- * This is not relevant at all.
- * Too late – this was only new 15 years ago.
- * There are potentially important implications.
But only 3 people in the World are going to care.
- * Maybe.
- * Yes.
- * Meh.

forget about it
drink beer
be happy

keep going

meh



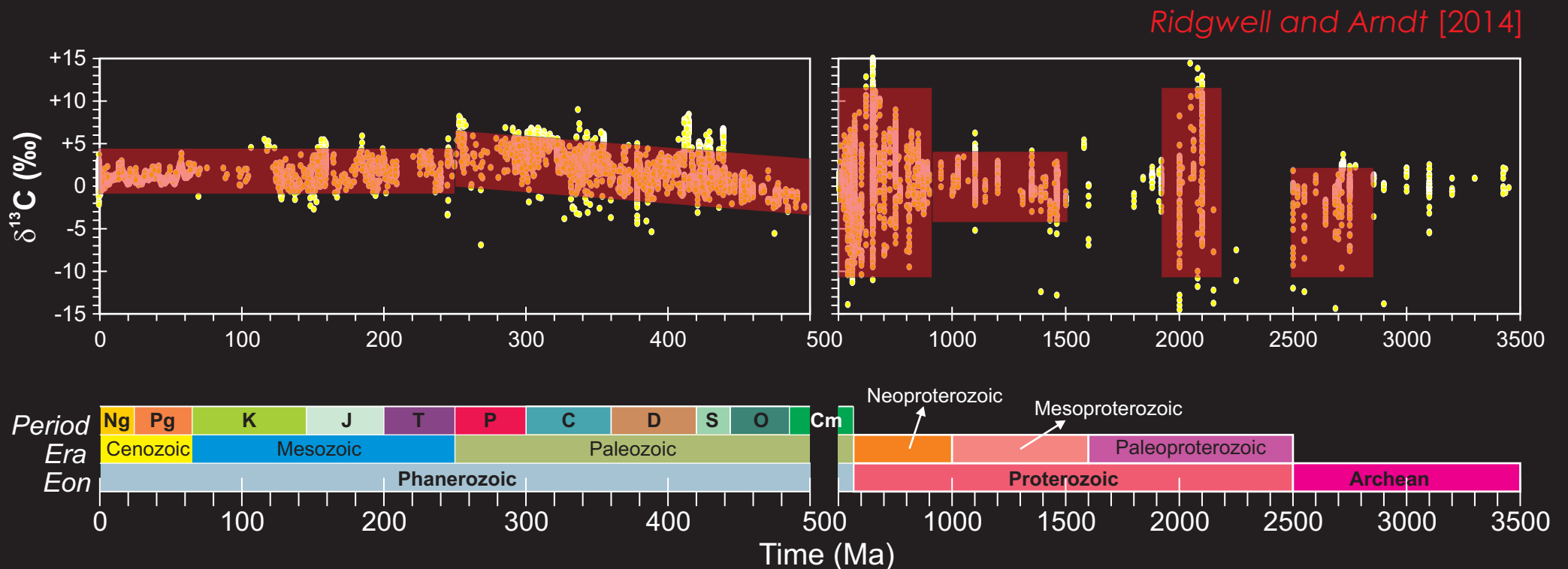
vs.



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



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





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

Injection (or removal) of isotopically light carbon?

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(at fixed carbonate weathering / burial)?


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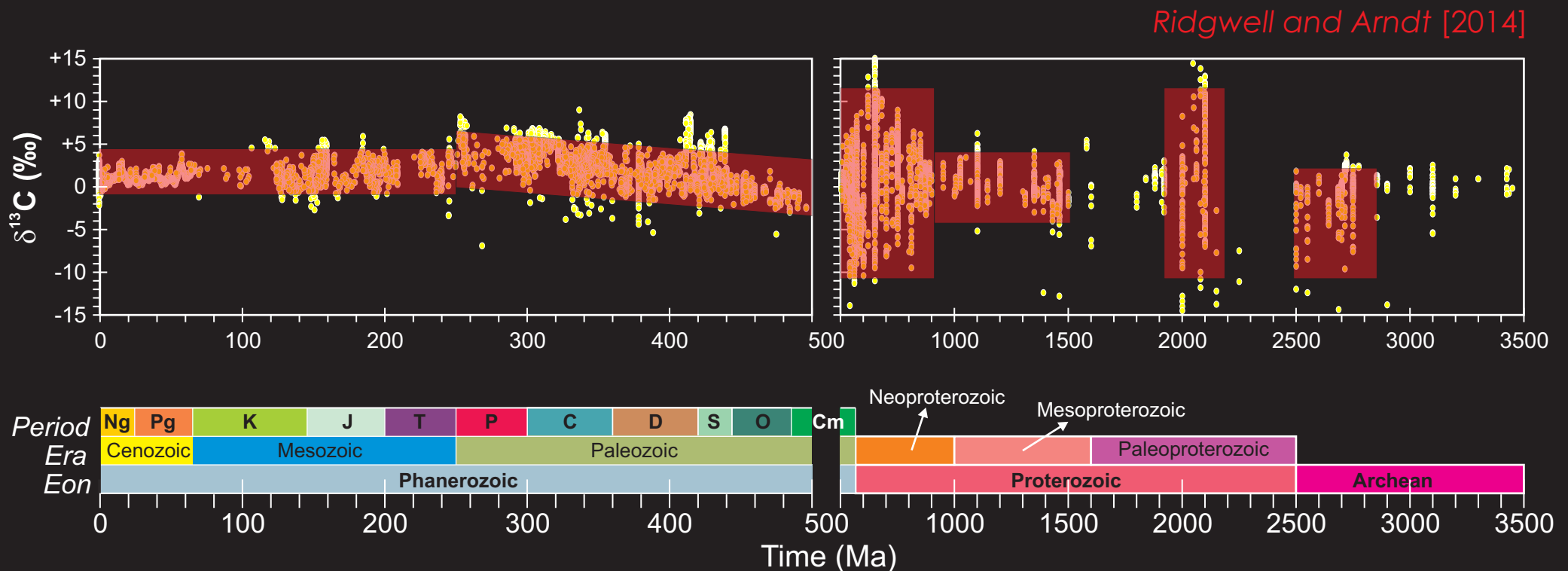
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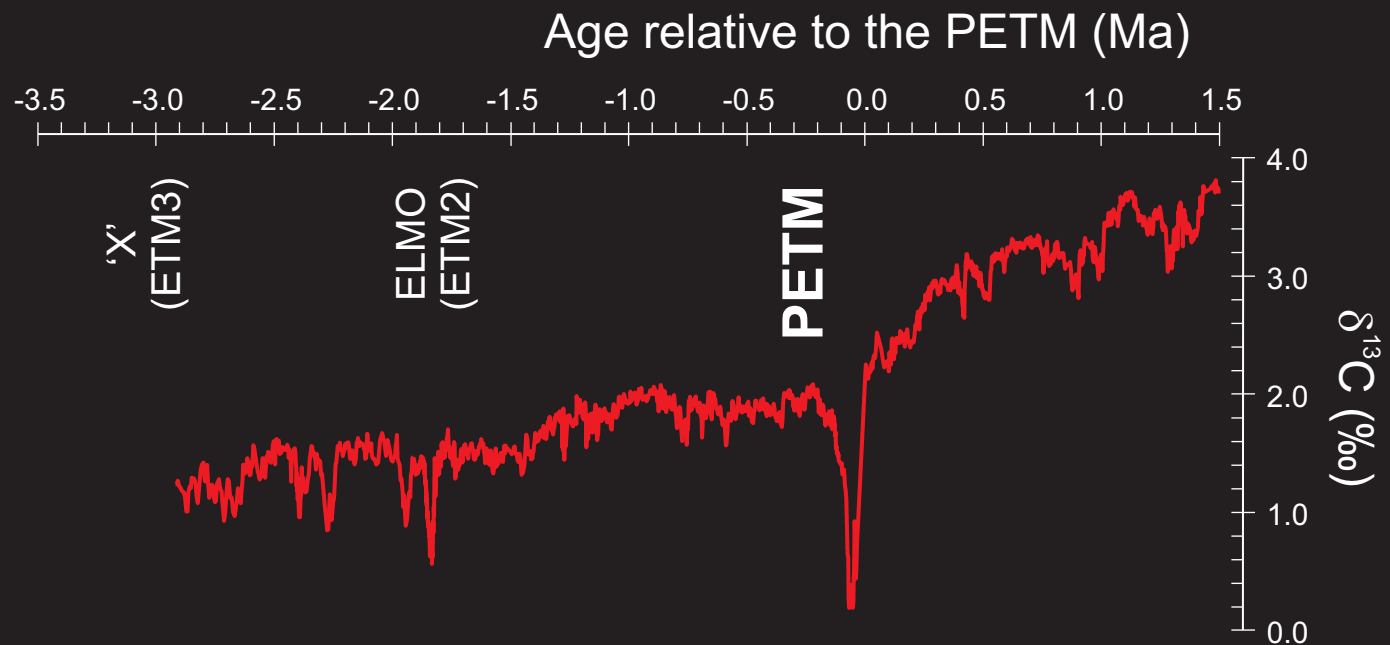
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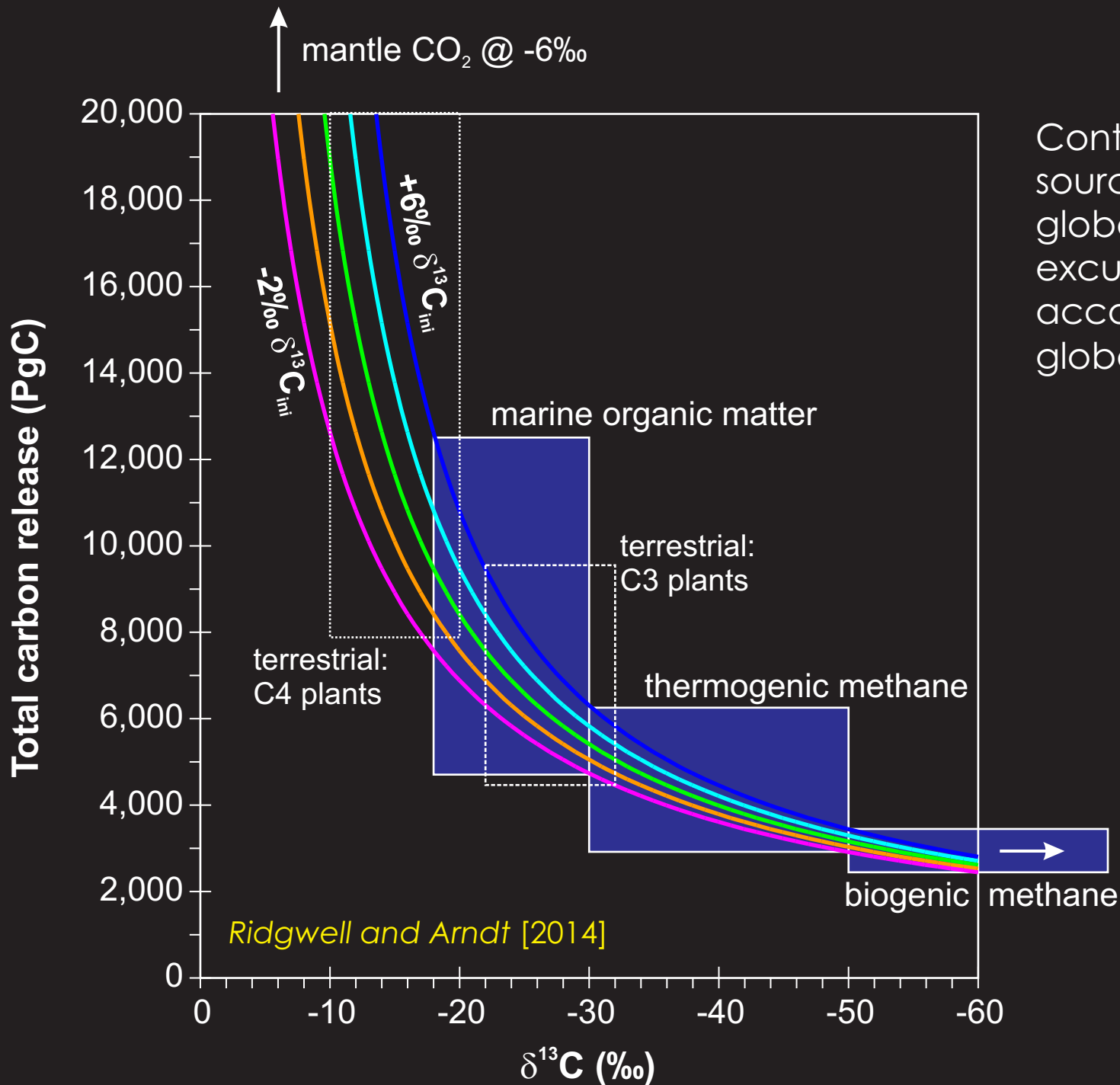
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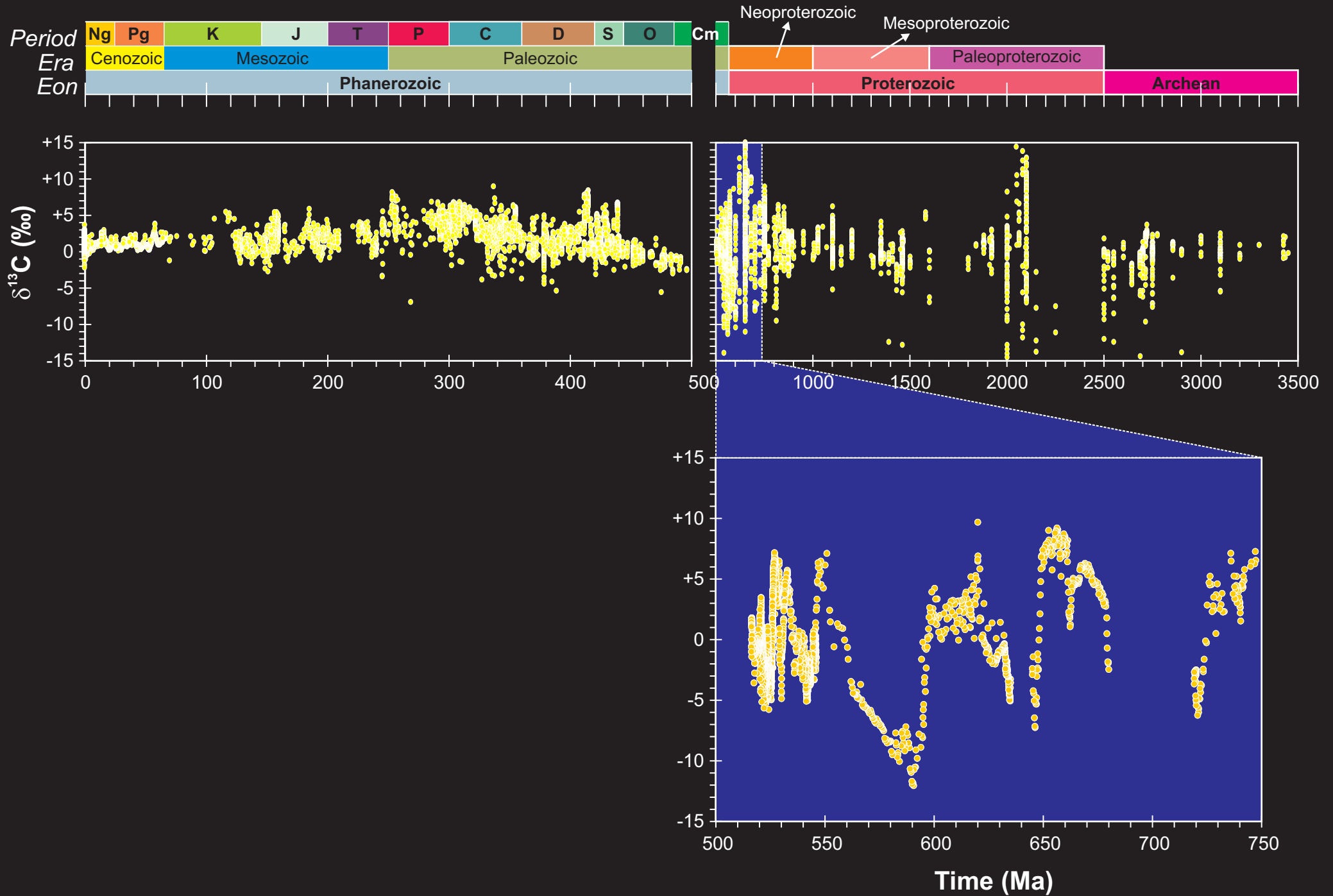


Carbonate $\delta^{13}\text{C}$ variability through time

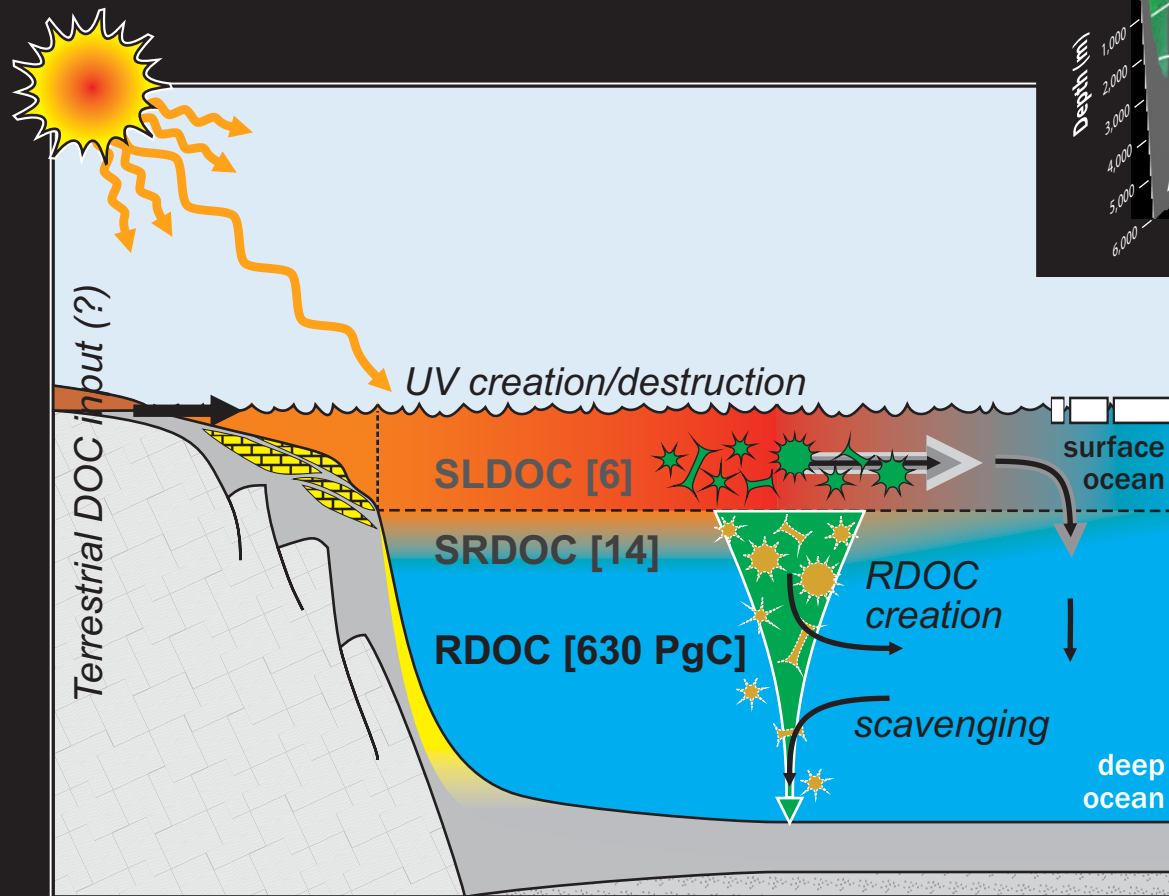
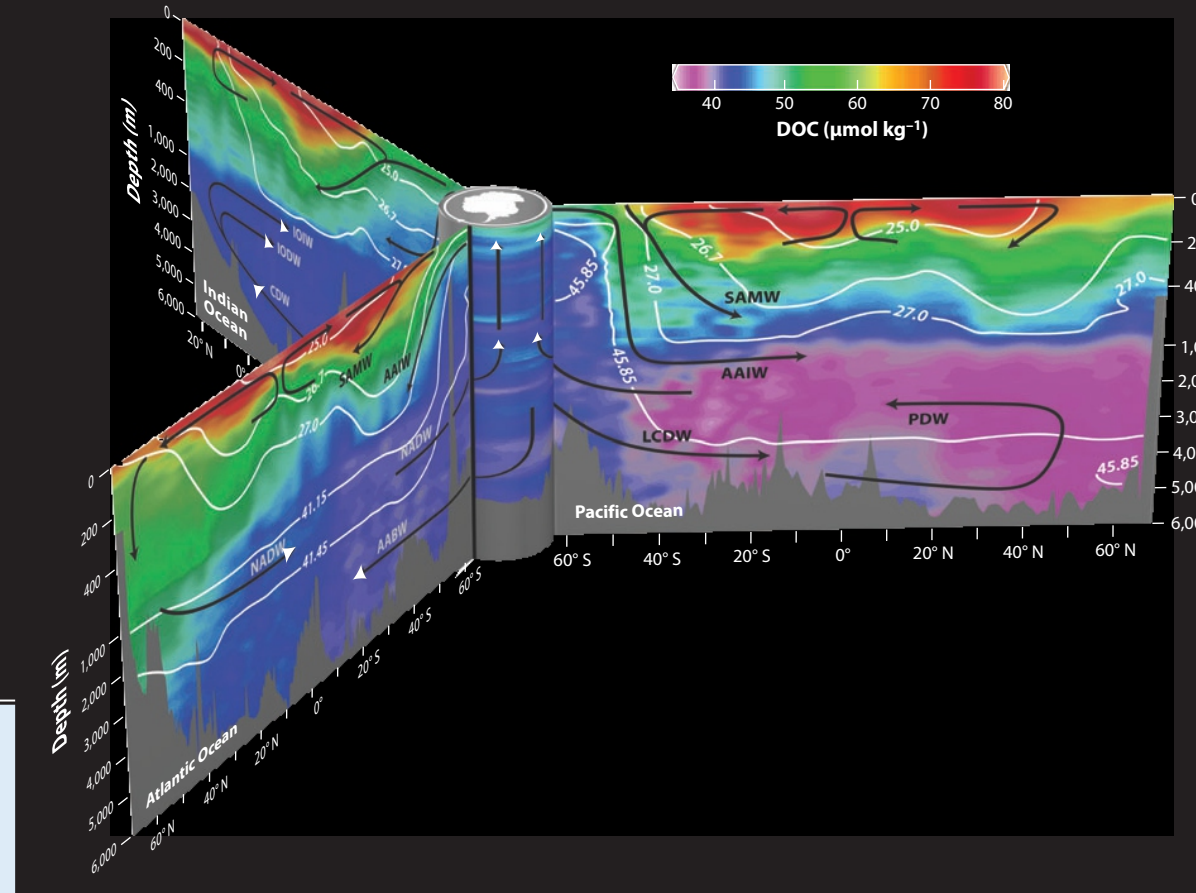


Contours of carbon release vs. source isotopic signature for a global -4‰ carbon isotopic excursion. Contours differ according to the initial mean global $\delta^{13}\text{C}$.

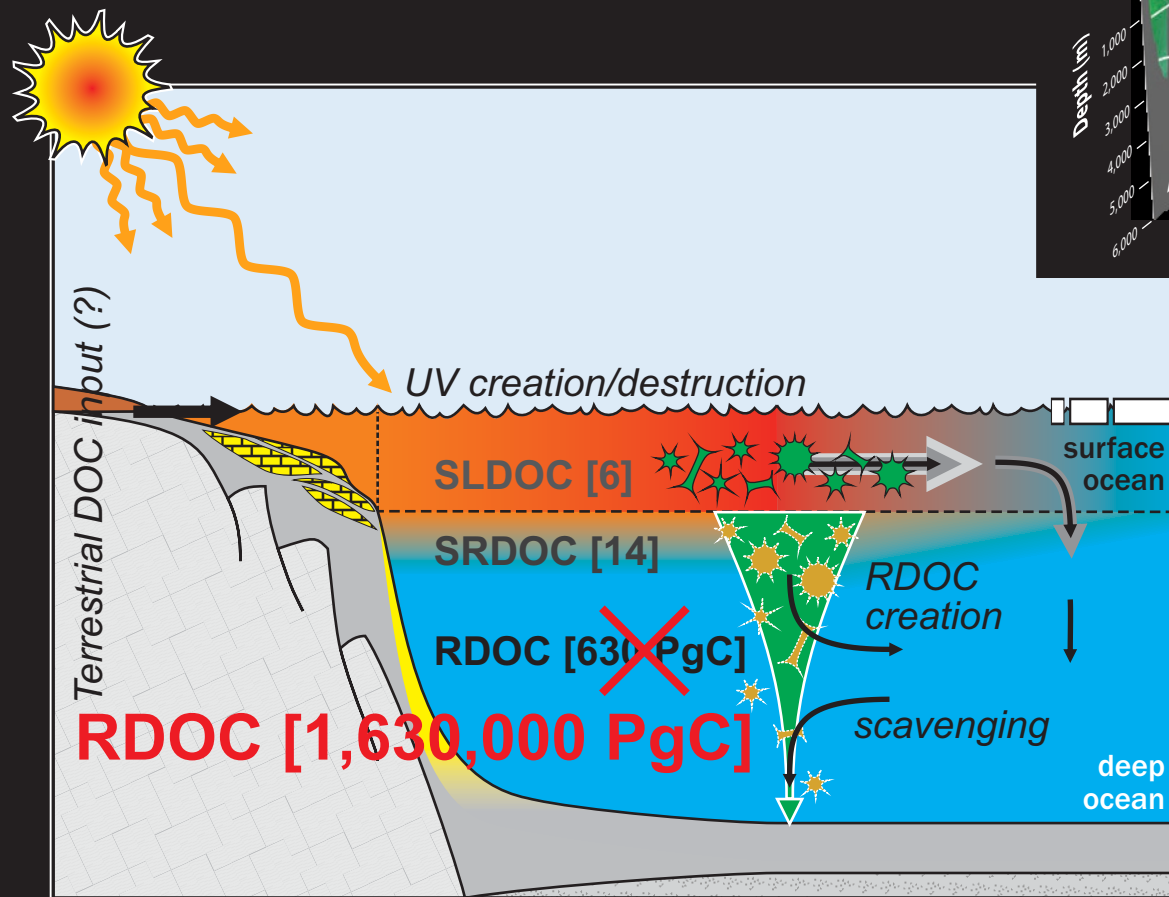
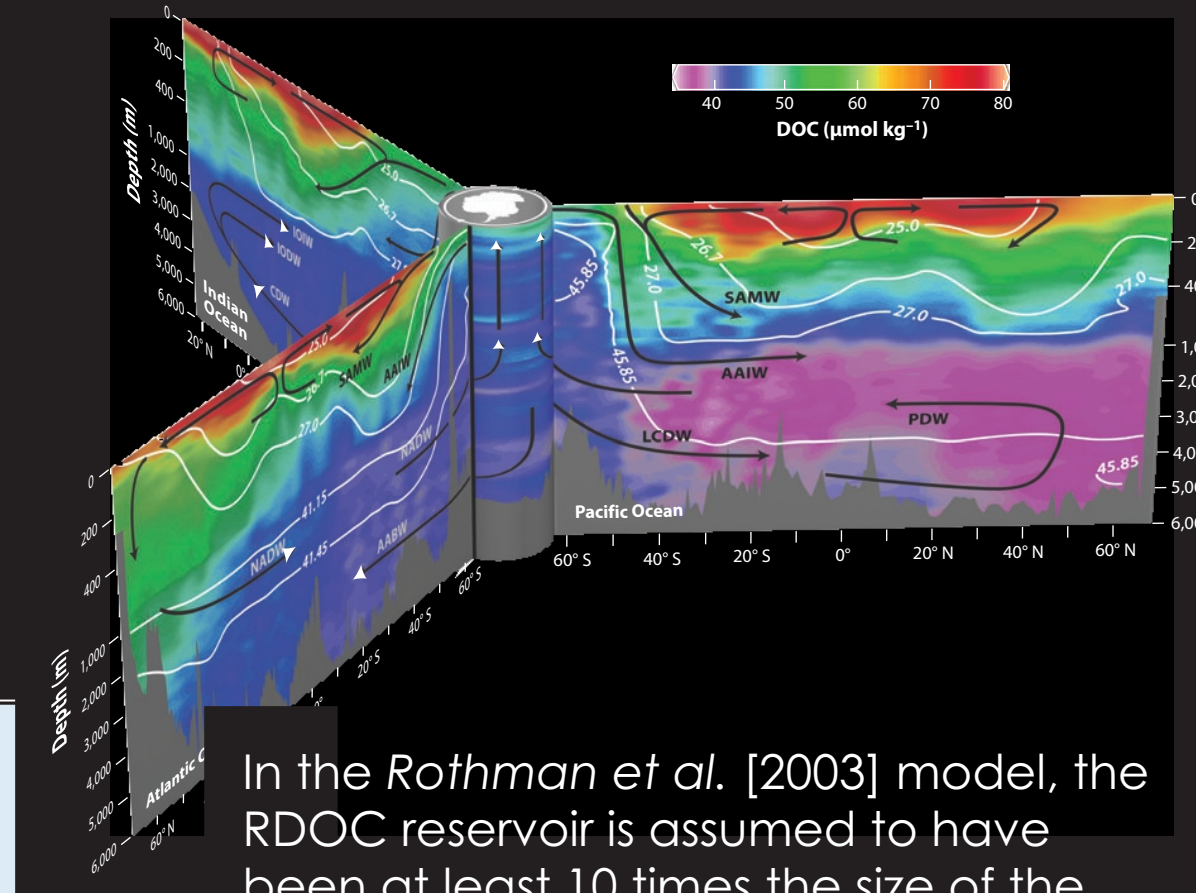
Carbonate $\delta^{13}\text{C}$ variability through time



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In the Rothman et al. [2003] model, the RDOC reservoir is assumed to have been at least 10 times the size of the inorganic (ocean DIC + atmospheric pCO_2) reservoir. For a modern DIC + pCO_2 reservoir of 39,000 PgC, this mean 390,000 PgC of DOC – more than 500 times larger than modern).

(For a higher late Precambrian DIC reservoir, the minimum DOC reservoir becomes 1.6×10^6 PgC, equivalent to concentration of a little over 1000 mgC per L of seawater and becoming the third most dominant dissolved species in the ocean after Cl^- .)



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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




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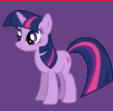
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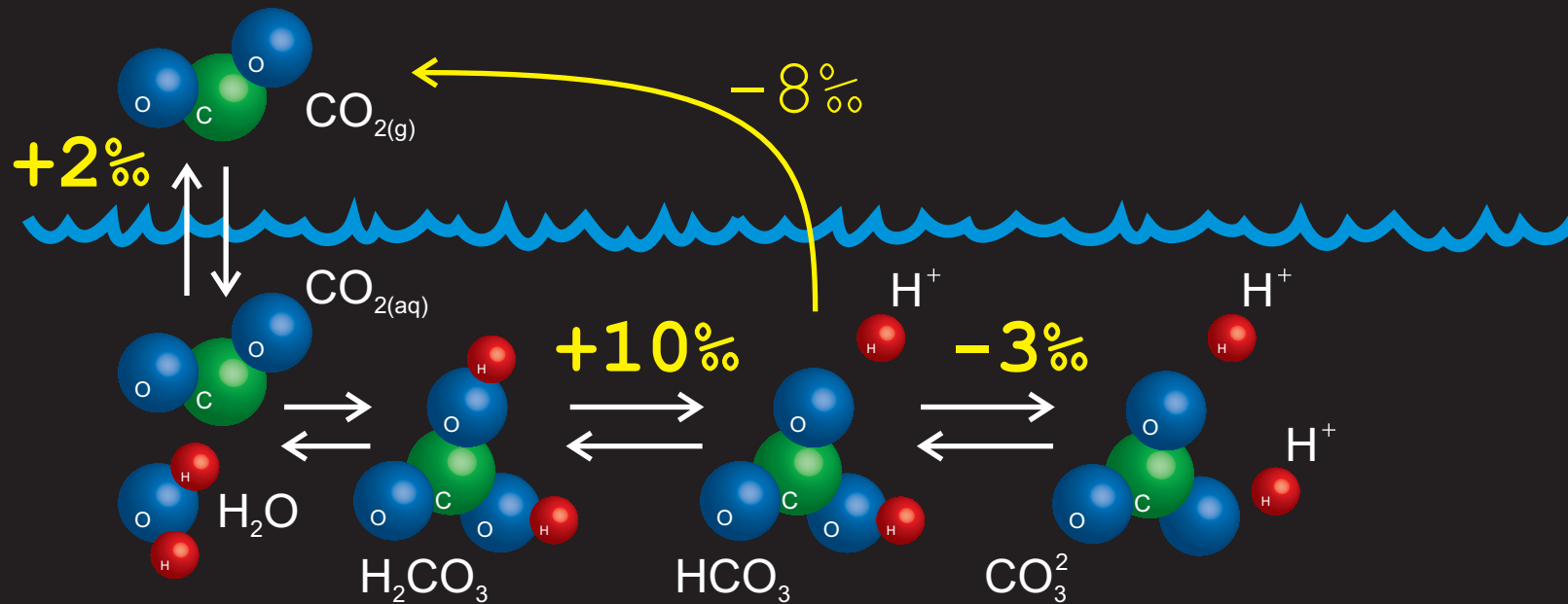
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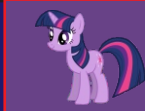
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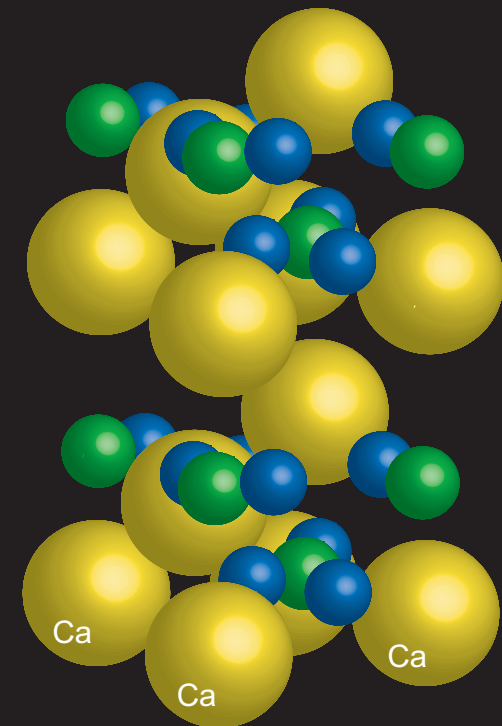
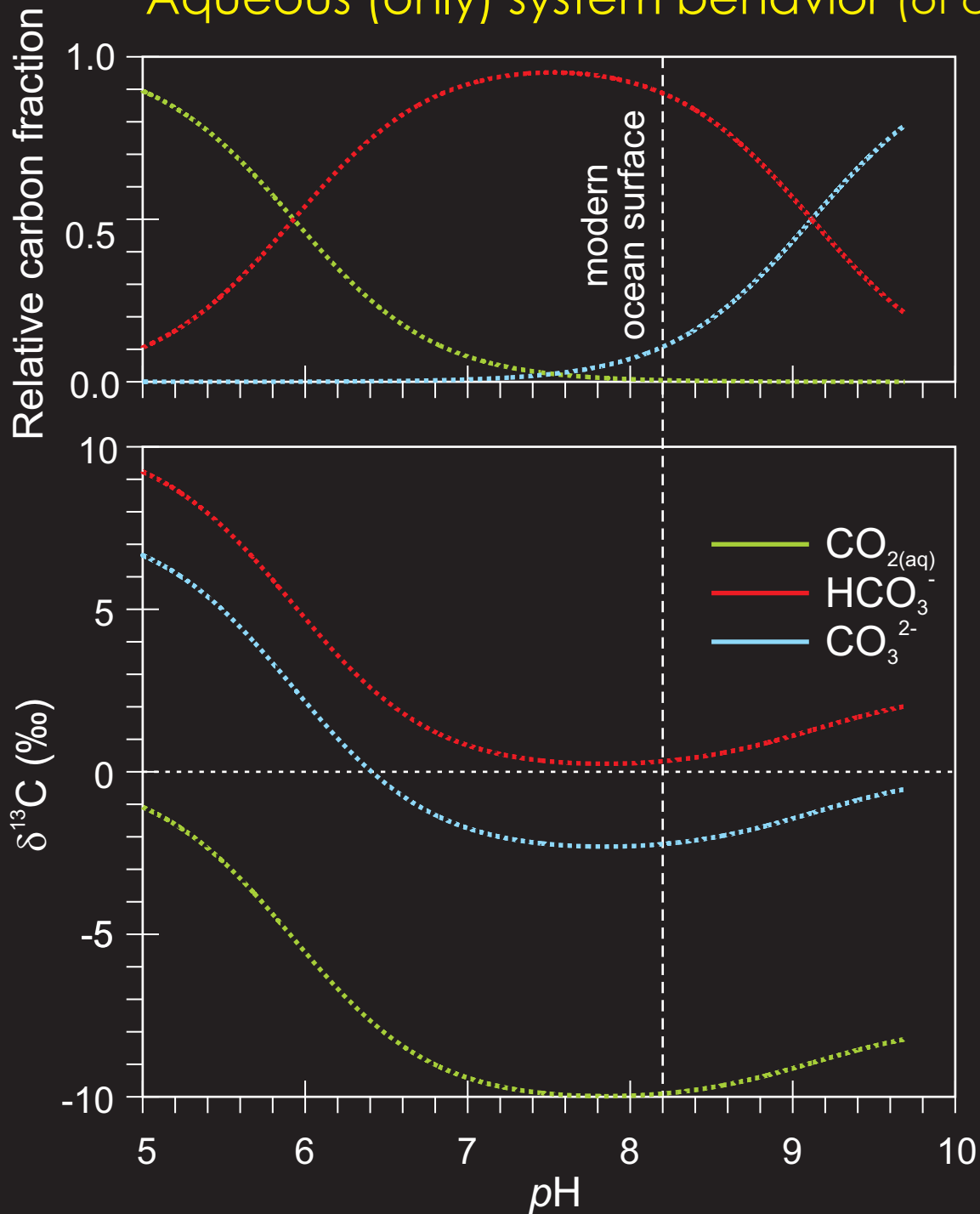
 pH-driven re-partitioning of the where the isotopic composition
of the mean surficial reservoir is held
(and what carbonate samples)

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

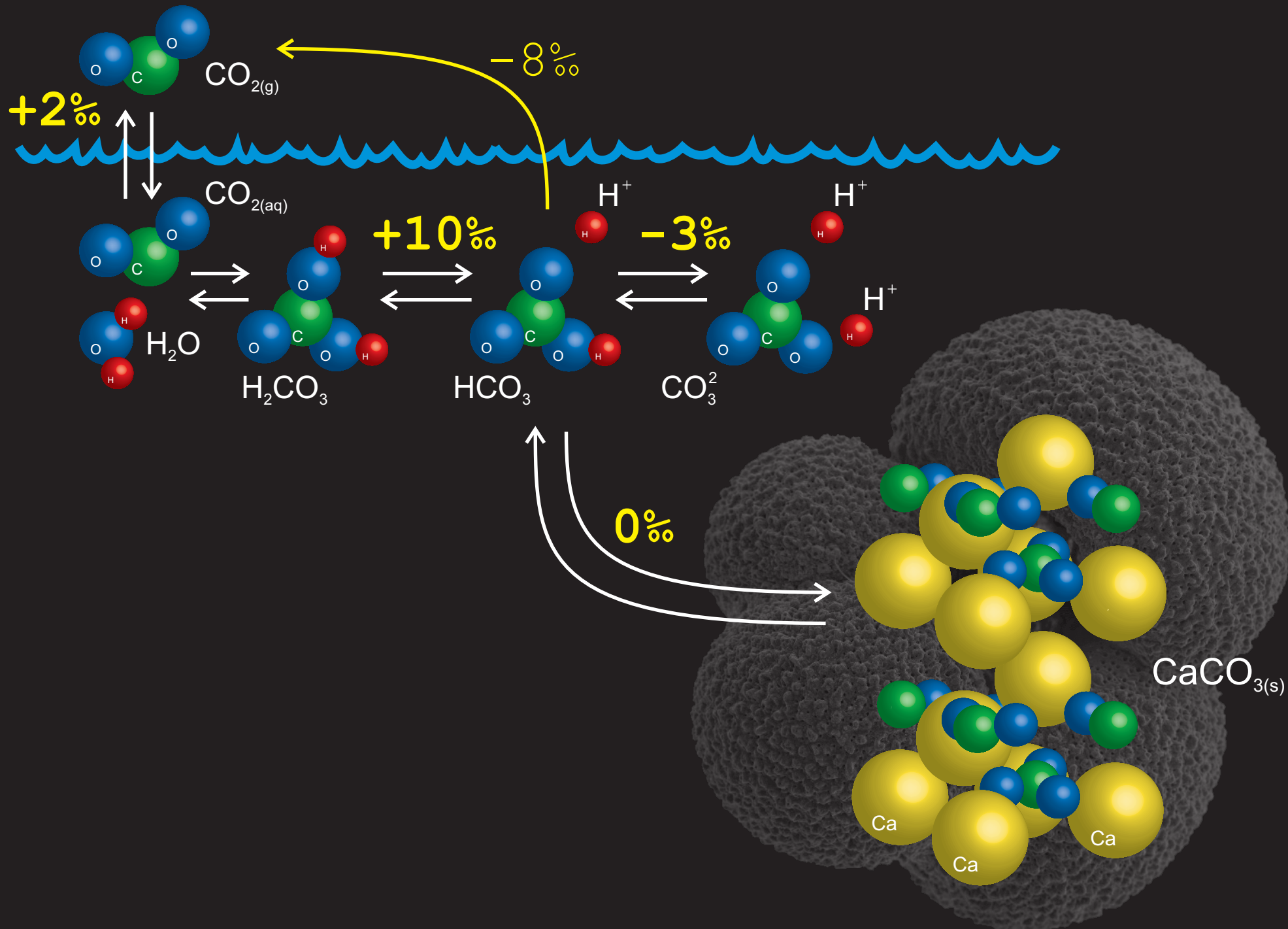
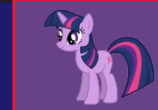


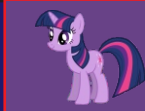


Aqueous (only) system behavior (of carbon partitioning between reservoirs)

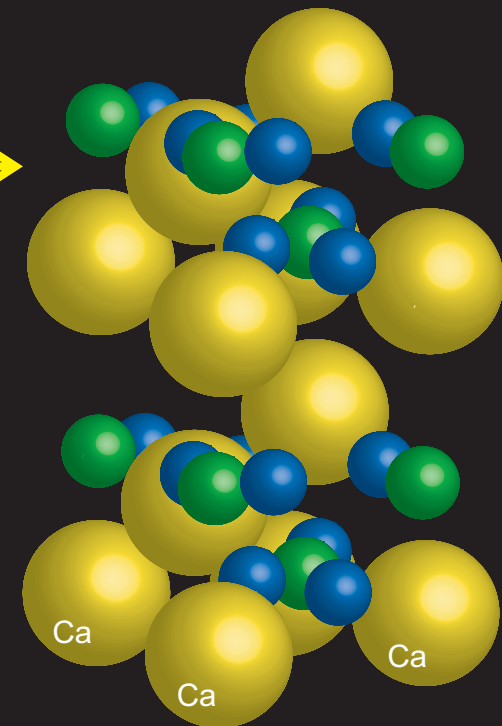
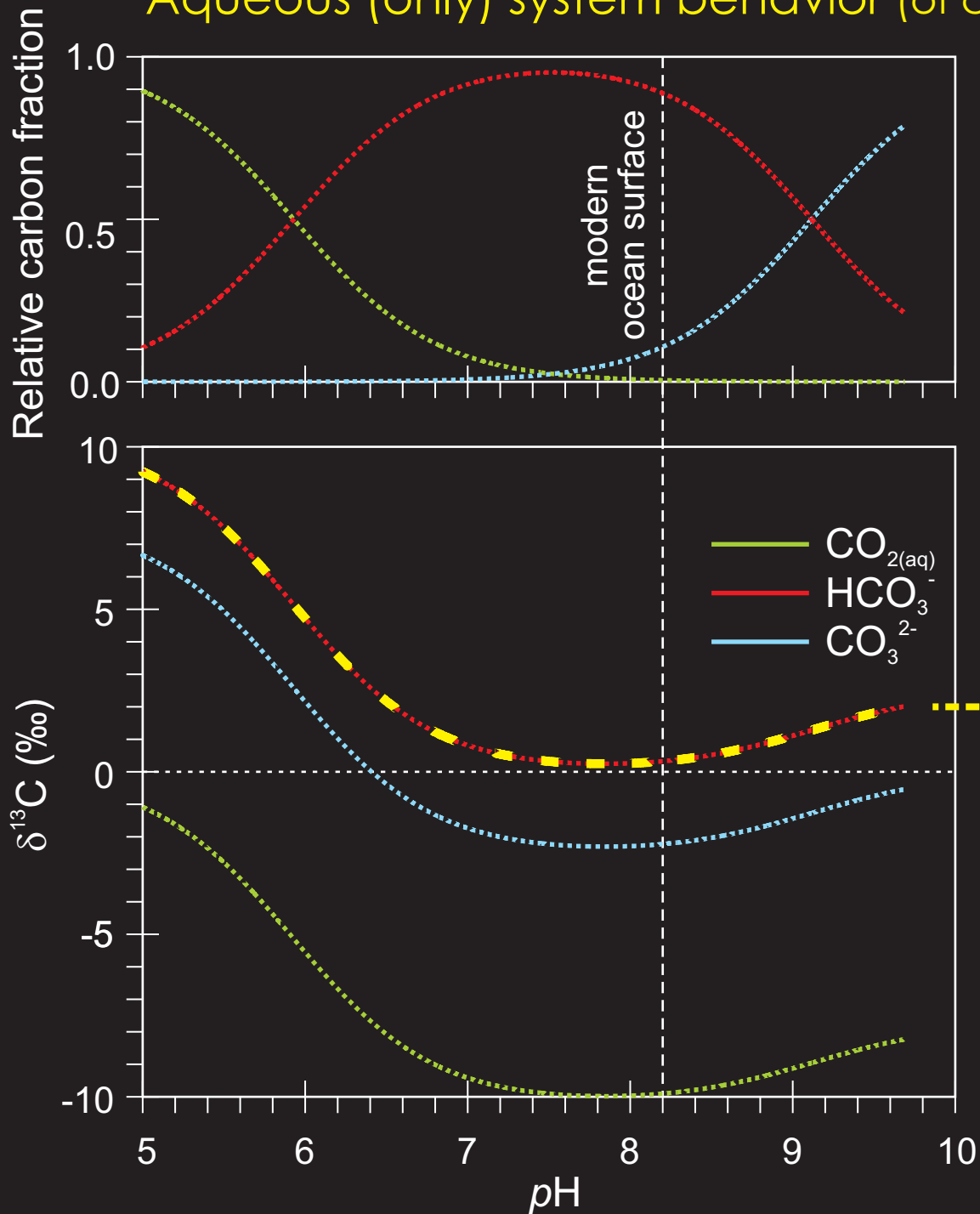


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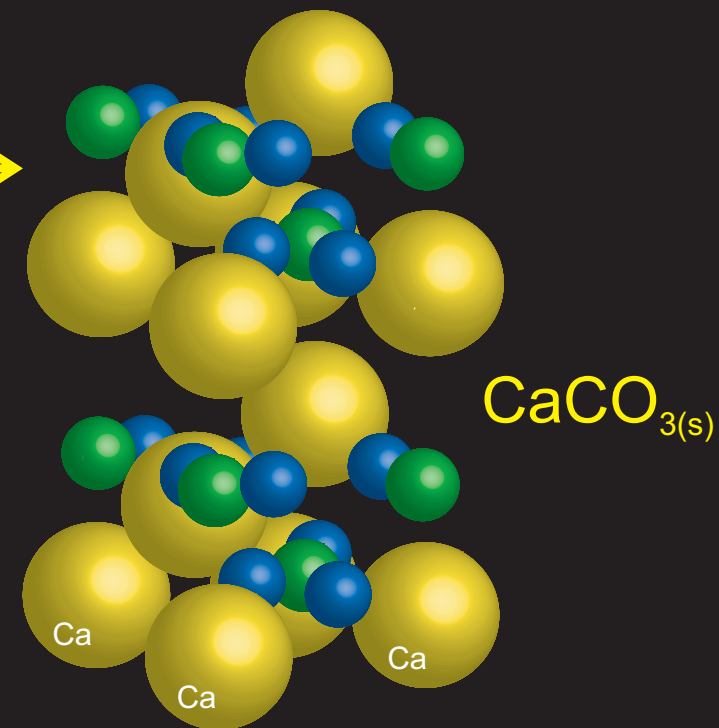
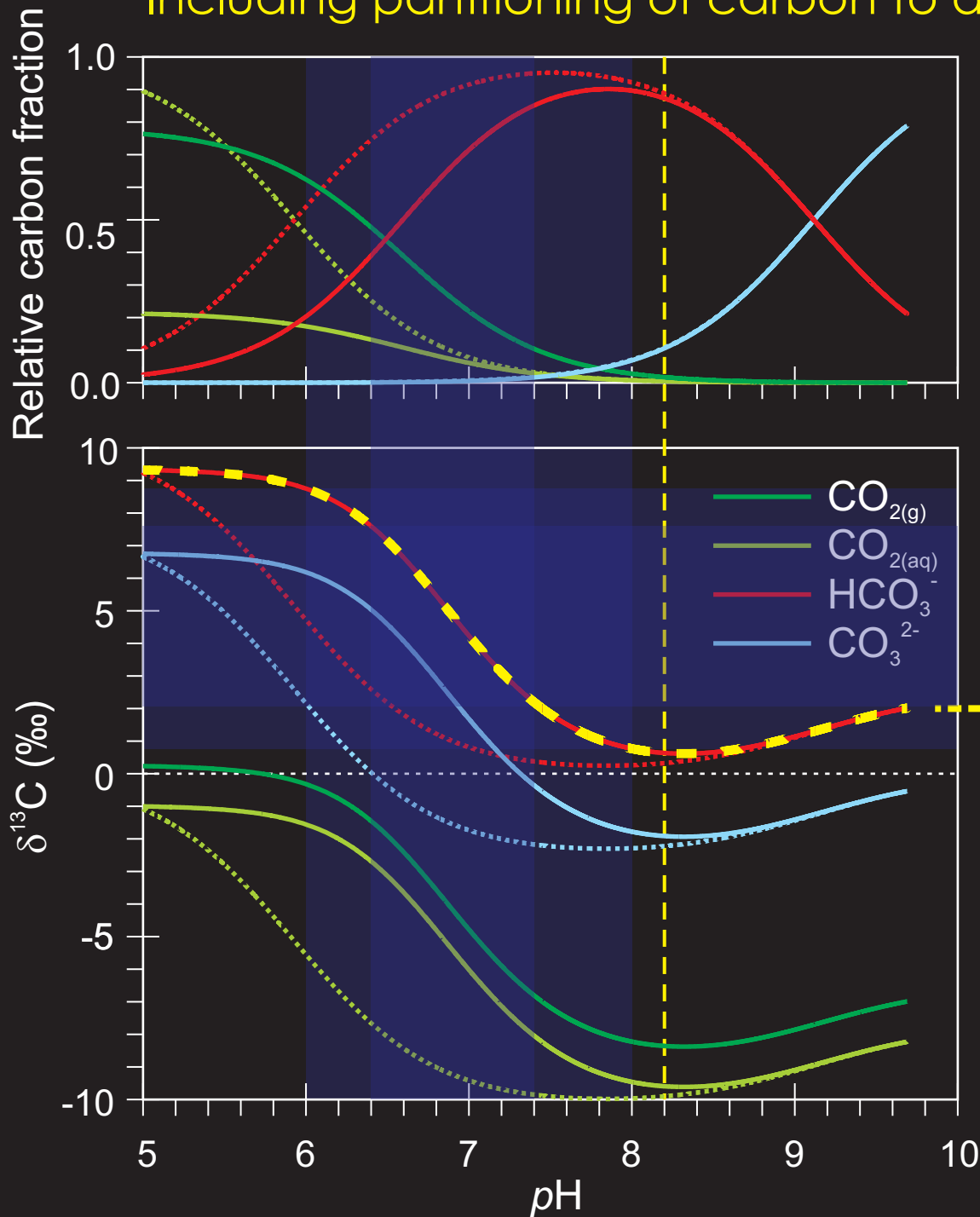


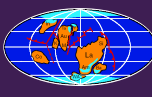
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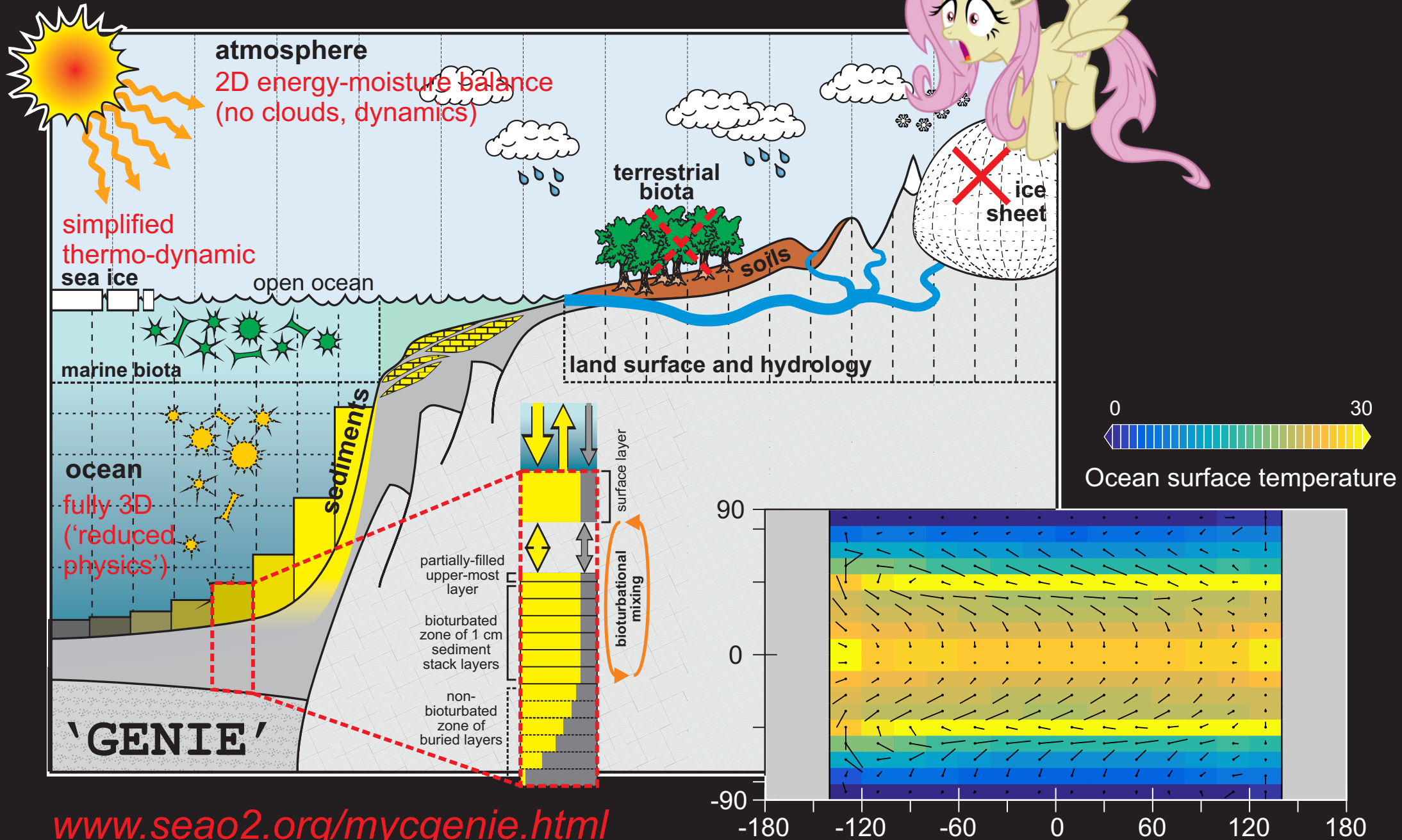


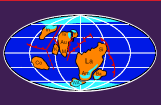
Including partitioning of carbon to atmosphere



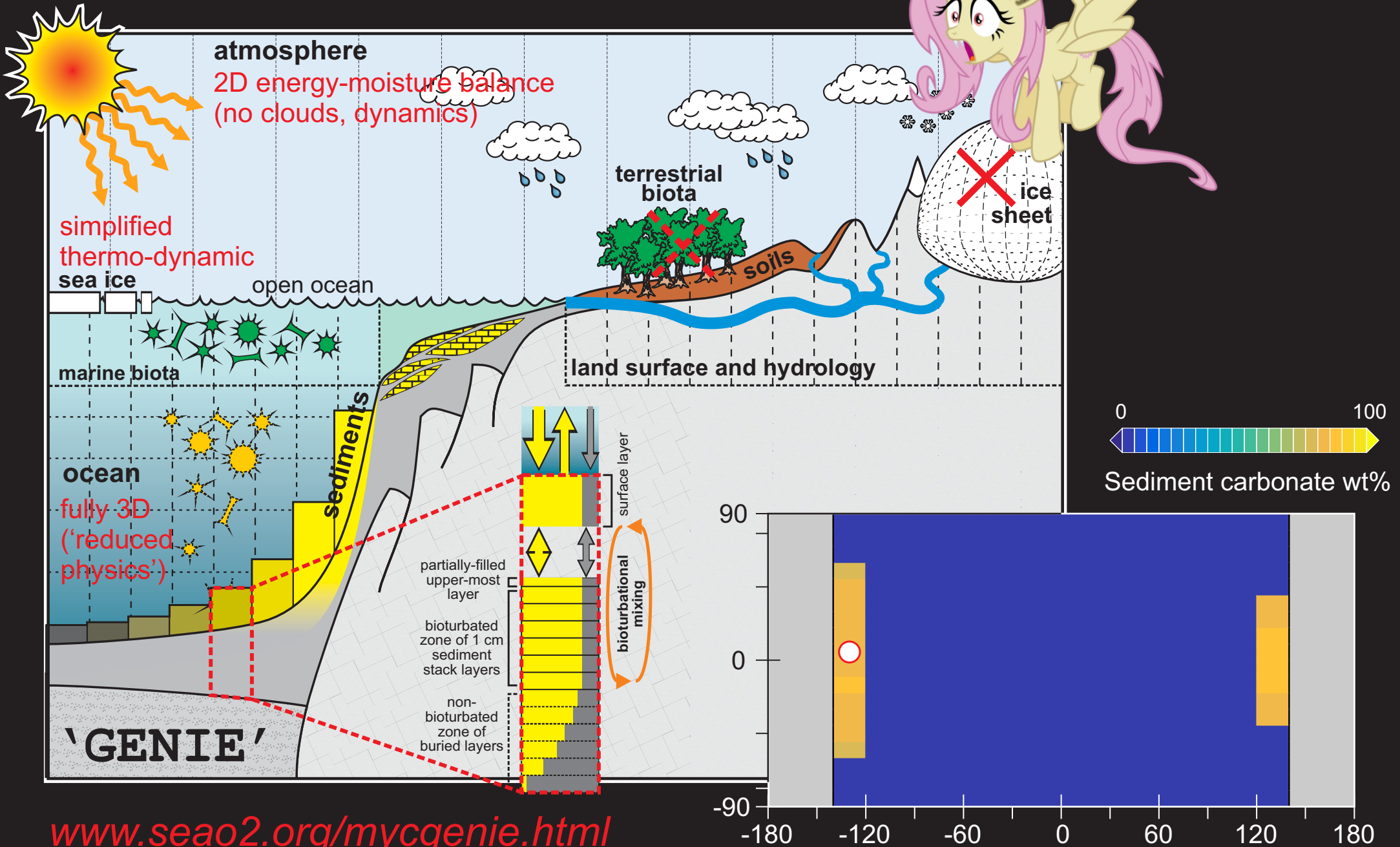


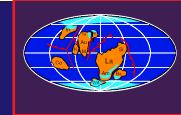
Earth system model – physical configuration



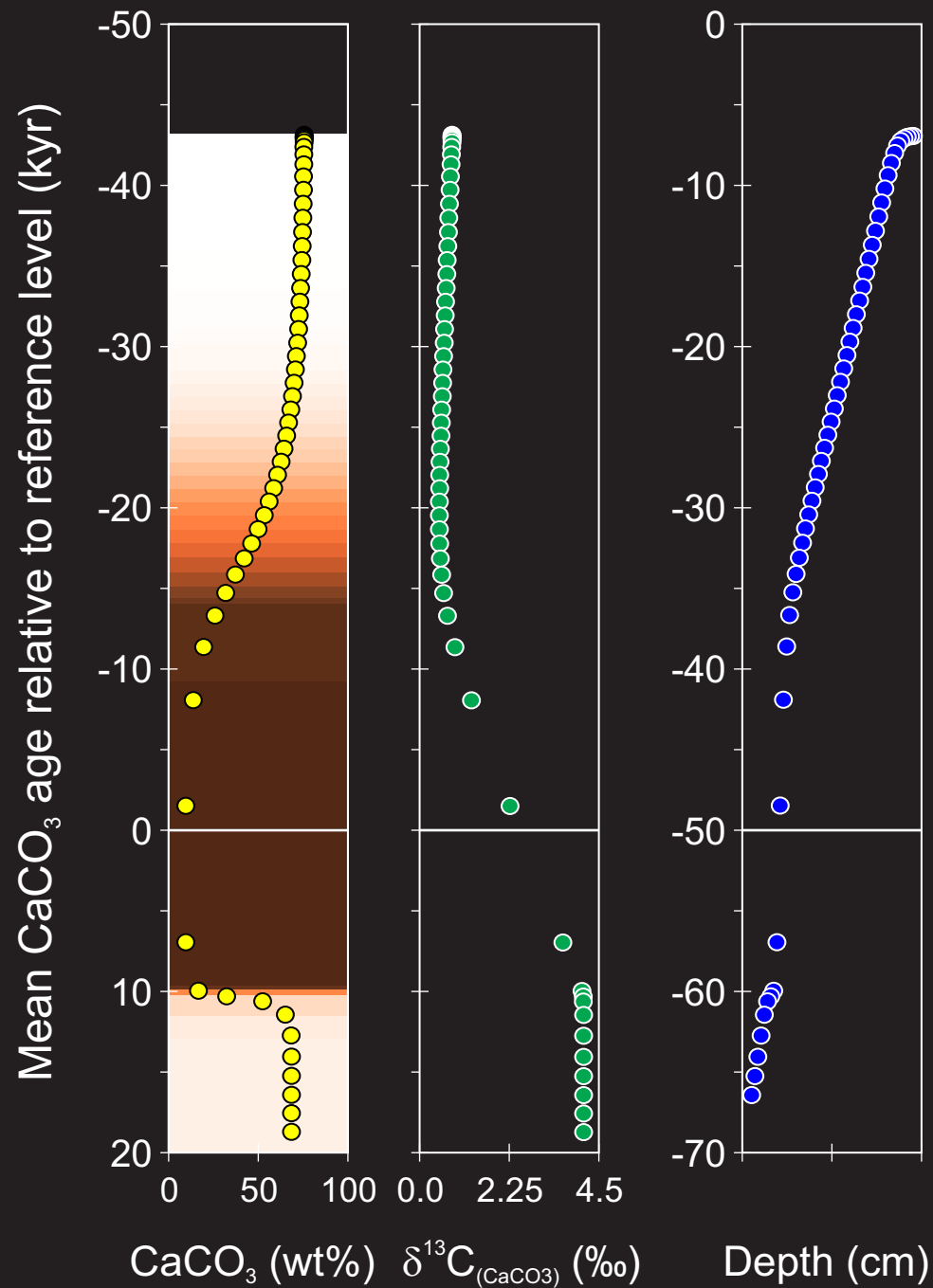


Earth system model – carbon cycle

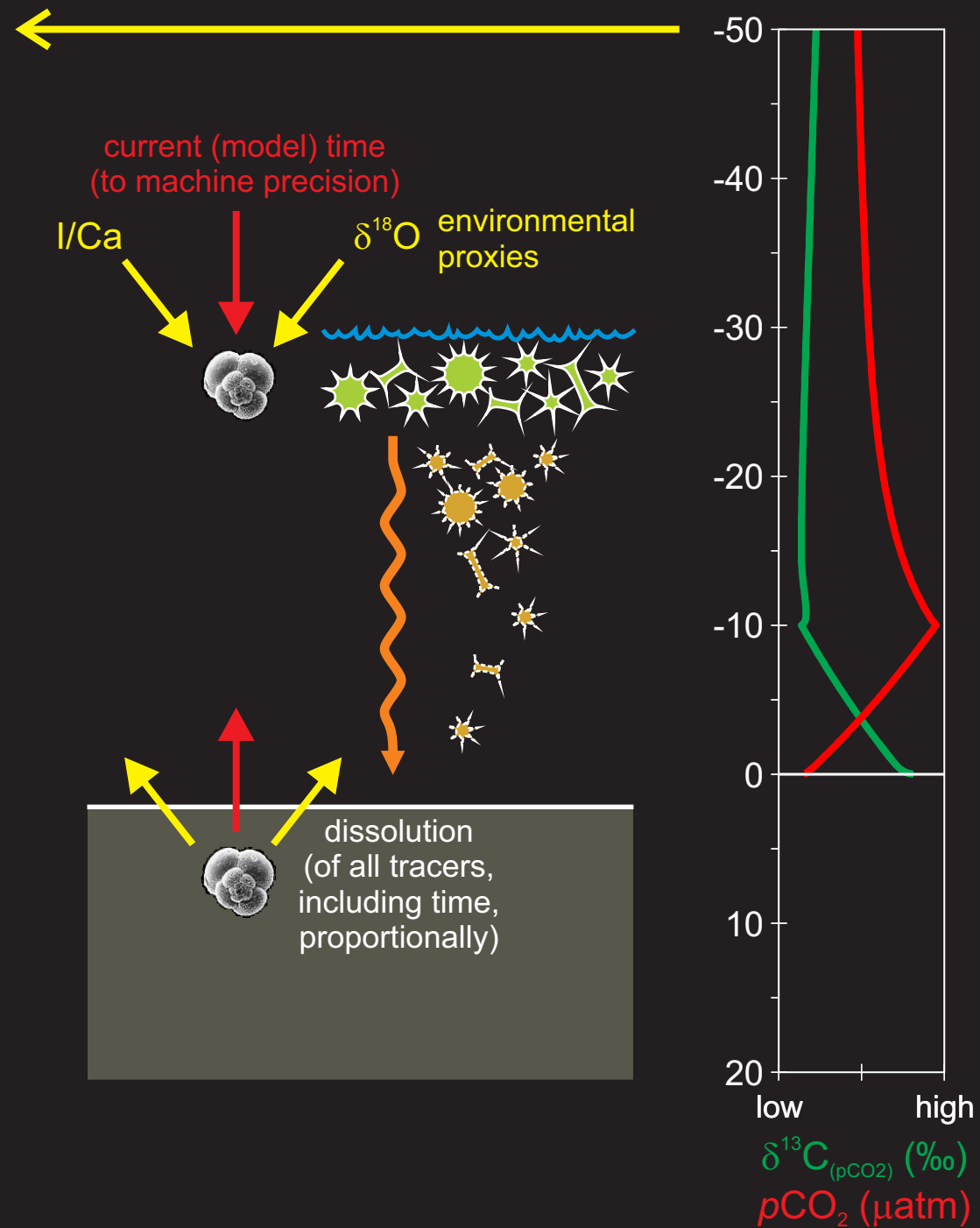




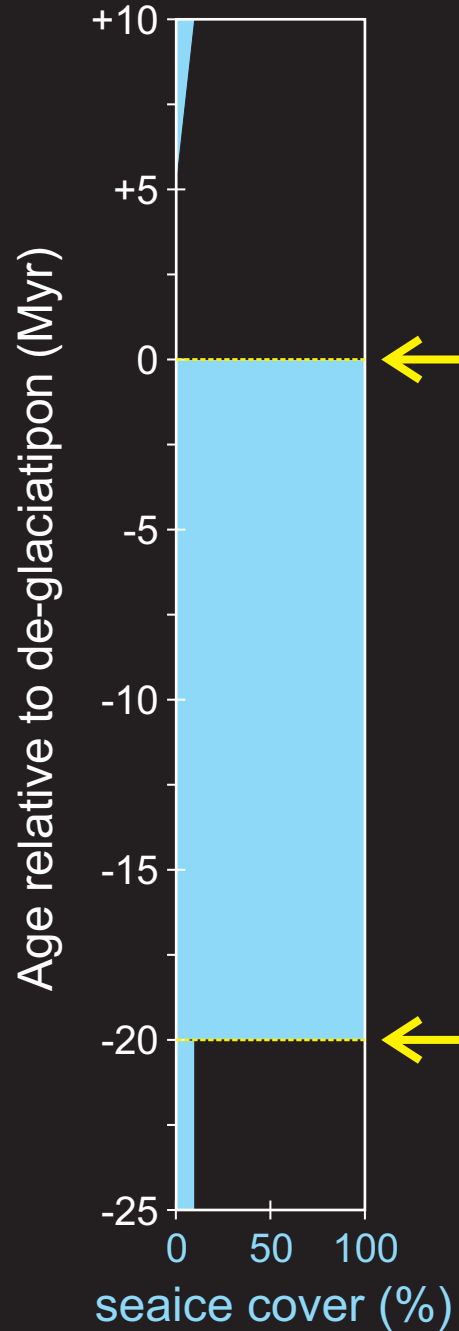
realized (model) sediment record



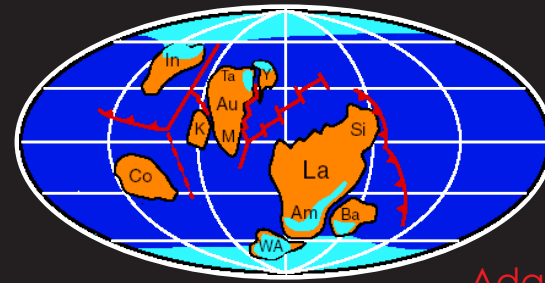
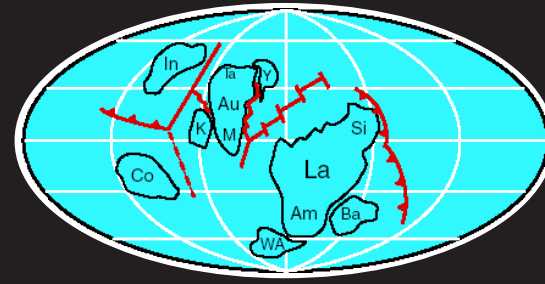
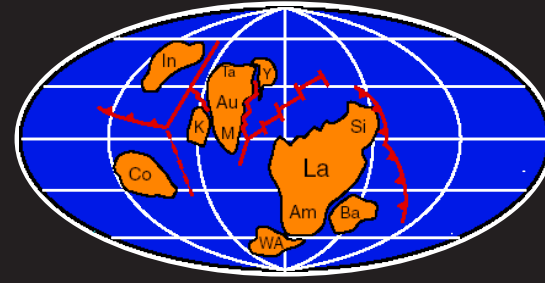
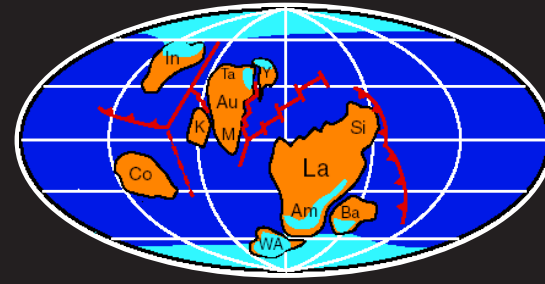
(model) environment

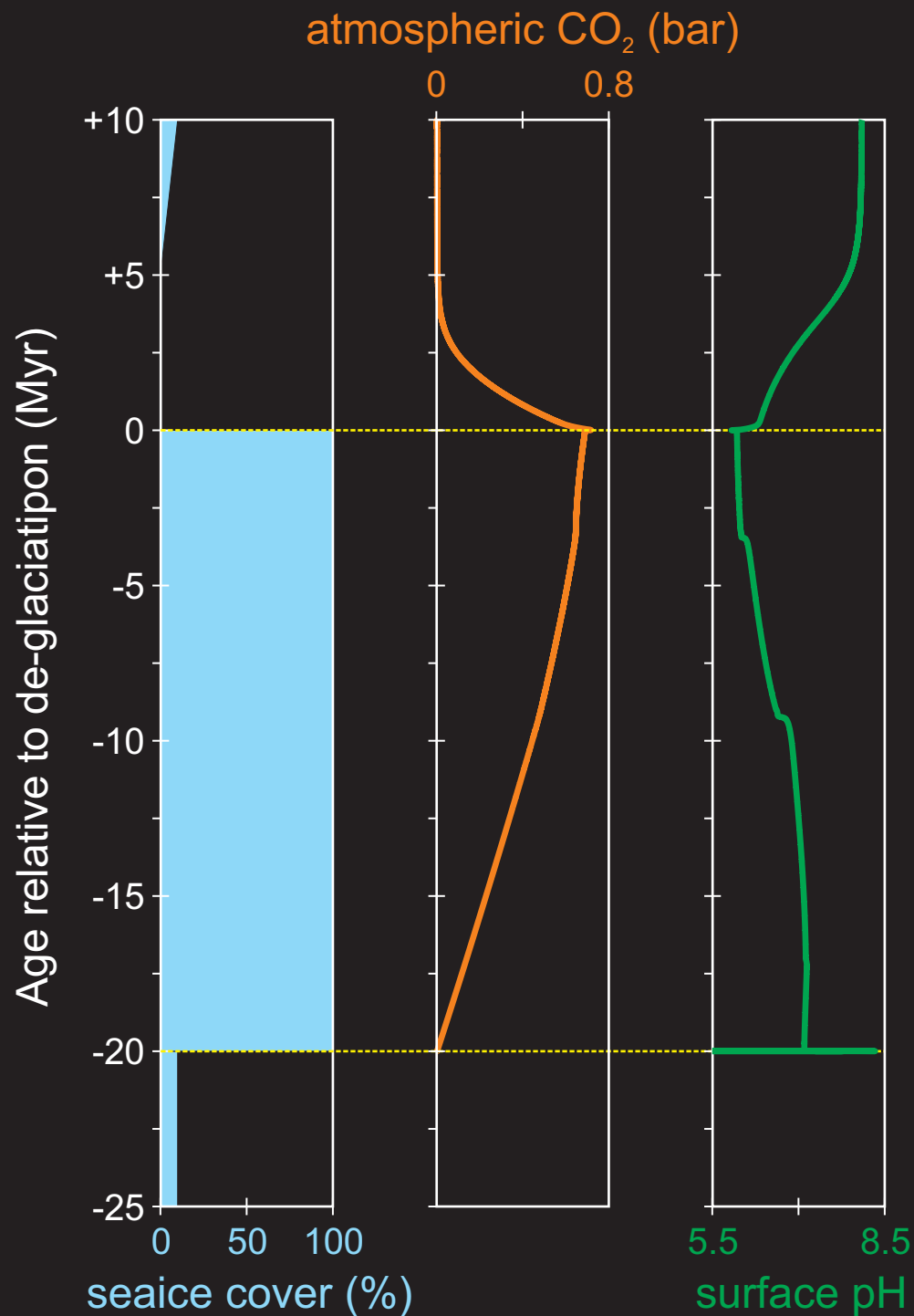


Numerical modelling – Approach



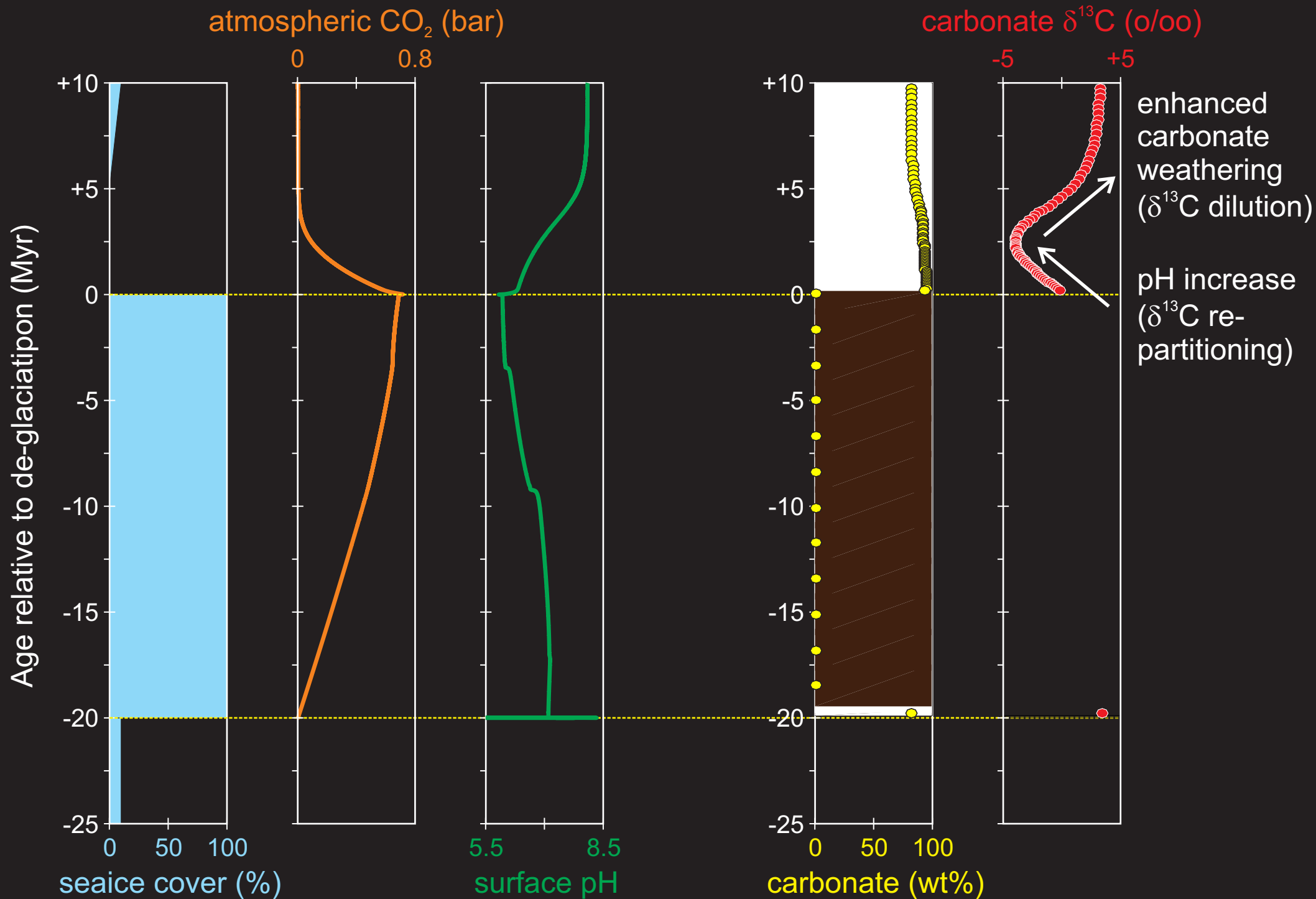
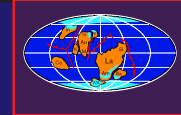
time





Enhanced weathering
 ⇒ CO₂ draw-down
 and pH increase

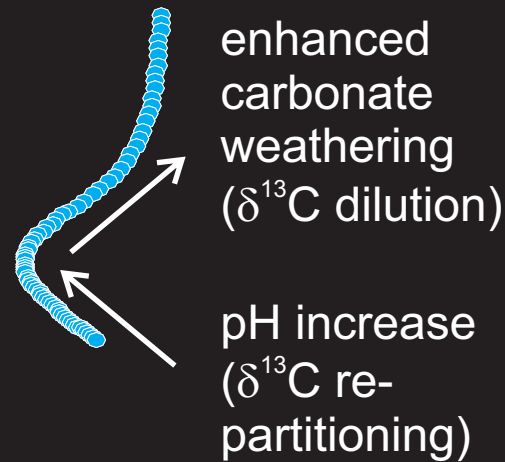
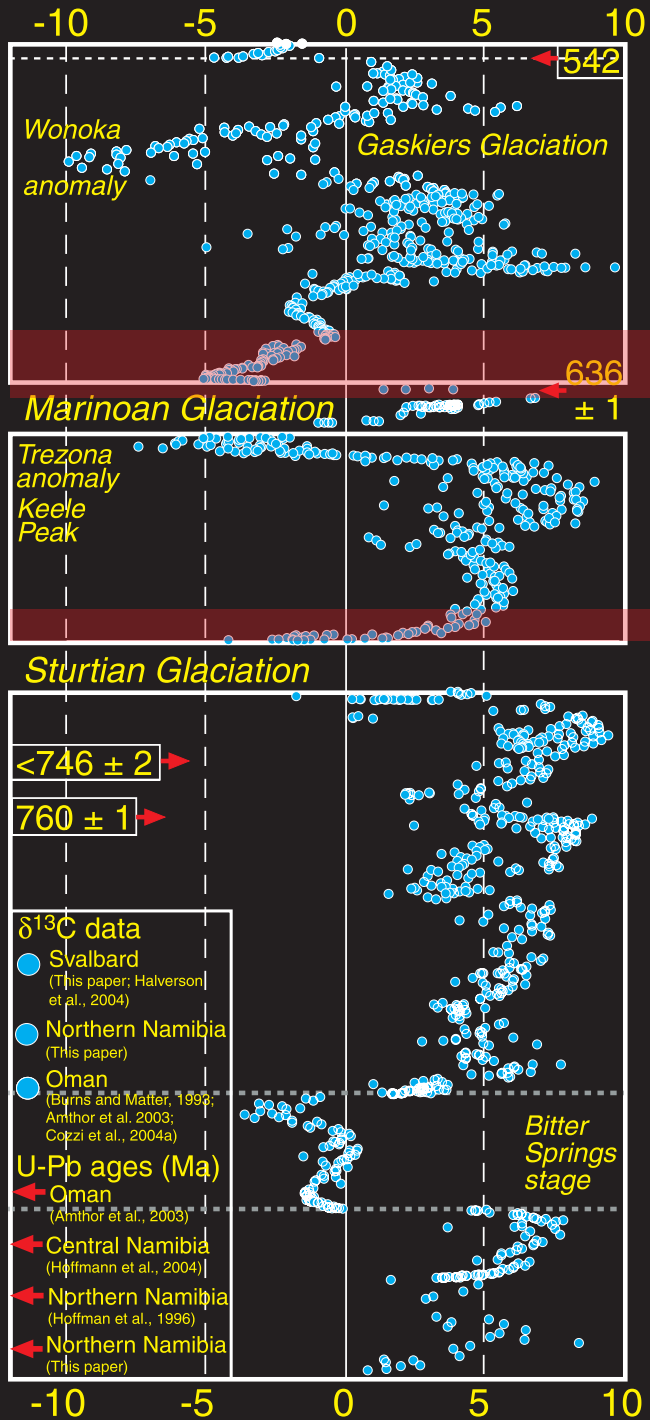
Continued CO₂ out-gassing
 but ... minimal weathering
 ⇒ CO₂ buildup @ -6 o/oo
 and ocean pH decline



Deep-time inferences (aka 'speculation')



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



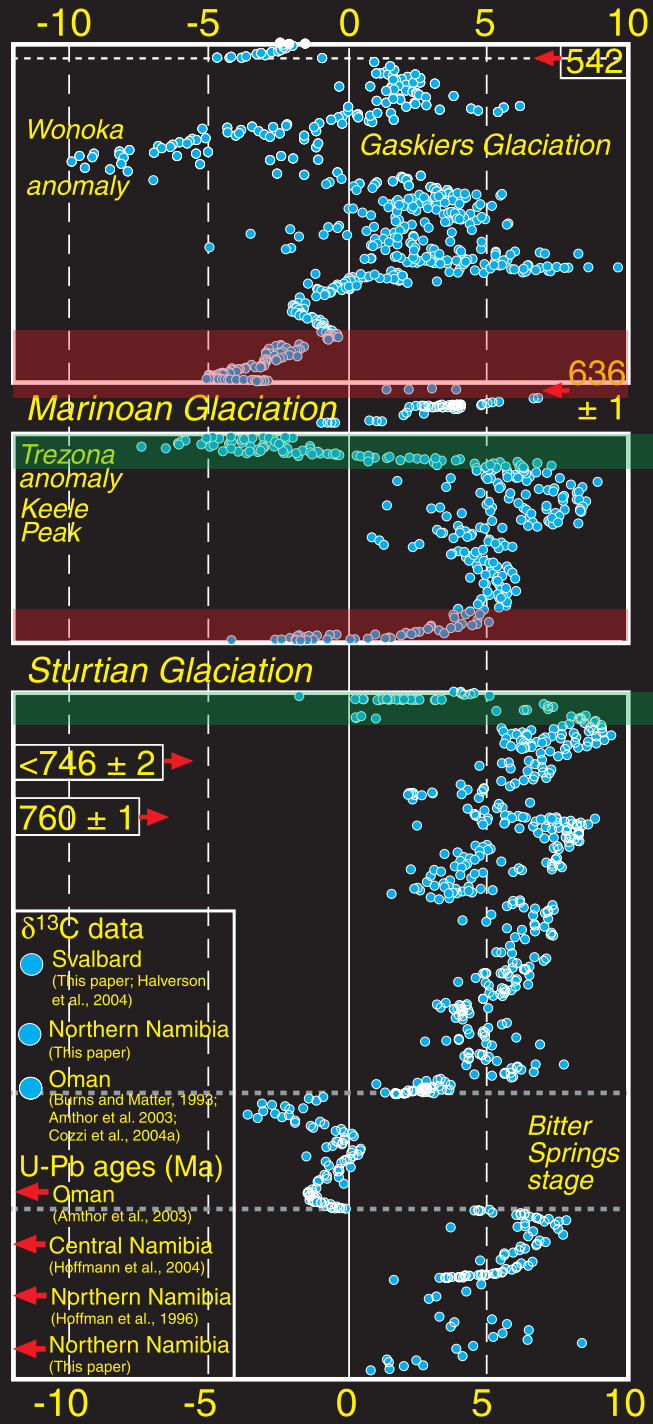
(model simulation on a very different x/y scale)

Adapted from: Halverson et al [2005]

Deep-time inferences (aka 'speculation')



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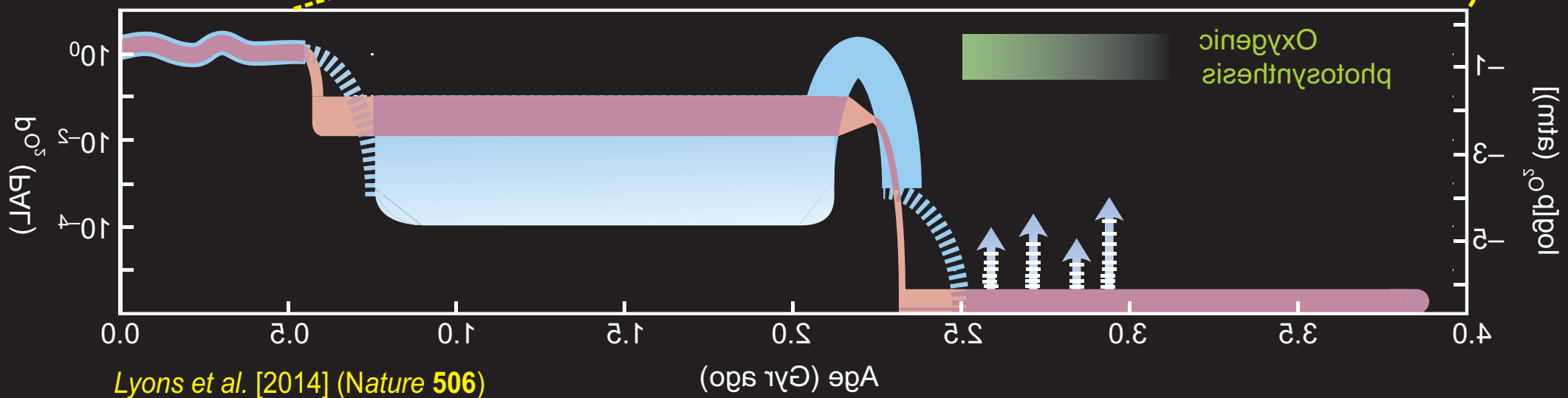
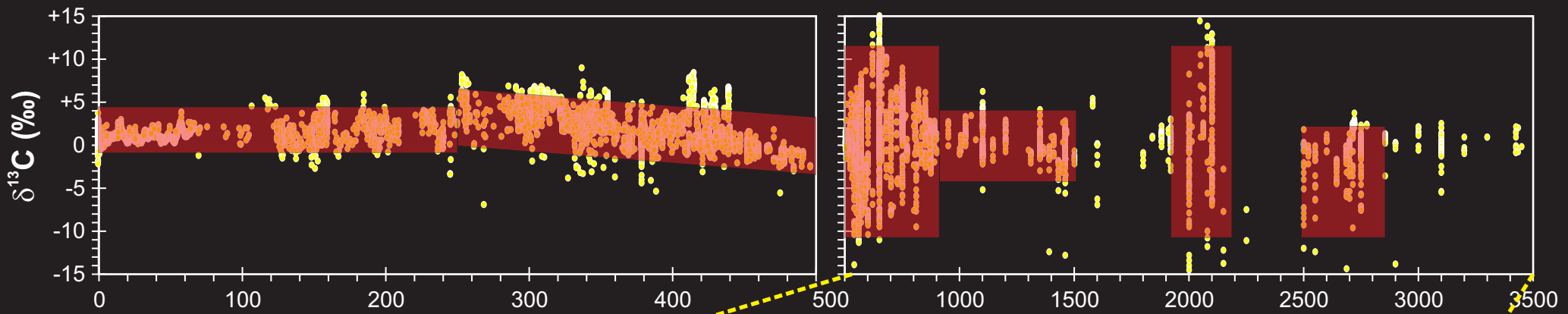
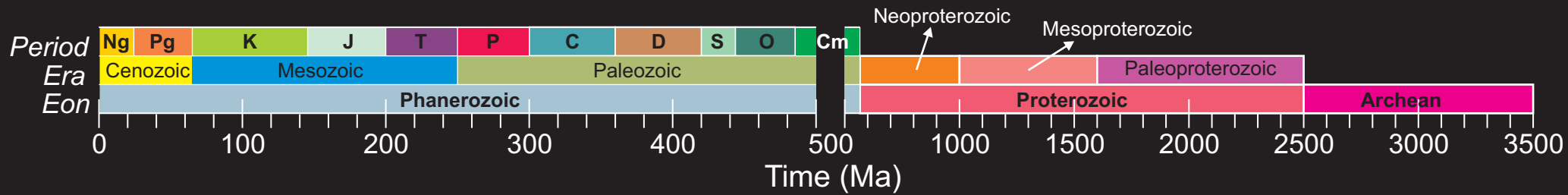
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Prominent declines (and partial recovery) in $\delta^{13}\text{C}$ prior to glacial inception.

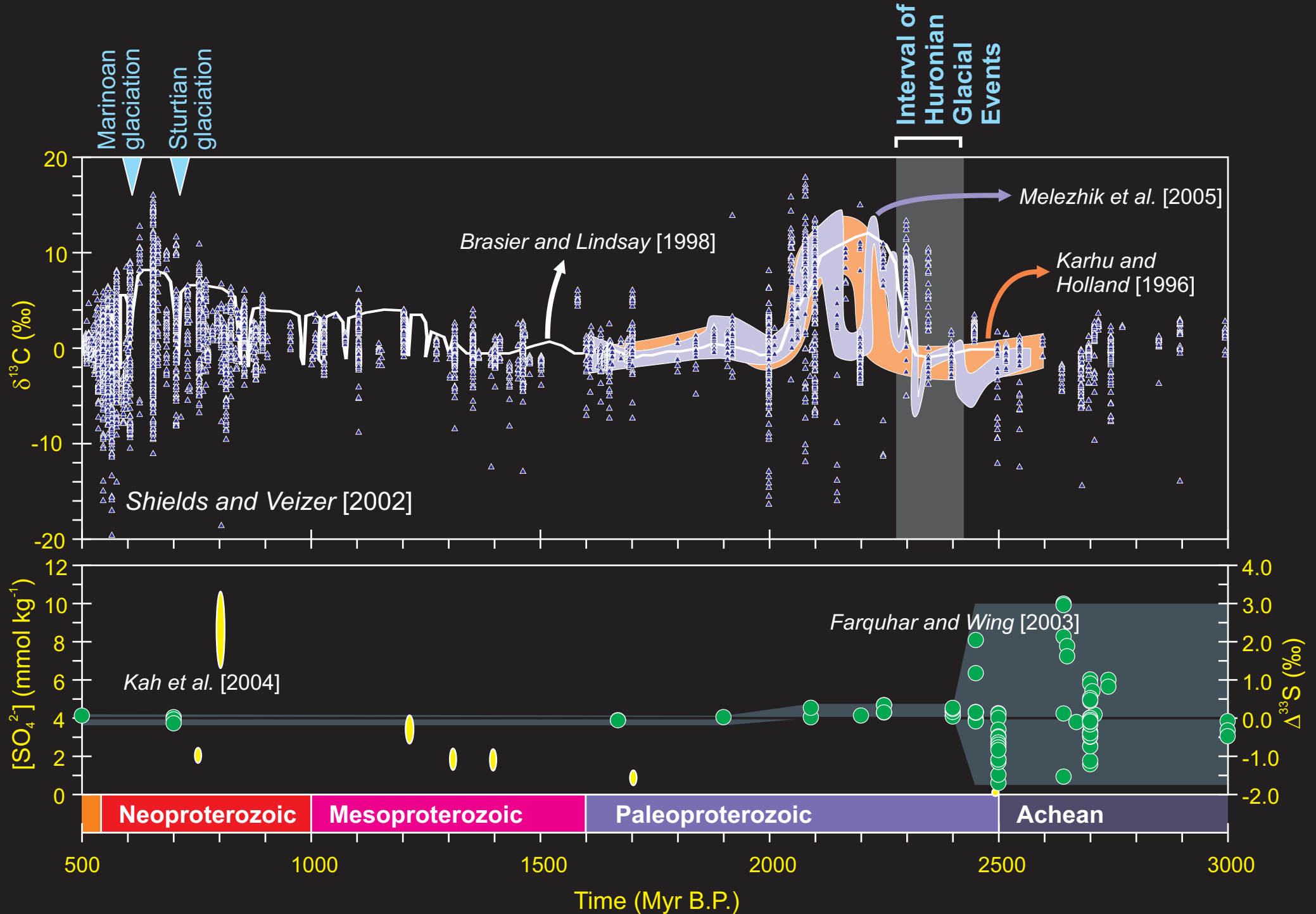
This would be consistent with a pH increase. How?

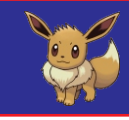
Perhaps enhanced basaltic weathering and CO_2 drawdown (from a state of low pH and high CO_2 @ -6 ‰)??

Deep-time inferences (aka 'speculation')



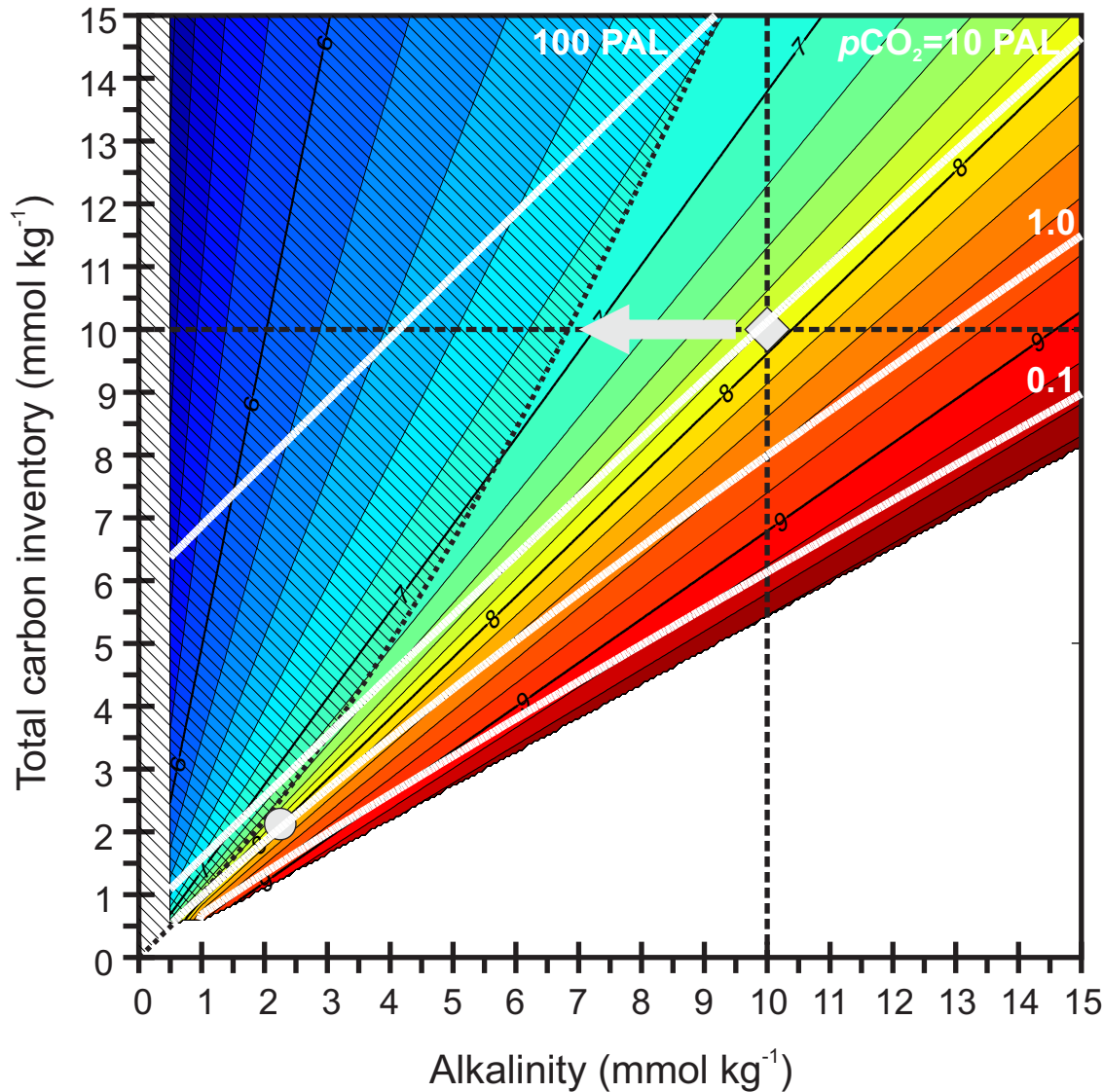
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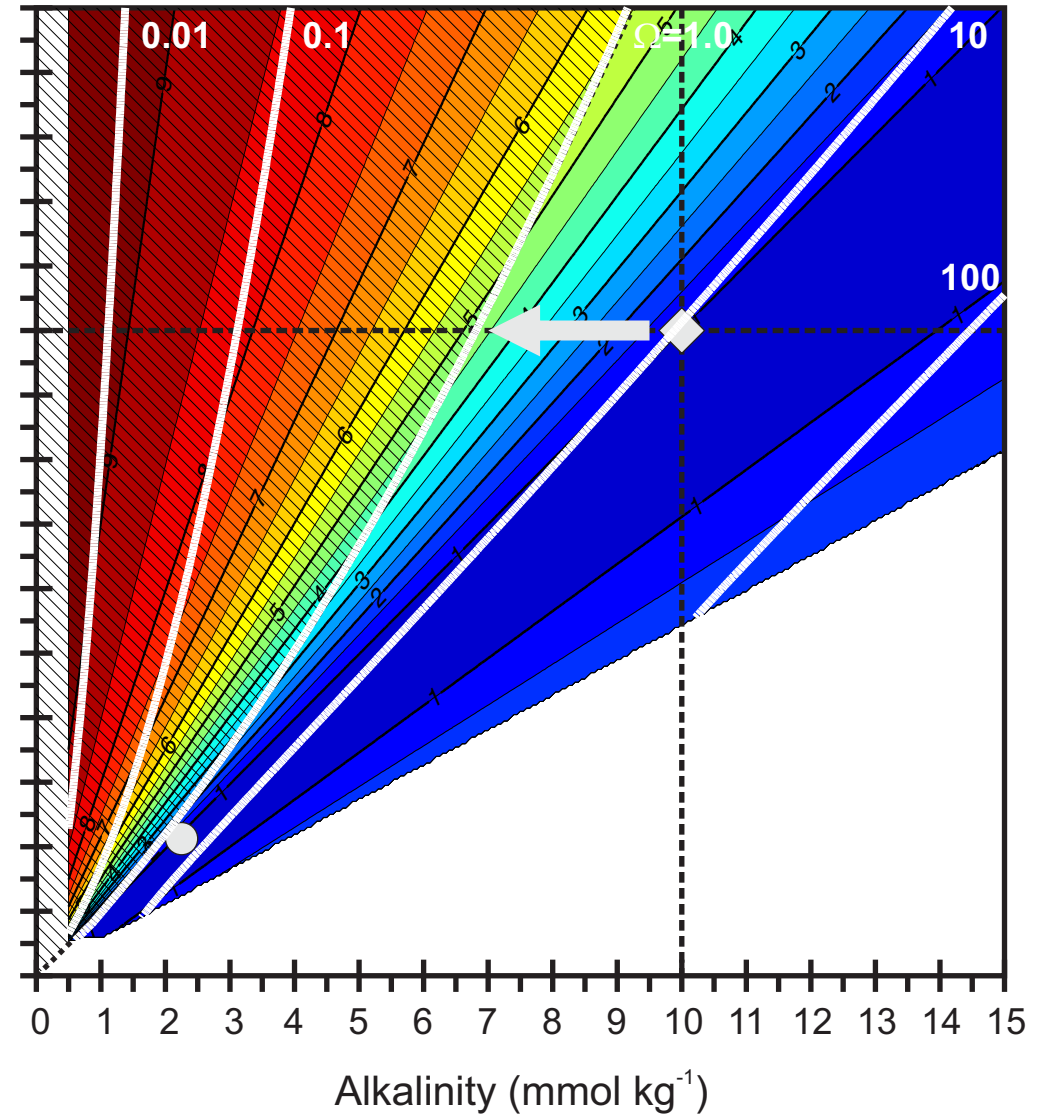


What does it take (e.g. sulphate increase/decrease) to change pH sufficiently?
How does it all (global carbonate cycling and carbonate buffering) pan out?

Mean ocean (surface) pH & pCO_2



Bicarbonate $\delta^{13}C$ & calcite Ω





vs.

