

Evolution of the Biological Pump

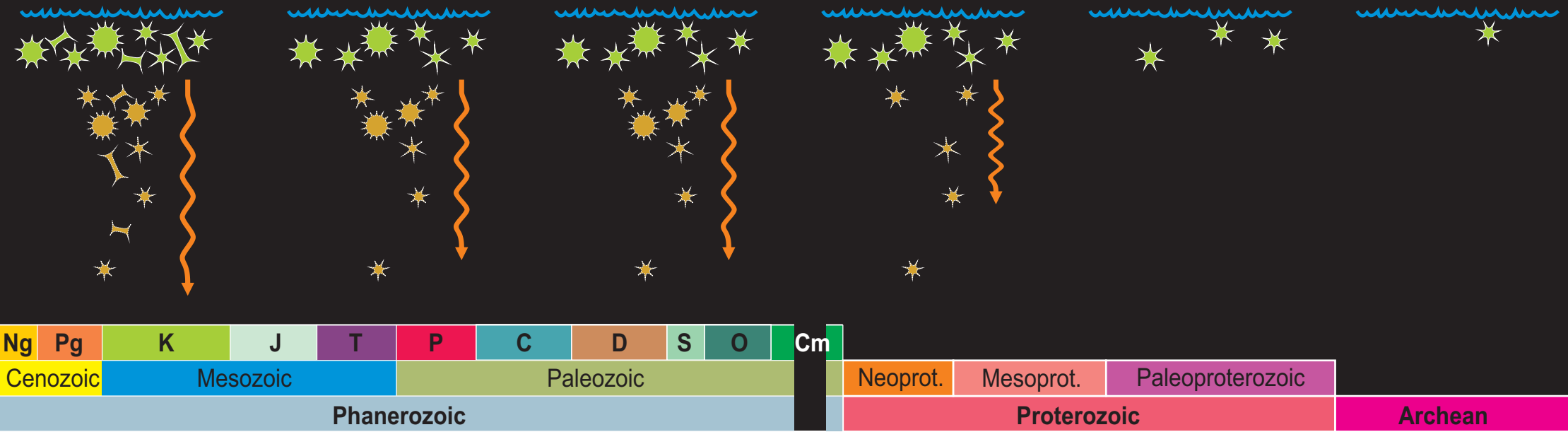
Chicheley Hall Royal Society

Evolution of Carbon Pumping for Dummies

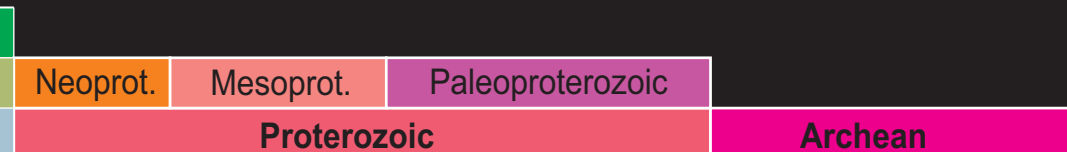
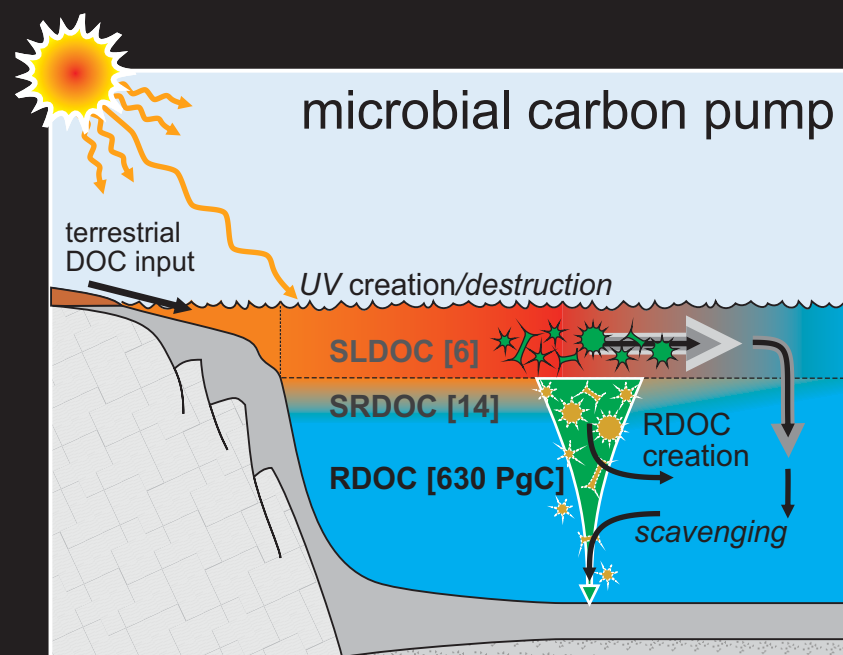
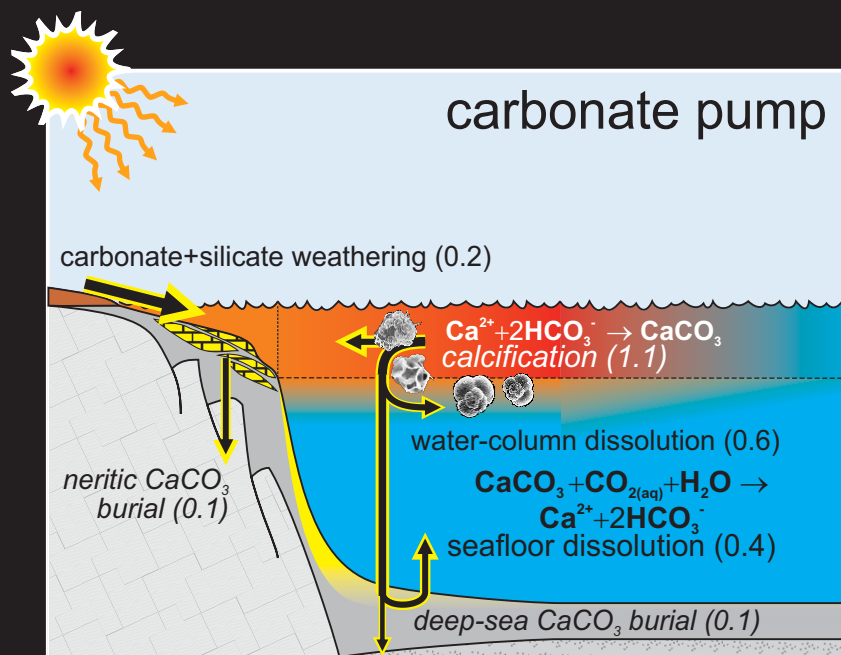
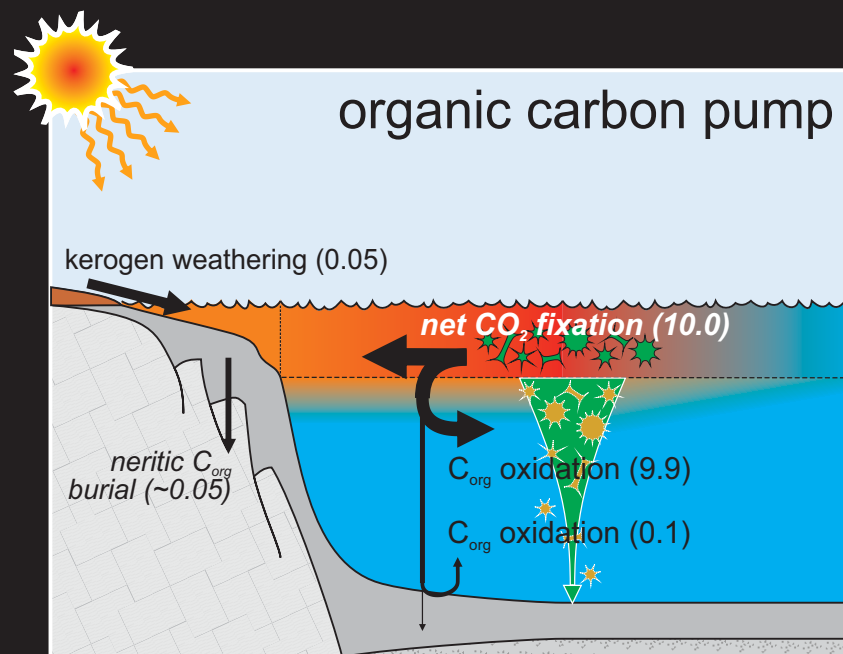
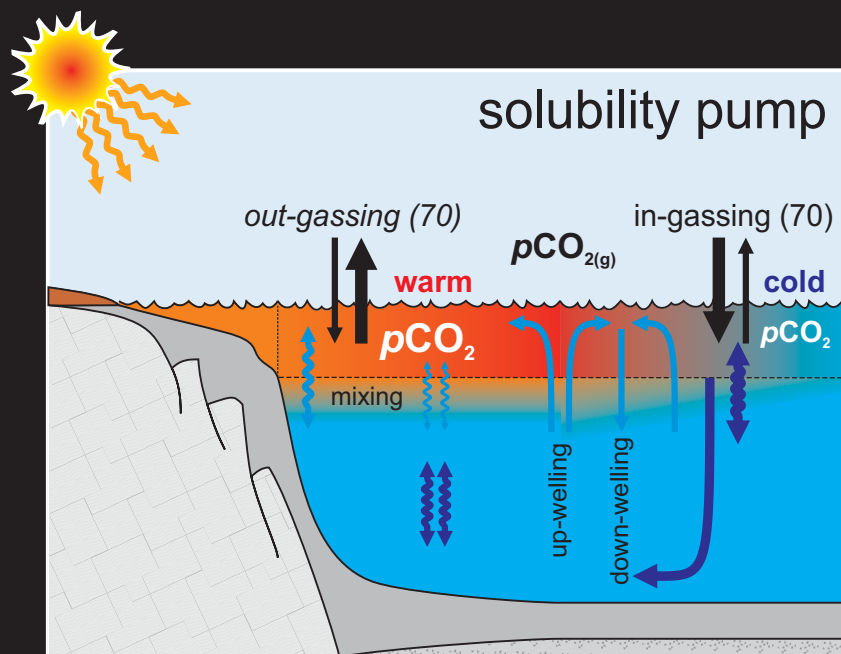
Andy Ridgwell

University of California – Riverside

University of Bristol



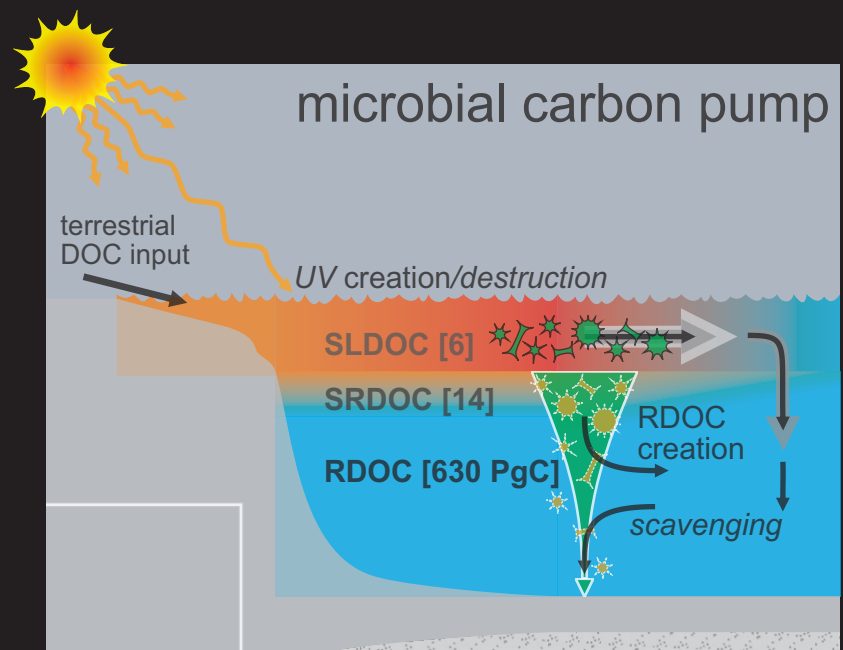
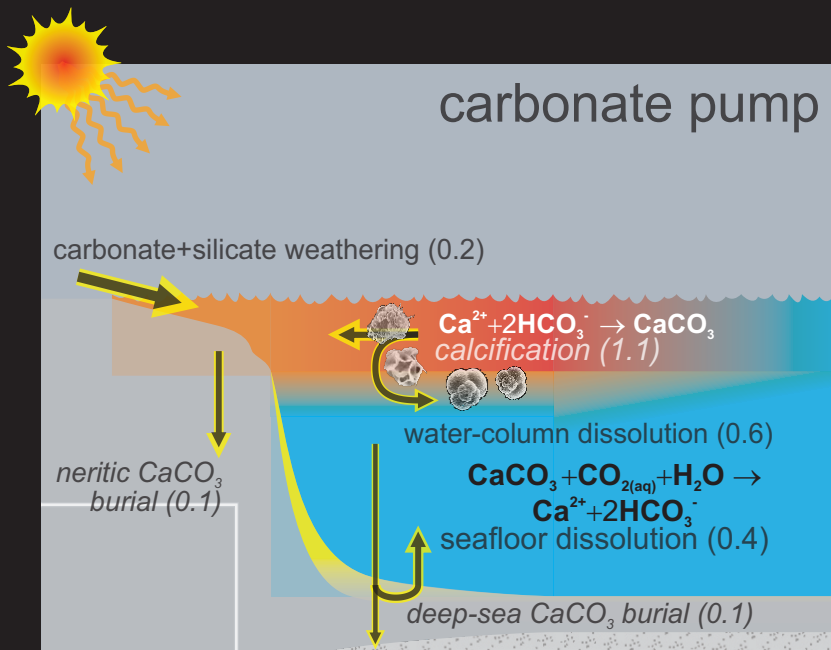
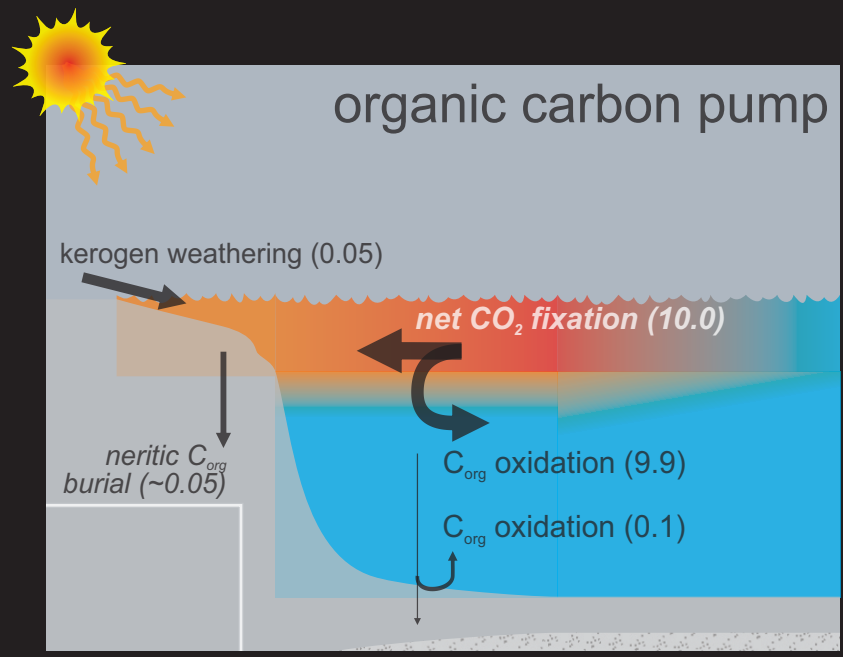
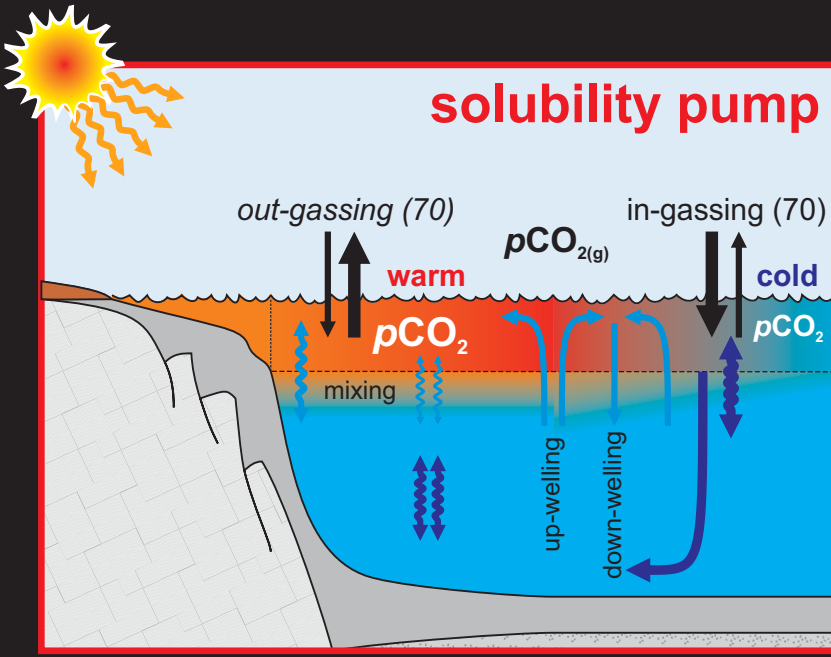
Outline



Outline



pump = f (ocean circulation, pole-to-equator SST, atm pCO₂, surface fCO₂)



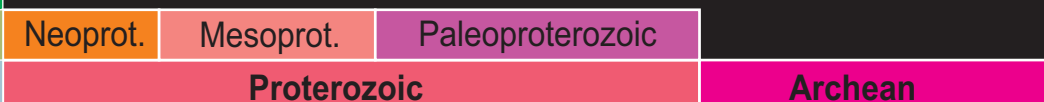
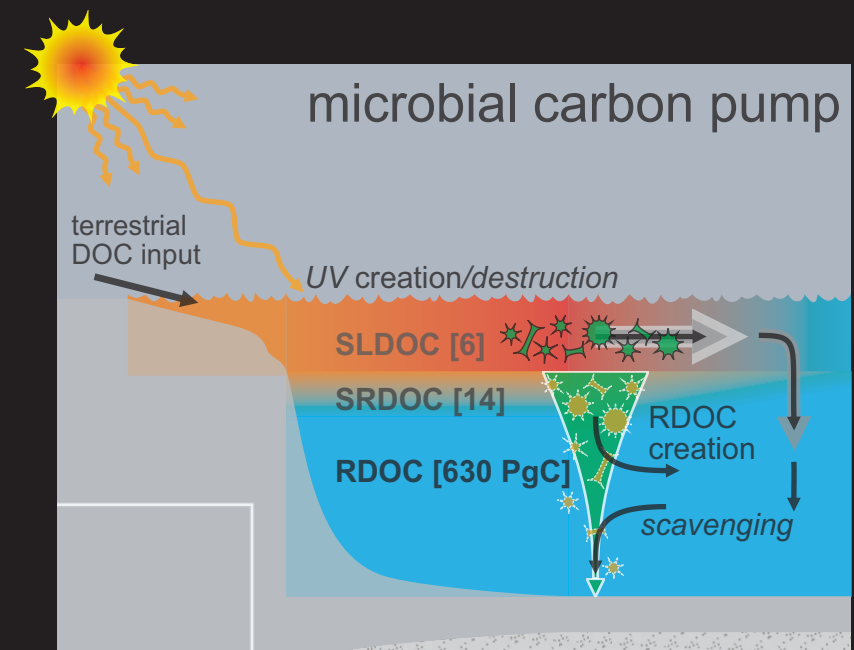
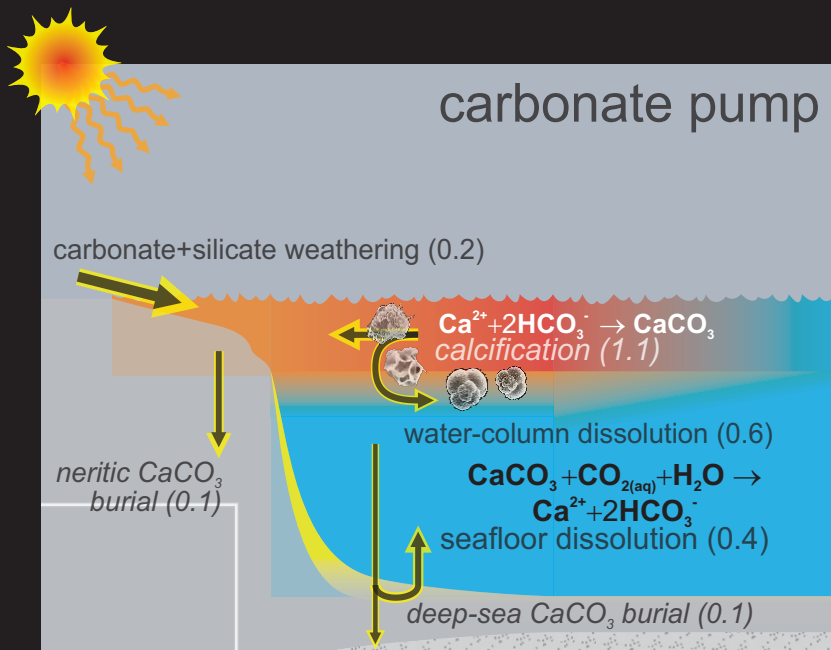
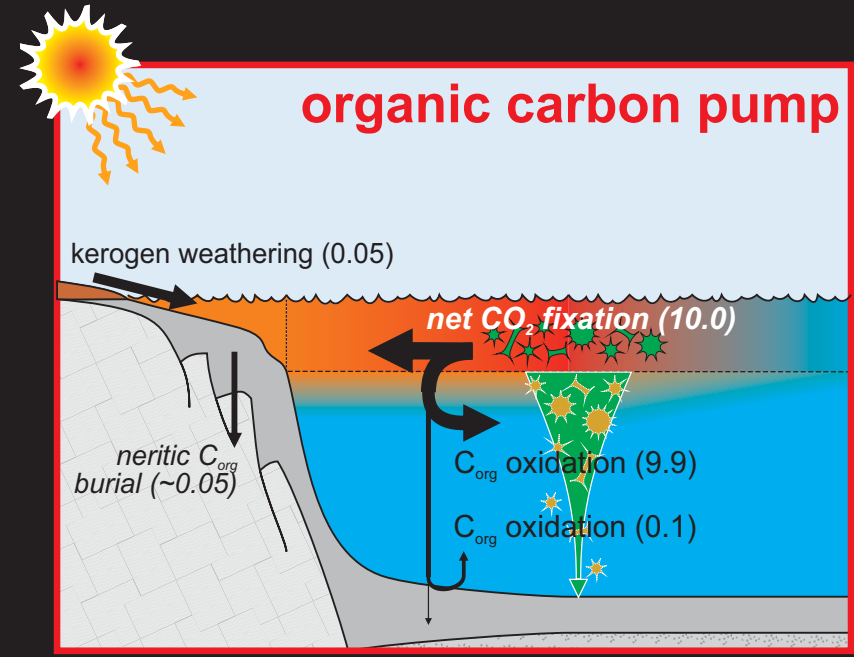
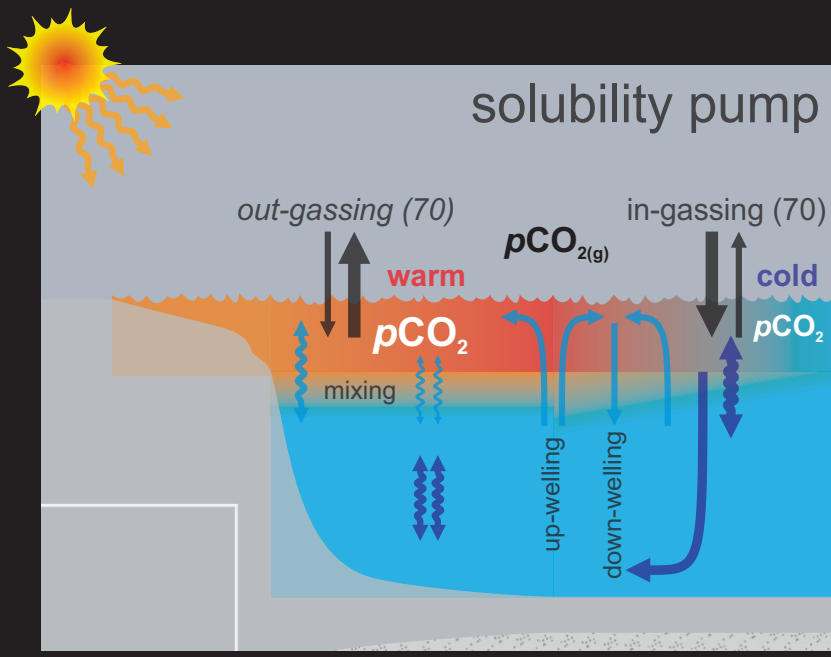
Ng	Pg	K	J	T	P	C	D	S	O	Cm
Cenozoic		Mesozoic			Paleozoic					
Phanerozoic										

Neoprot.	Mesoprot.	Paleoproterozoic
Proterozoic		

Archean



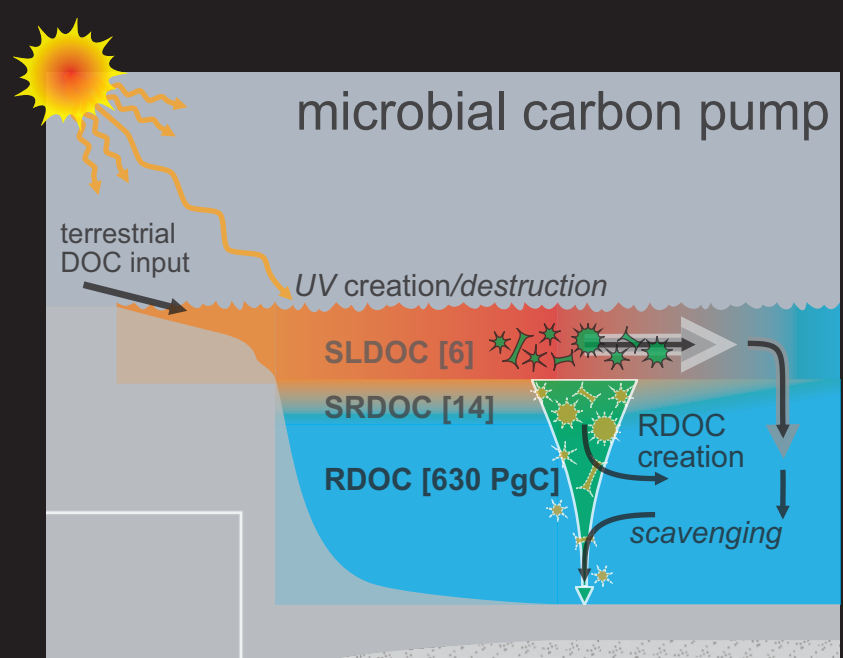
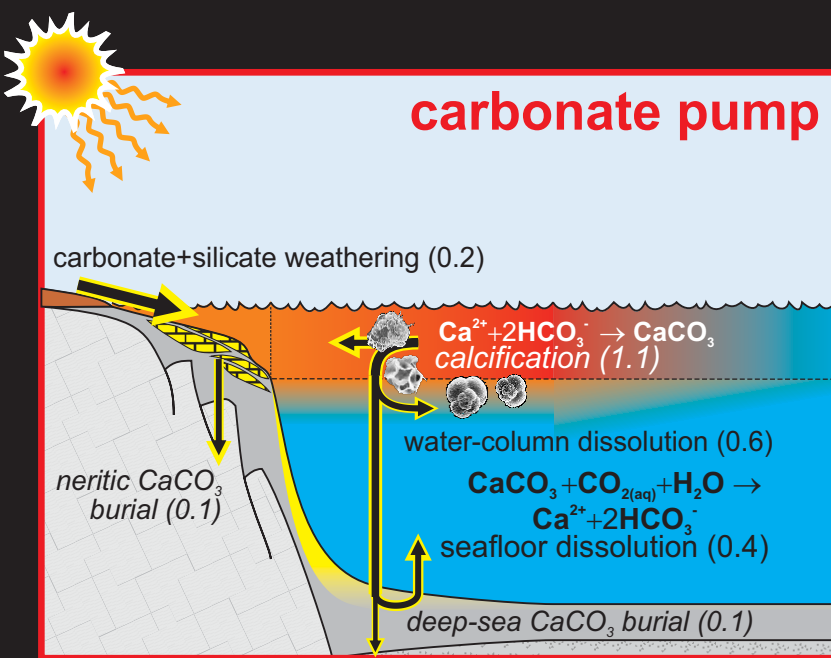
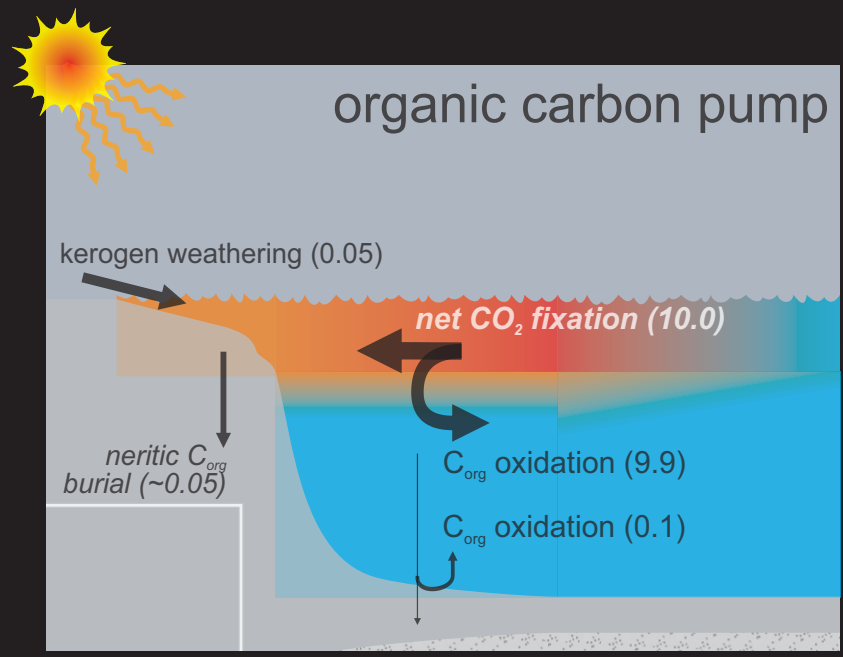
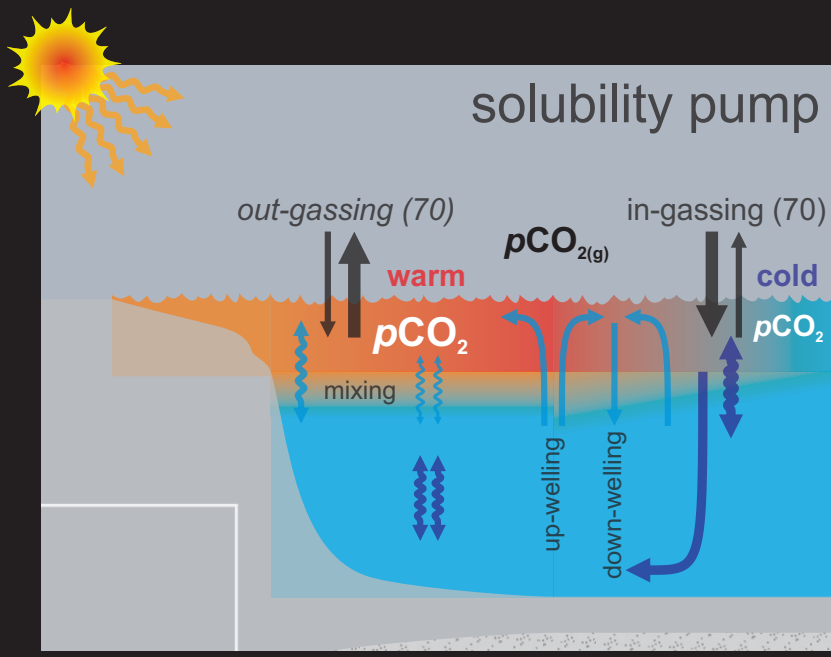
pump = f(biological export (I(...)), remineralization (I(...)))



Outline



pump = f (biological export (I(...)),
 remineralization (I(...)))



Ng	Pg	K	J	T	P	C	D	S	O	Cm
Cenozoic		Mesozoic			Paleozoic					
Phanerozoic										

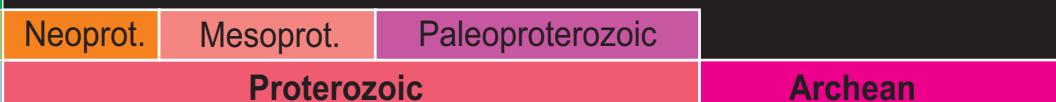
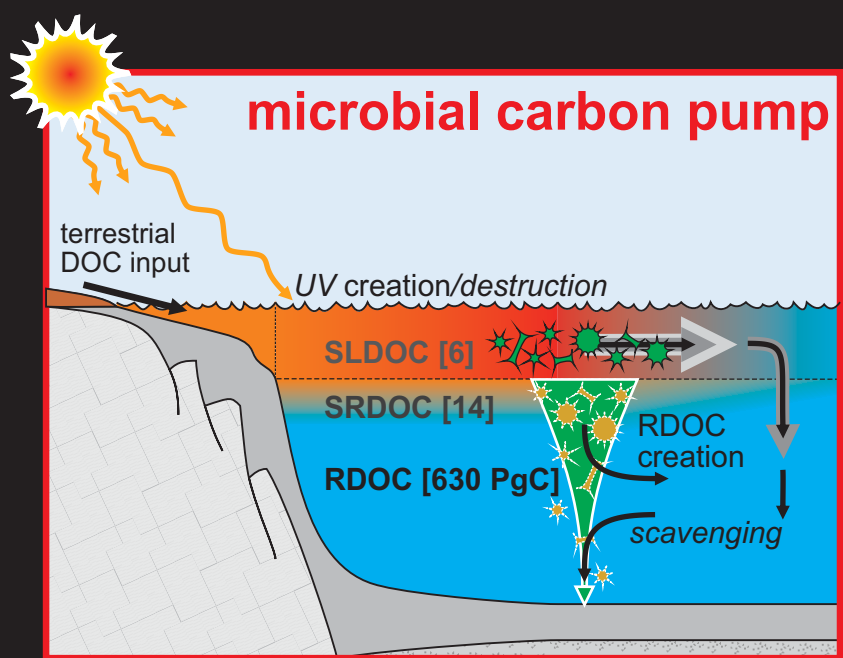
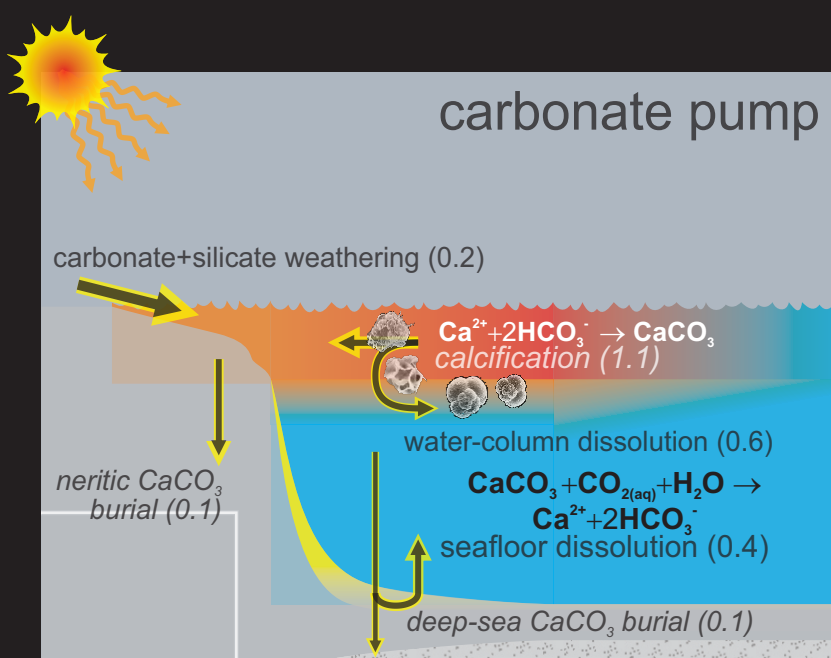
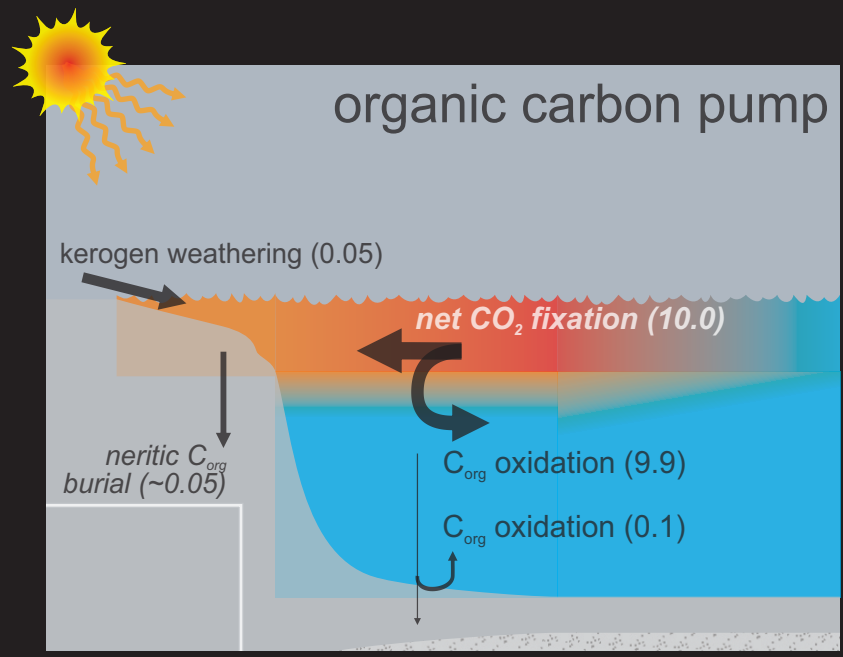
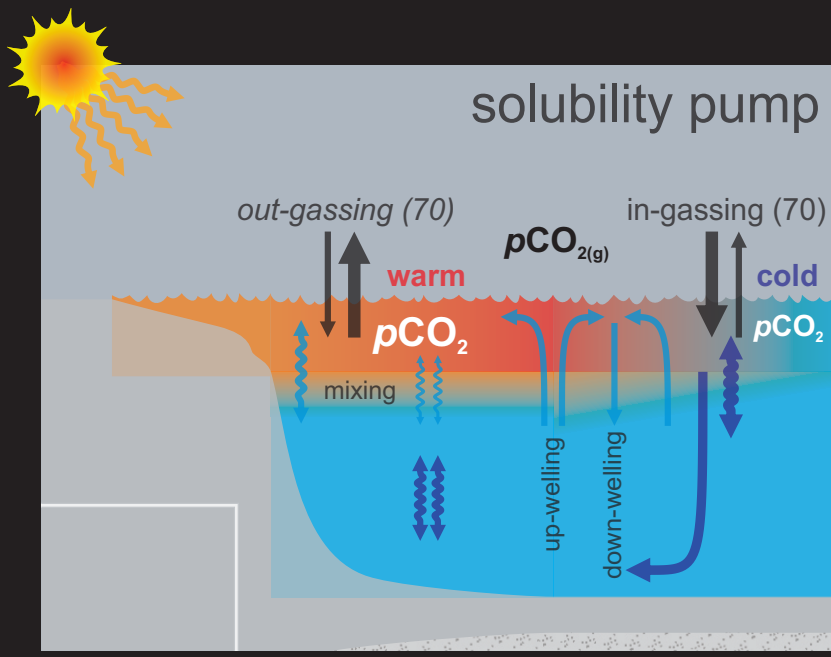
Neoprot.	Mesoprot.	Paleoproterozoic
Proterozoic		

Archean

Outline



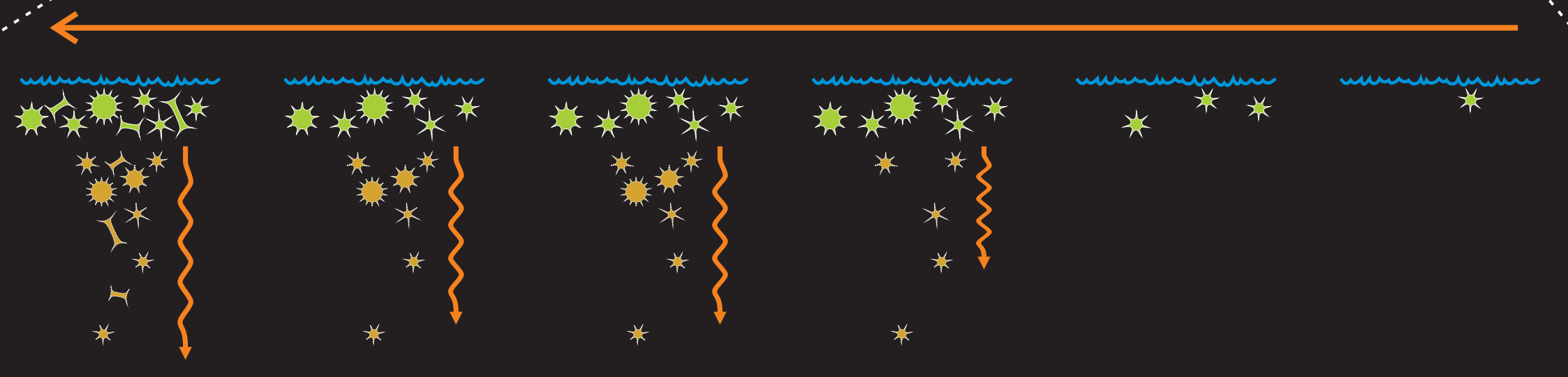
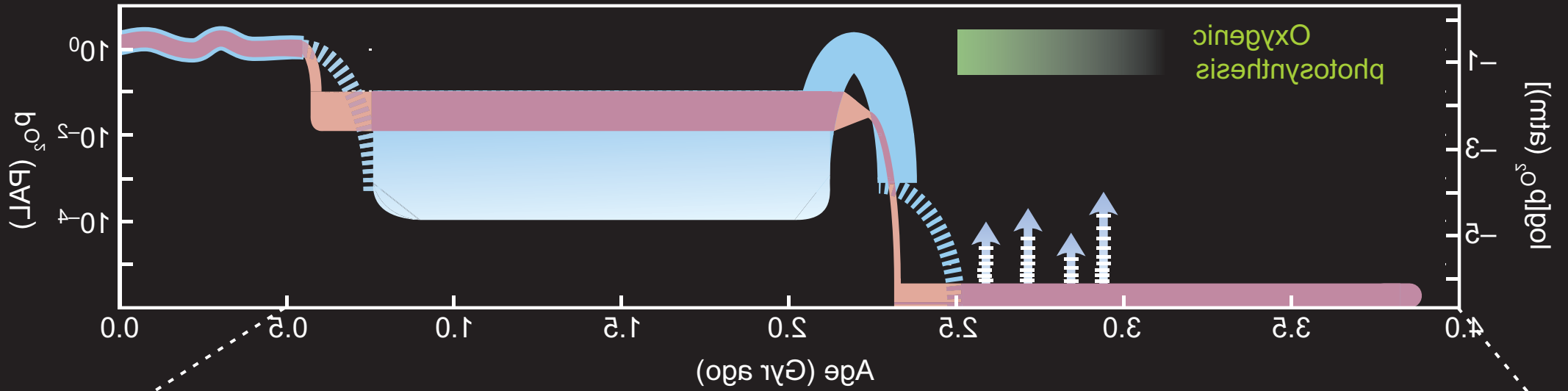
pump = f (circulation, biological pump),
 POM/DOM quality,
 redox???, ???



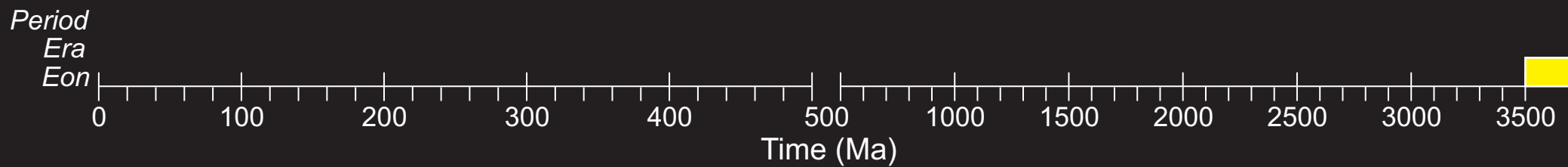
Outline

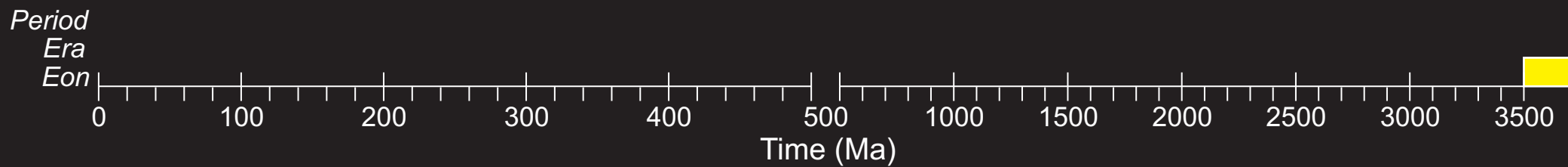
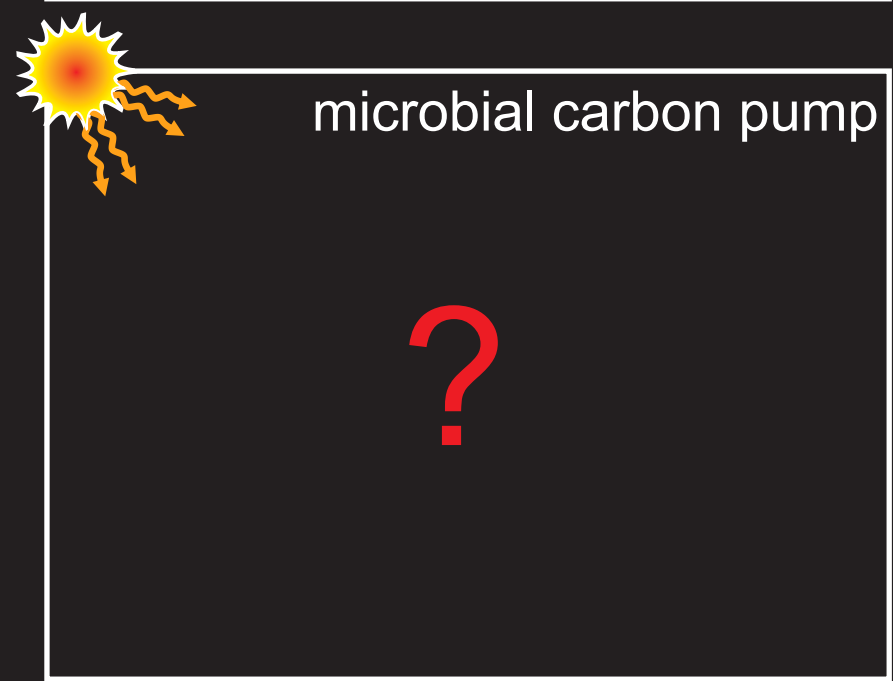
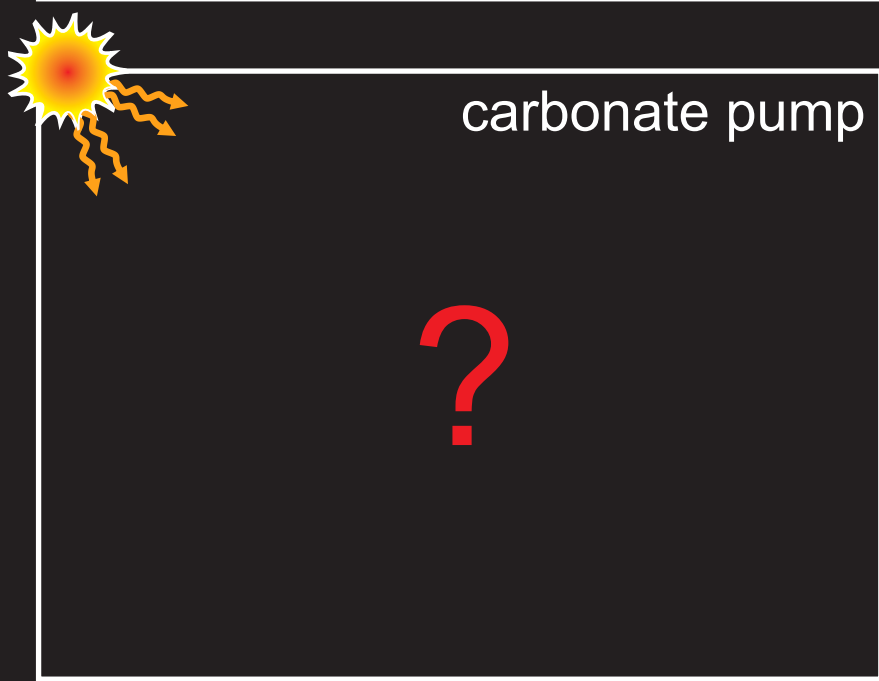
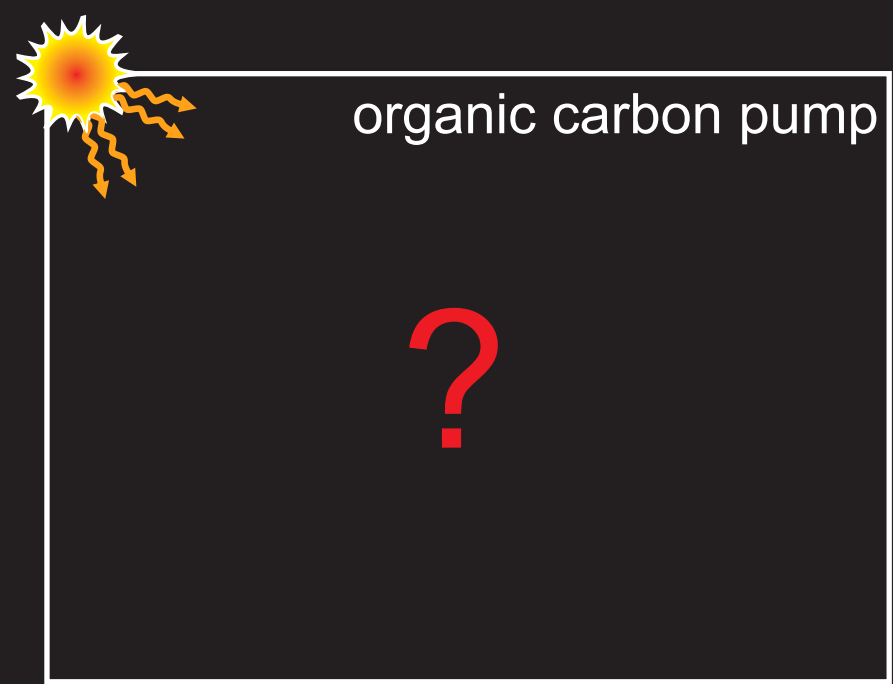
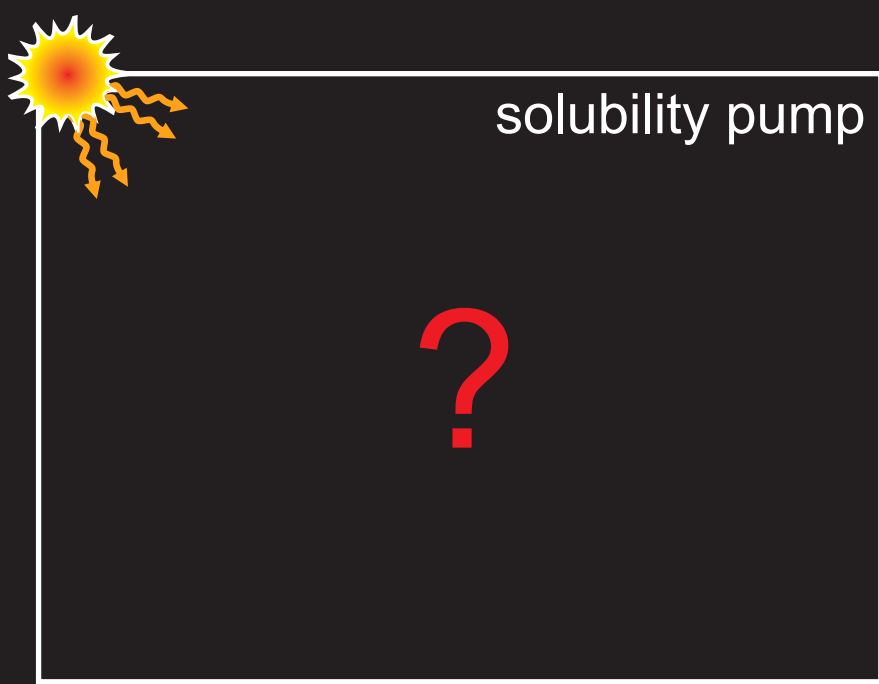


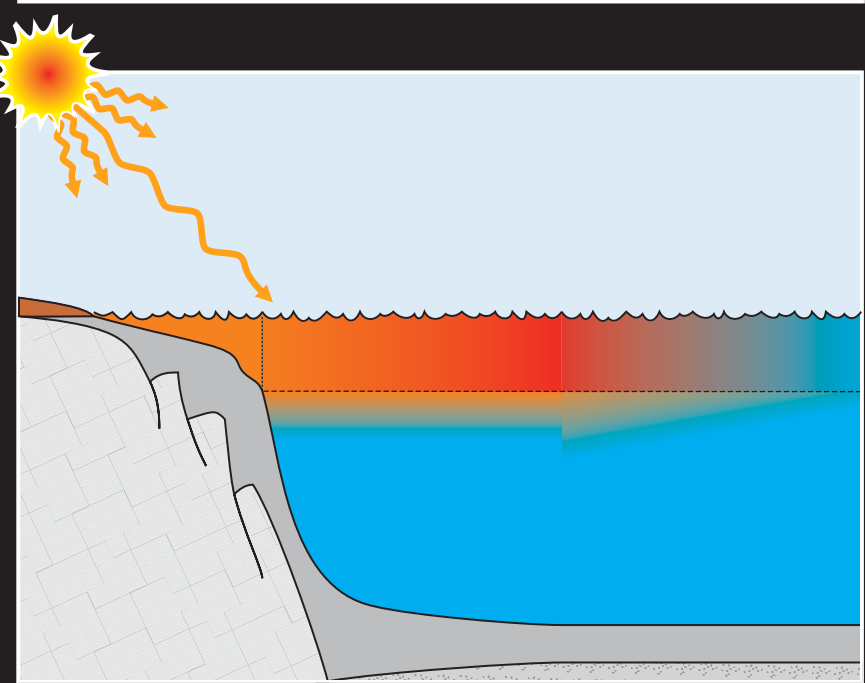
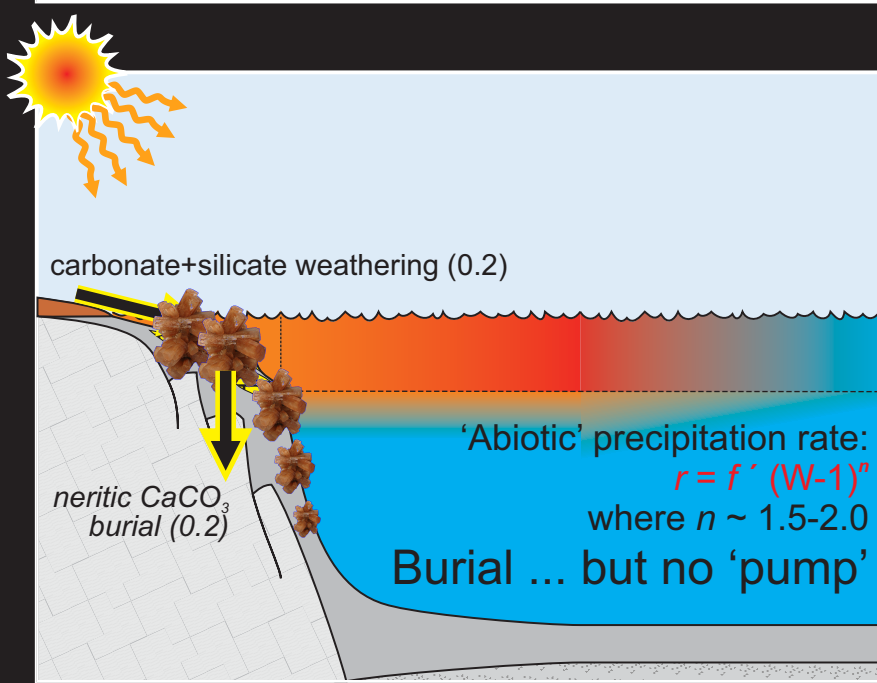
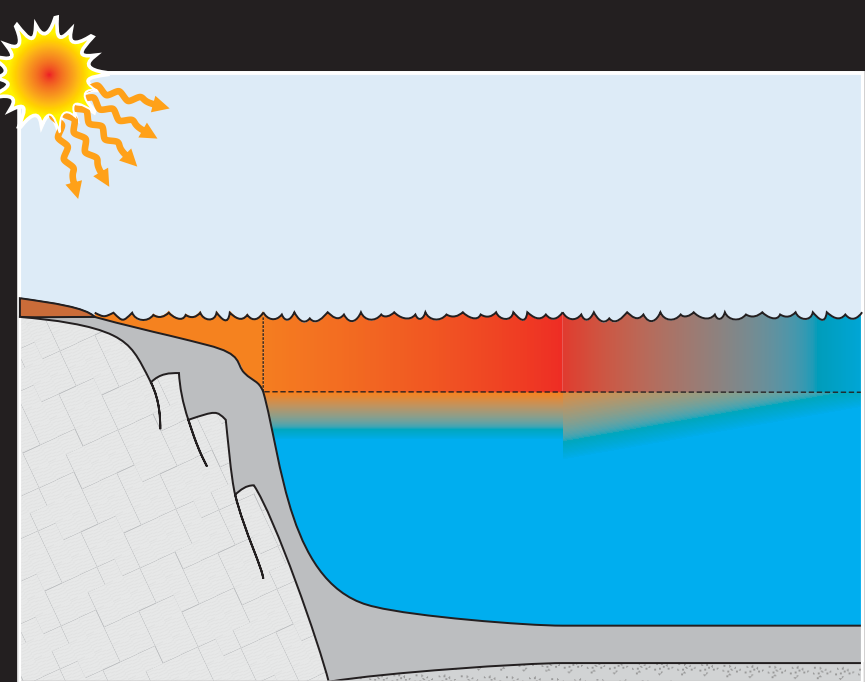
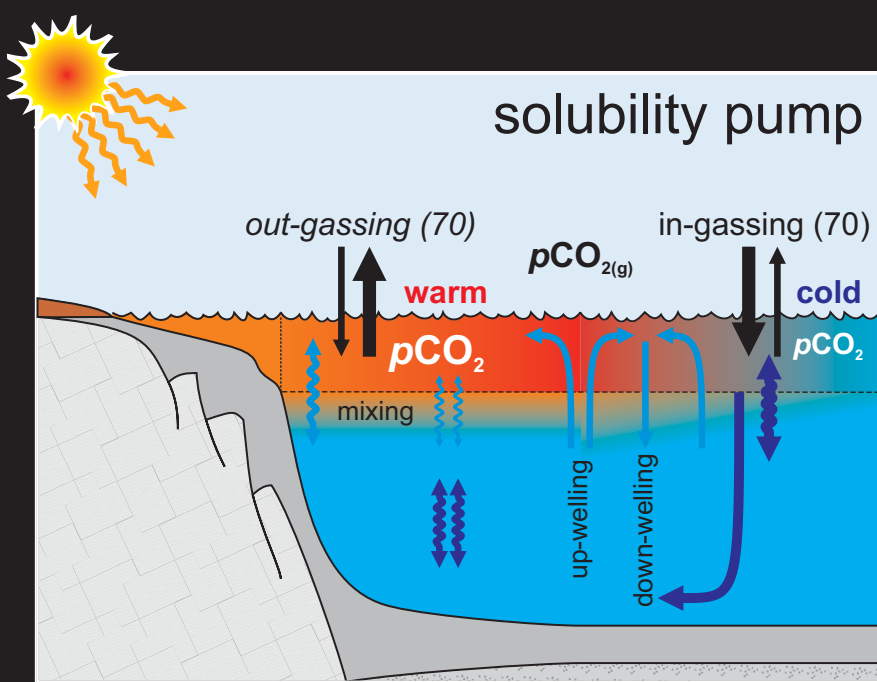
[Lyons et al. [2014] (Nature 506)]



Origins ...







Period
Era
Eon



Time (Ma)

The Force awakens ... ???

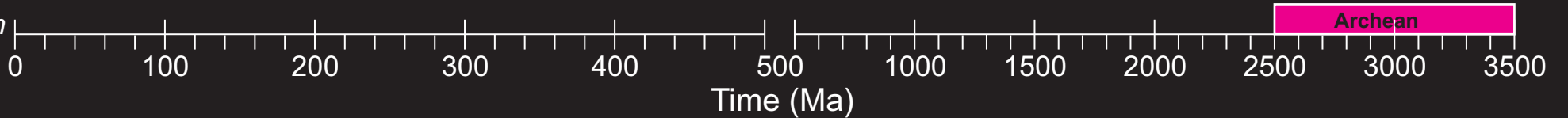


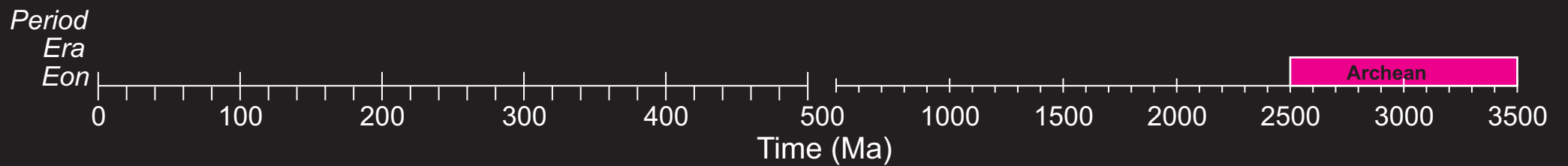
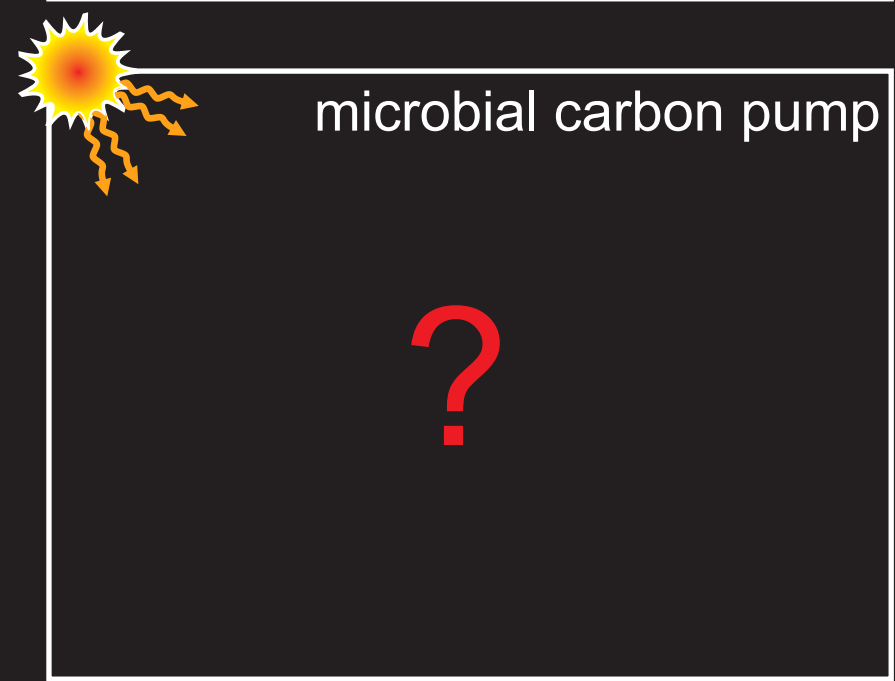
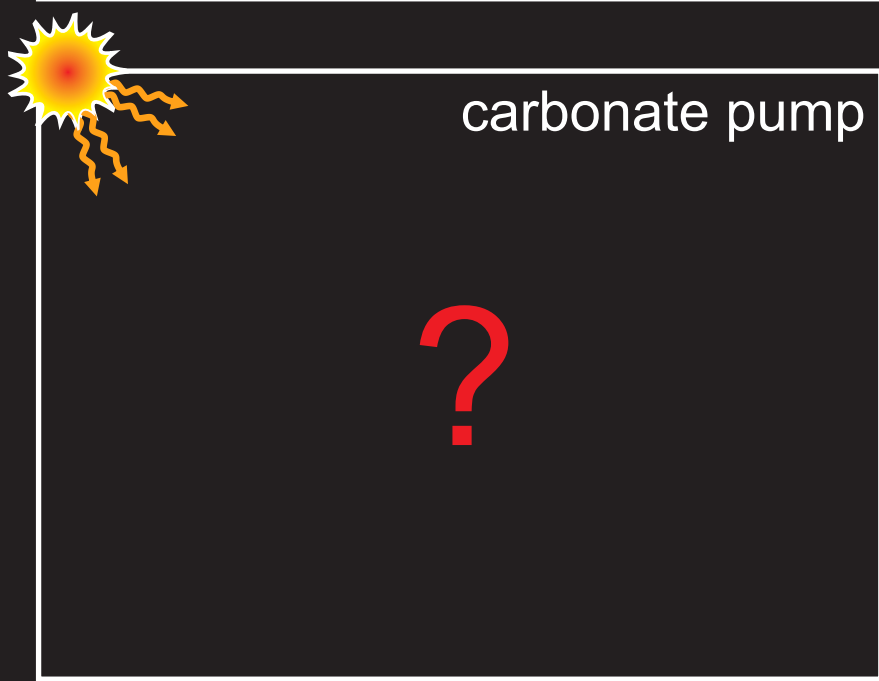
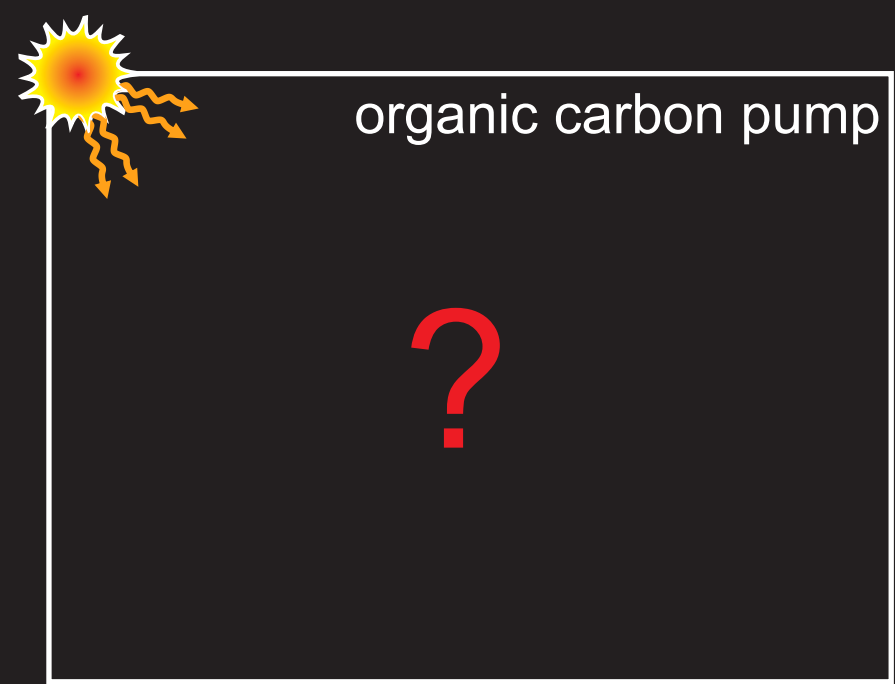
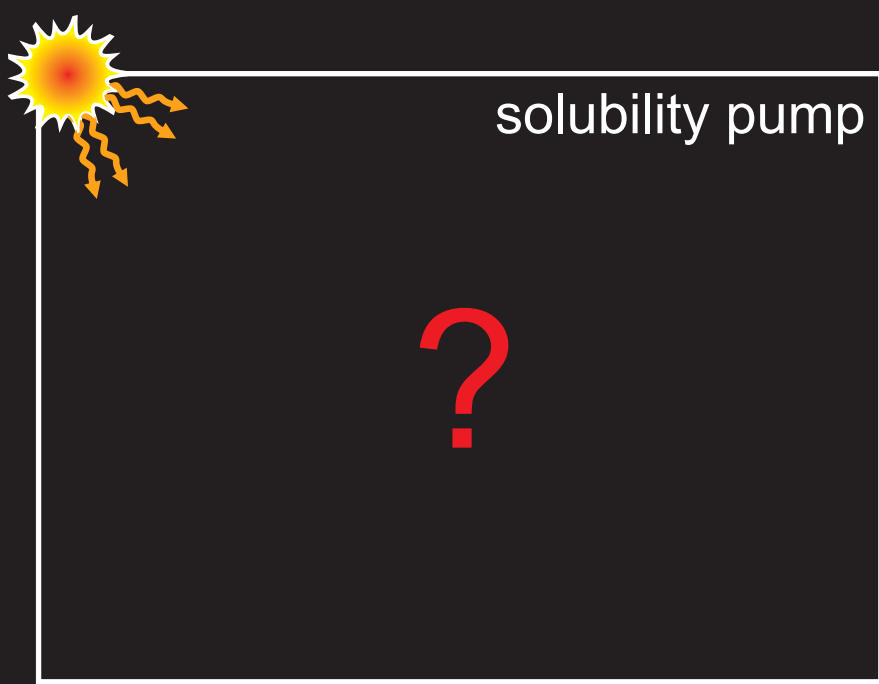
Evolutionary innovations
& plankton assemblage

Cyanobacteria

origin of photosystems I and II

Period
Era
Eon

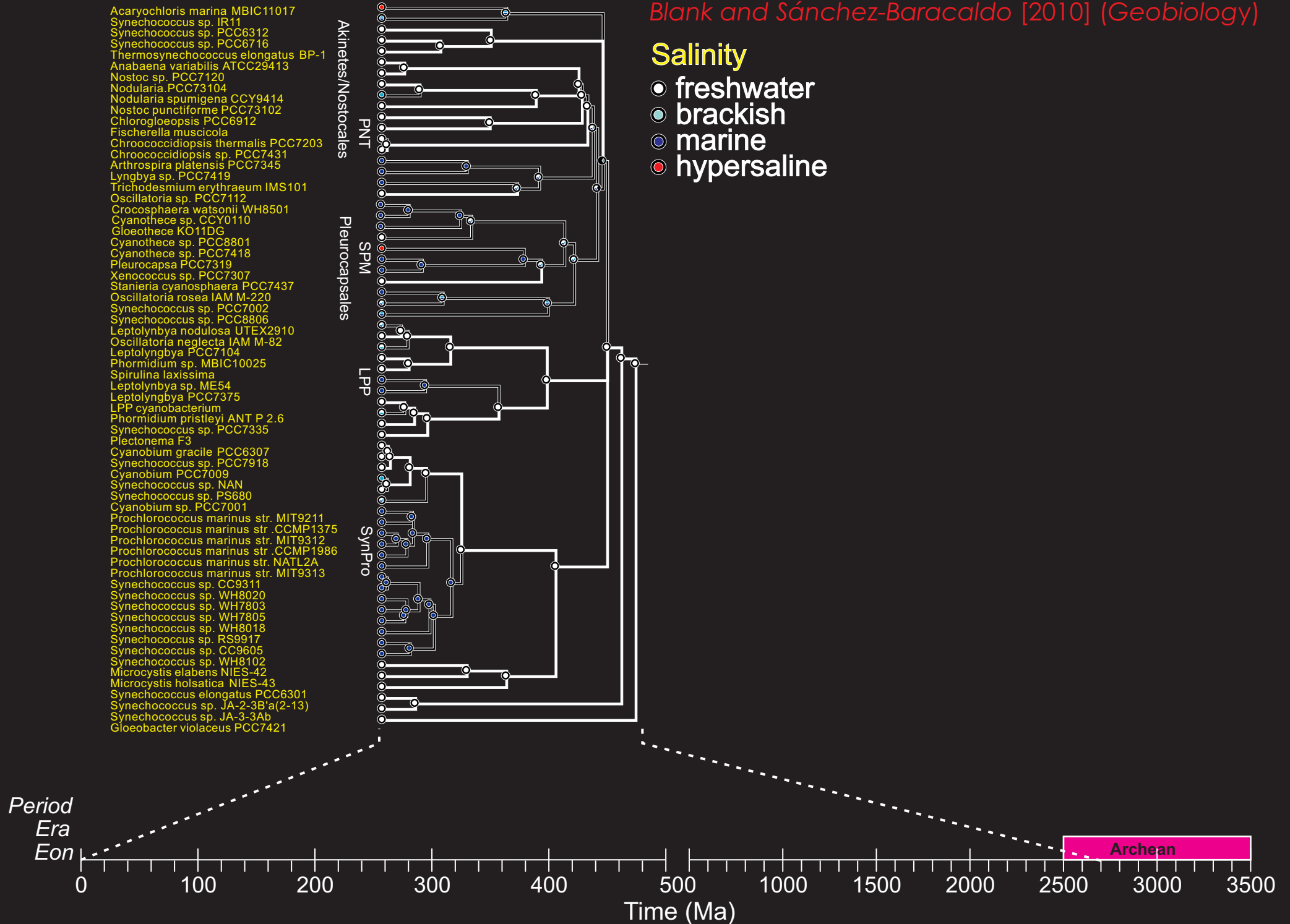


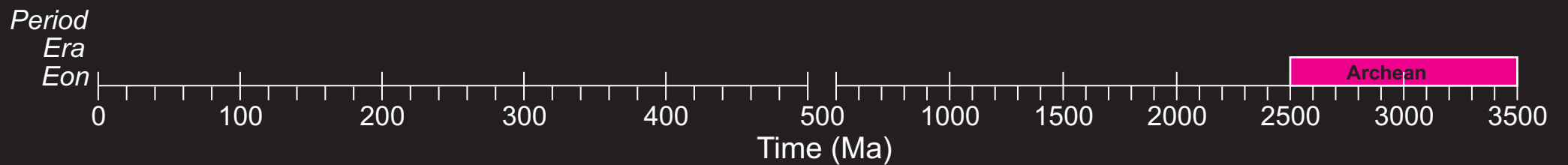
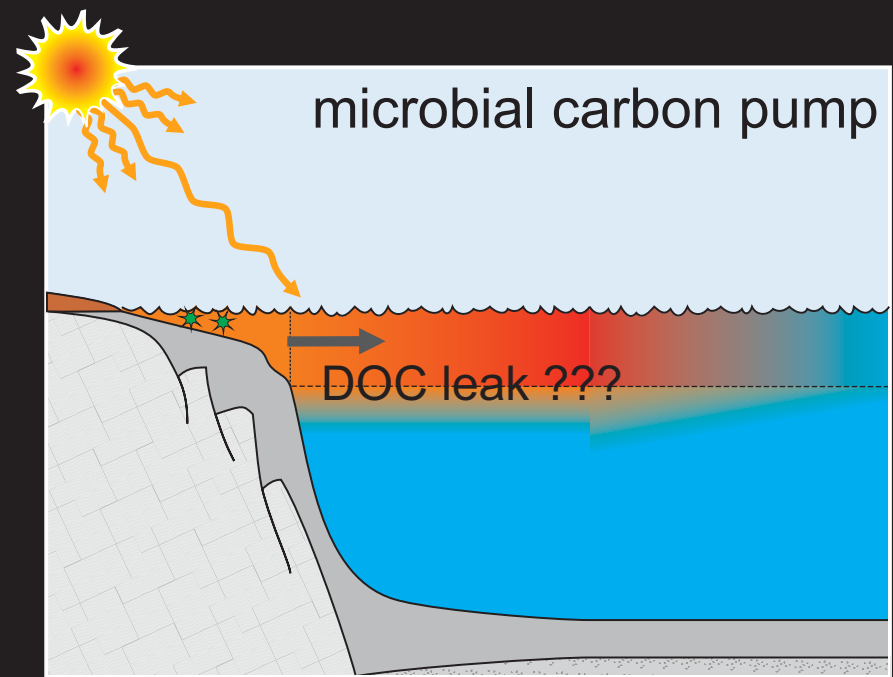
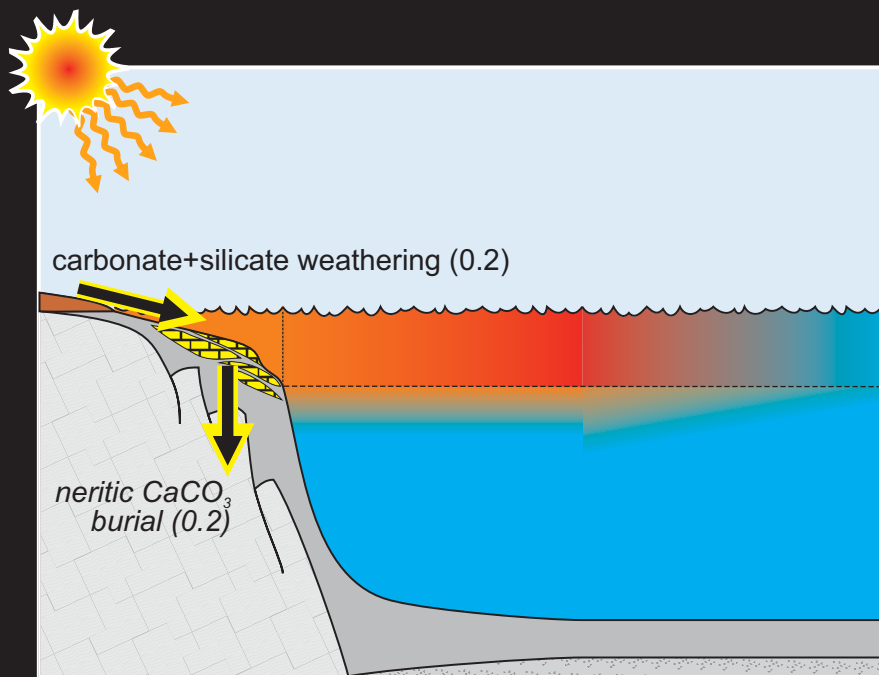
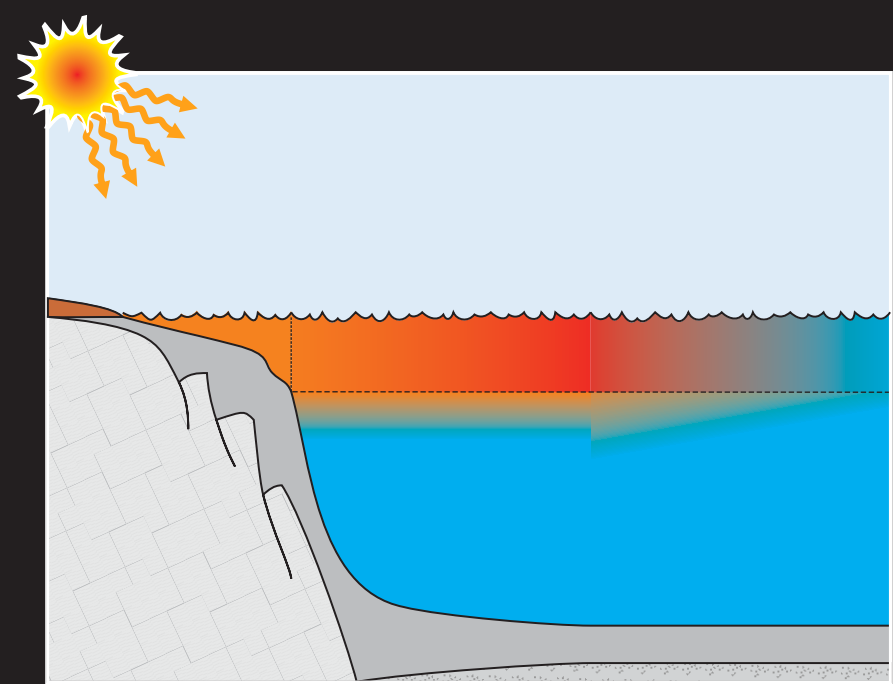
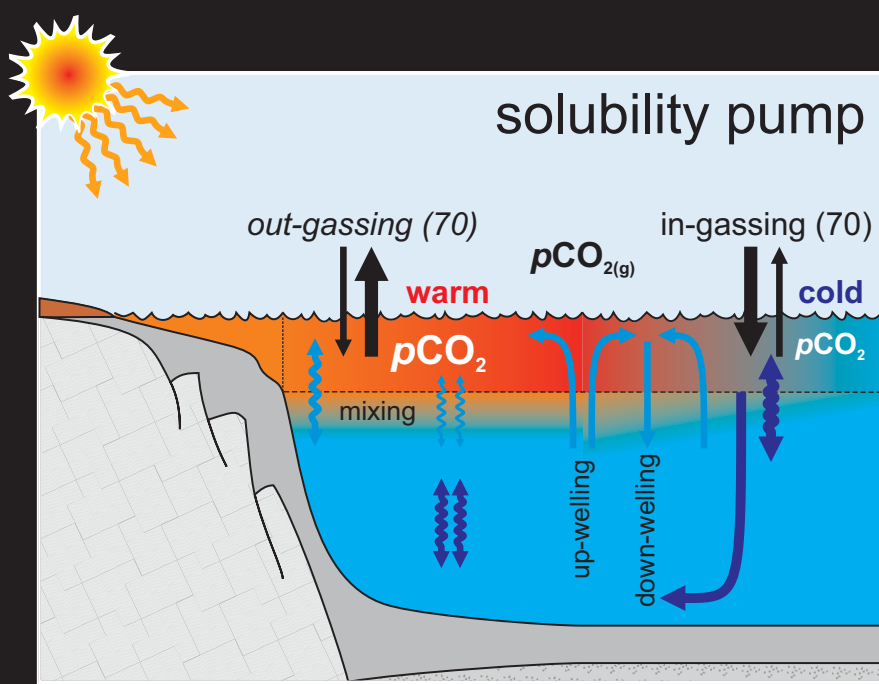


The Force awakens ... ???



Blank and Sánchez-Baracaldo [2010] (Geobiology)

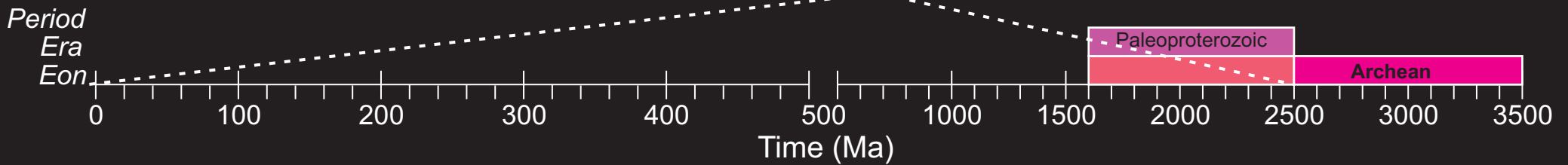
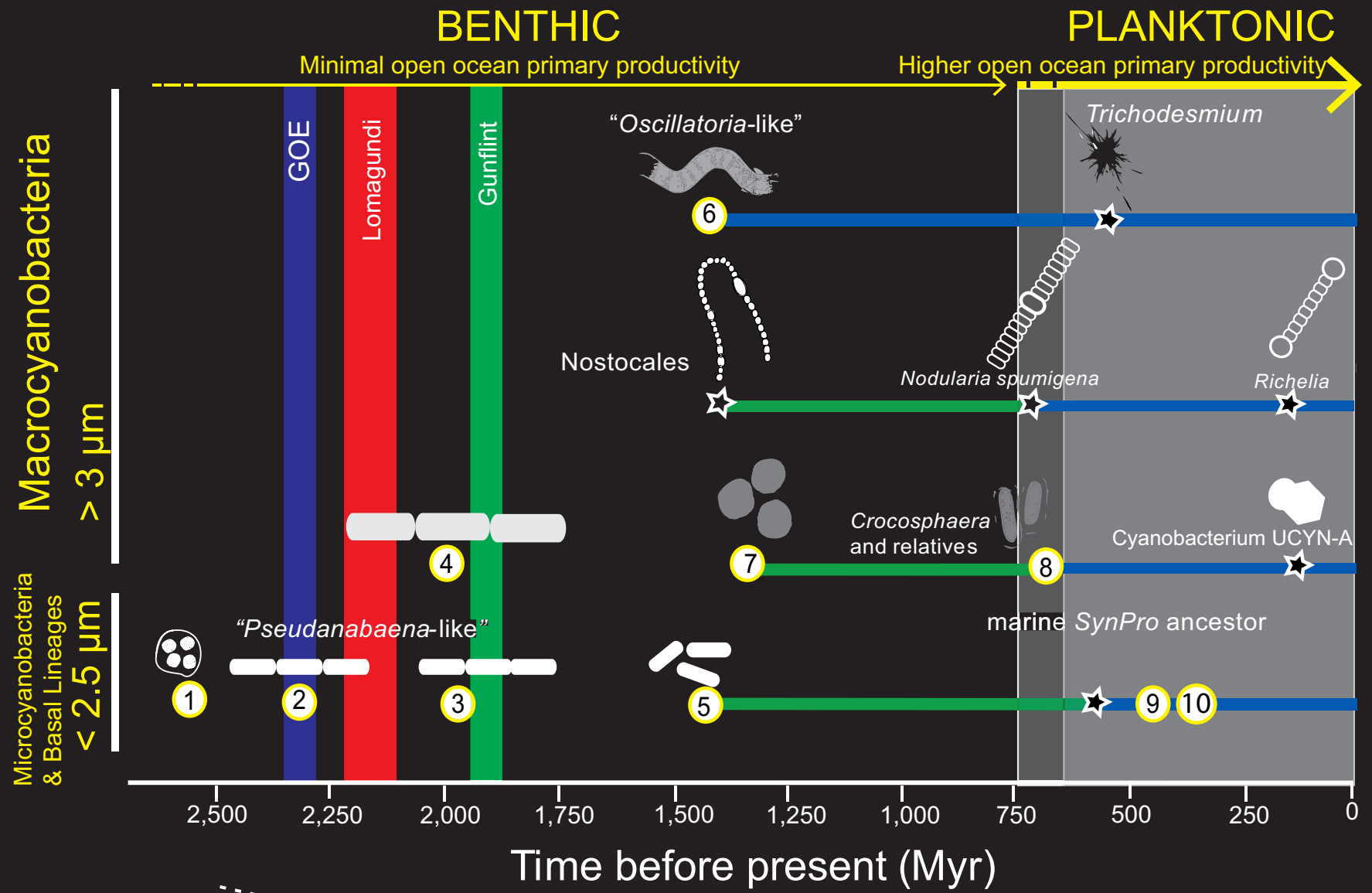


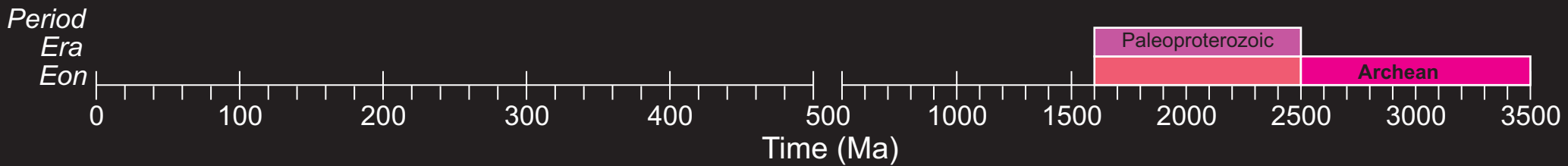
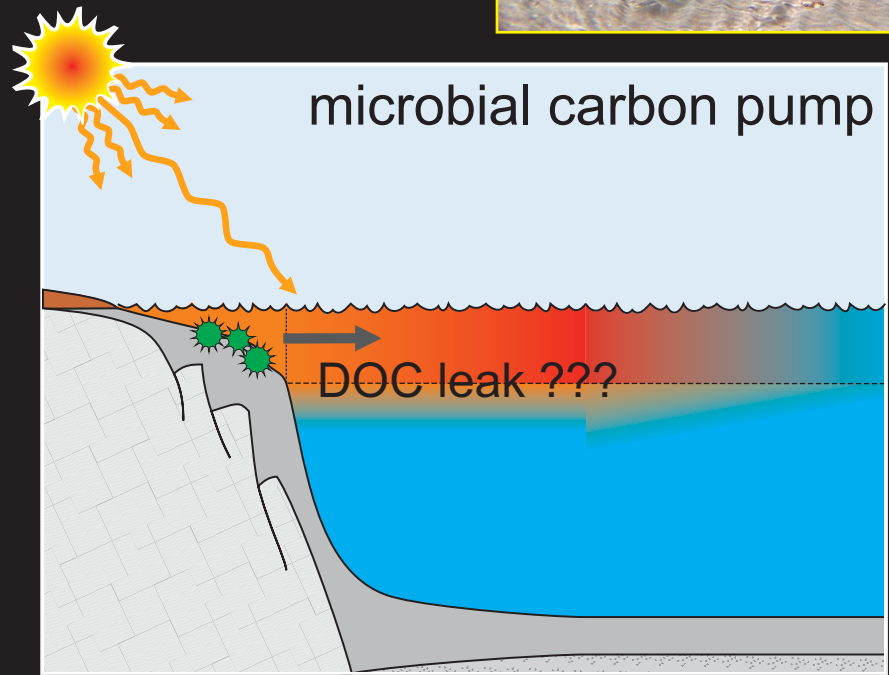
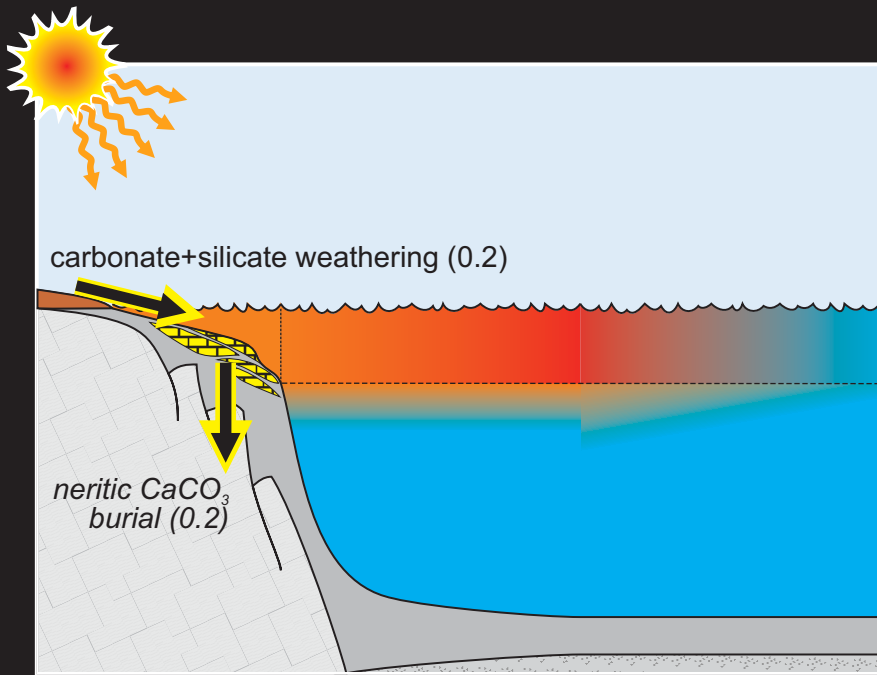
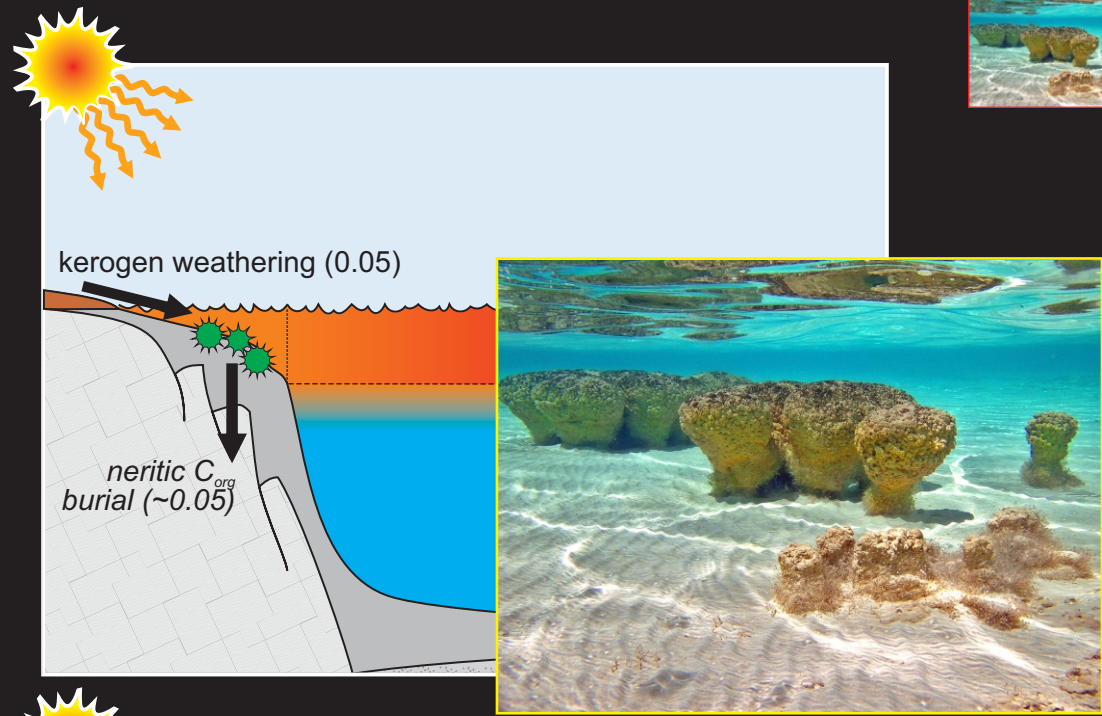
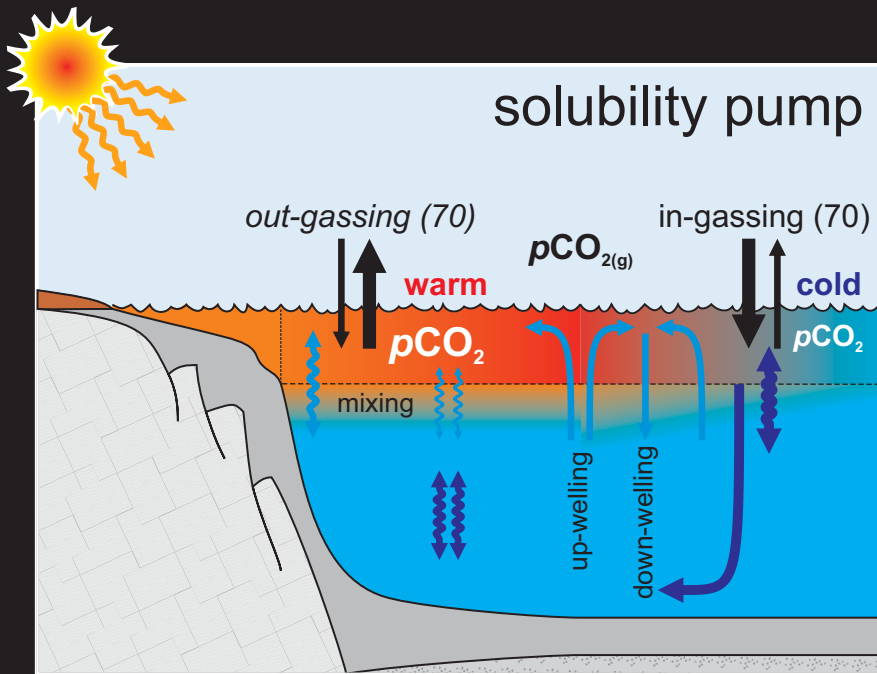


The Force awakens ... ???



Sánchez-Baracaldo [2015] (Scientific Reports)





The Force awakens ... ???

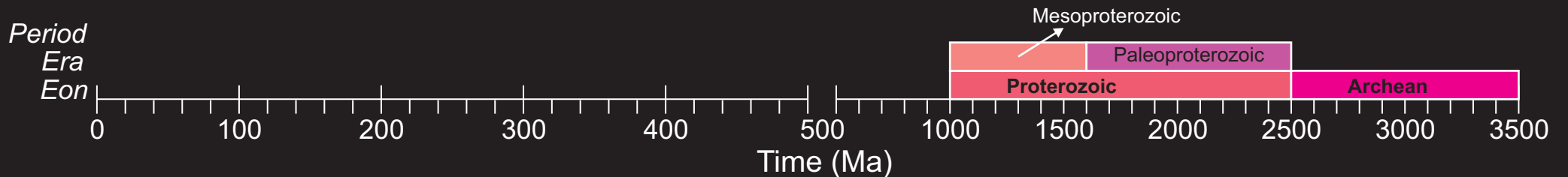


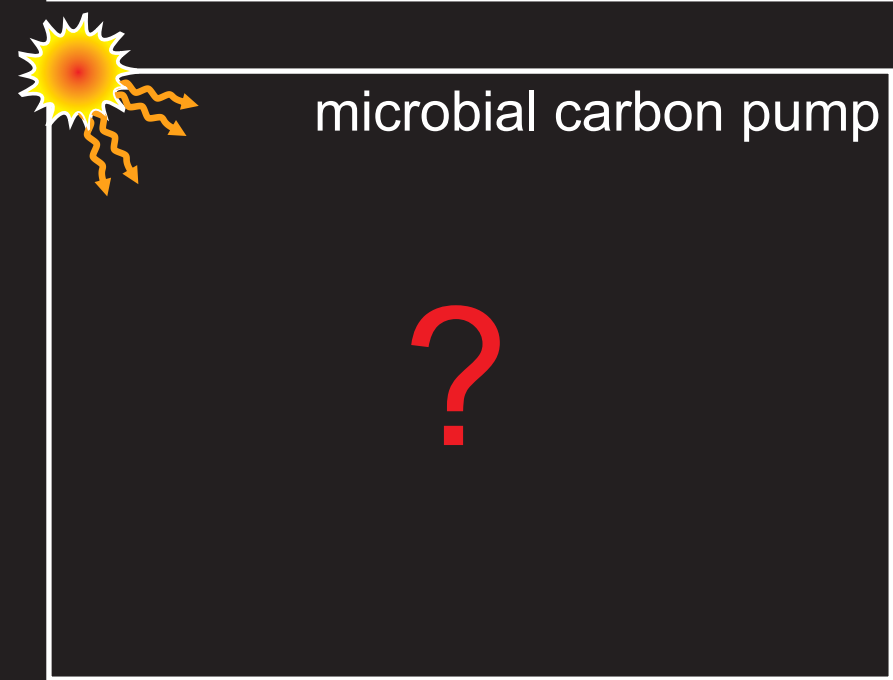
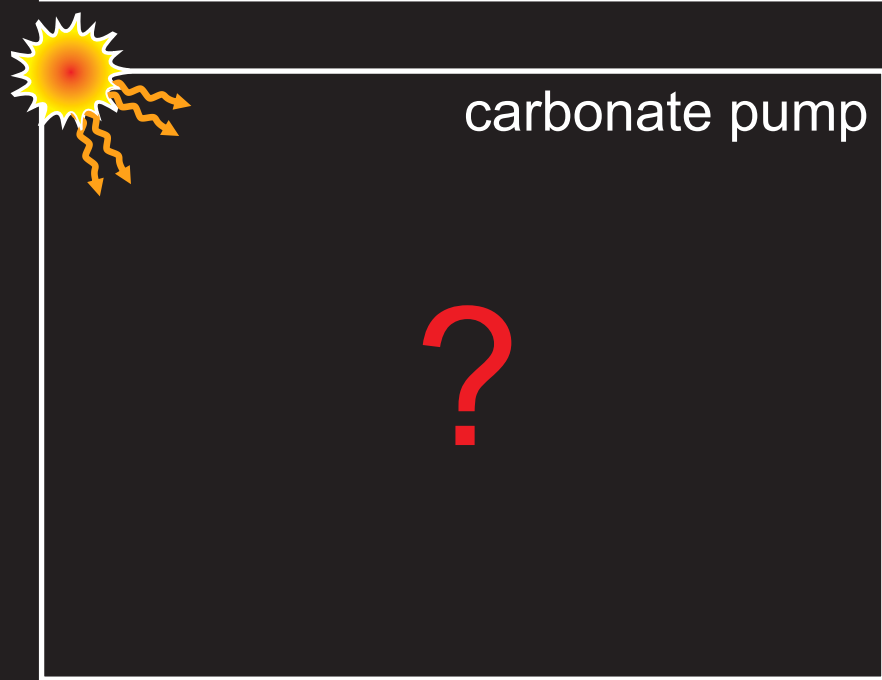
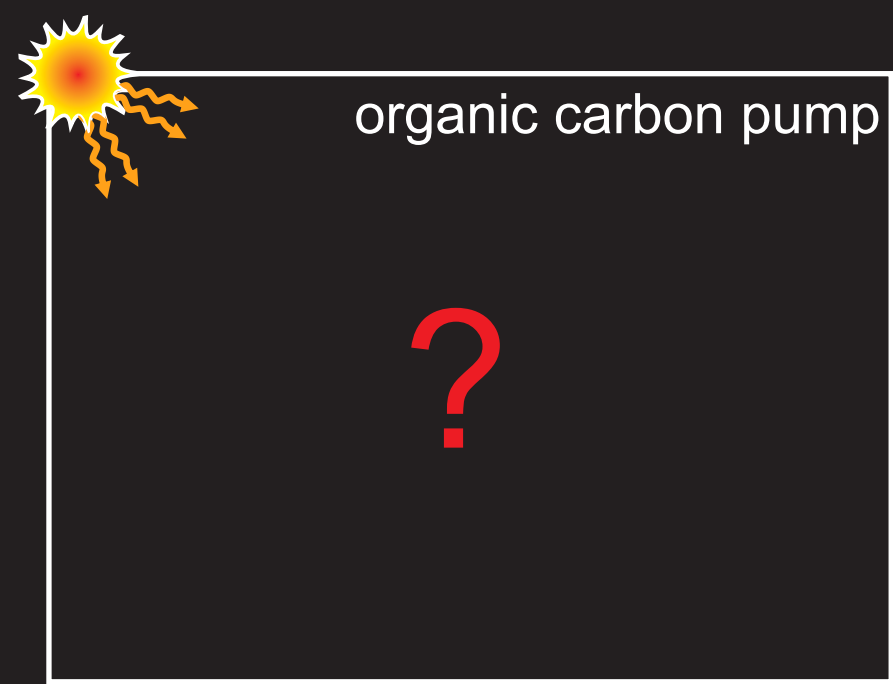
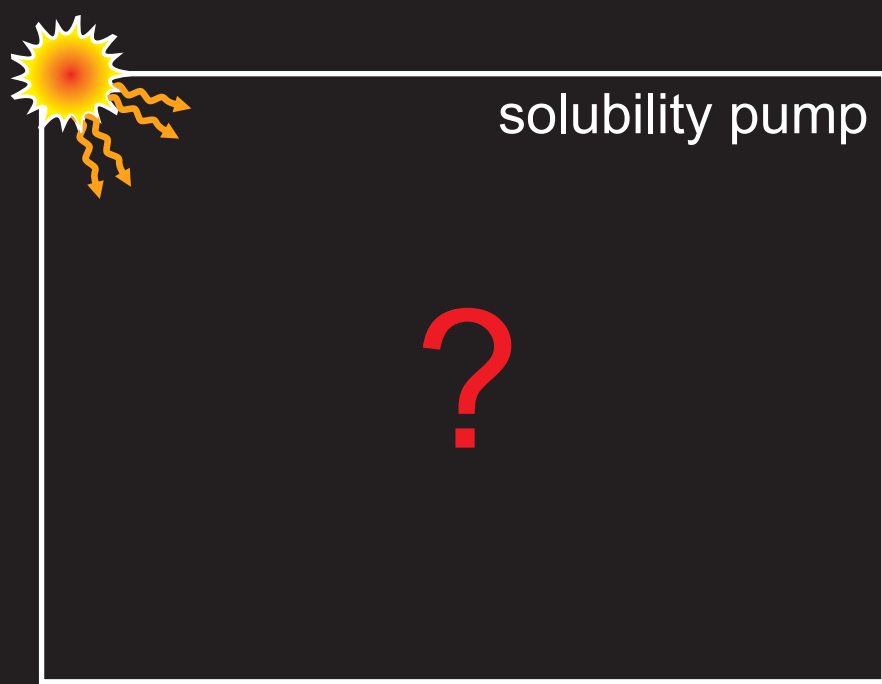
Evolutionary innovations
& plankton assemblage

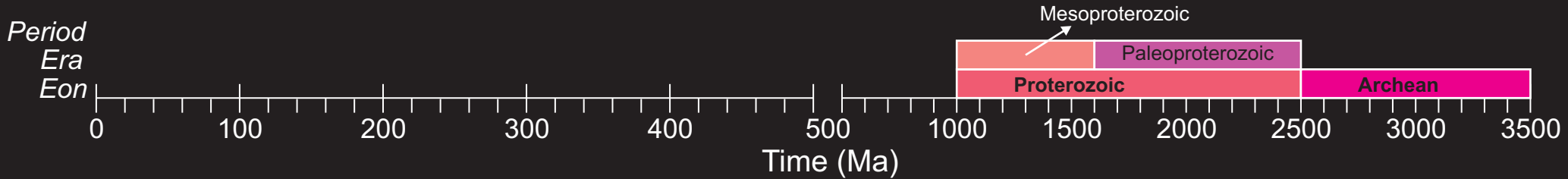
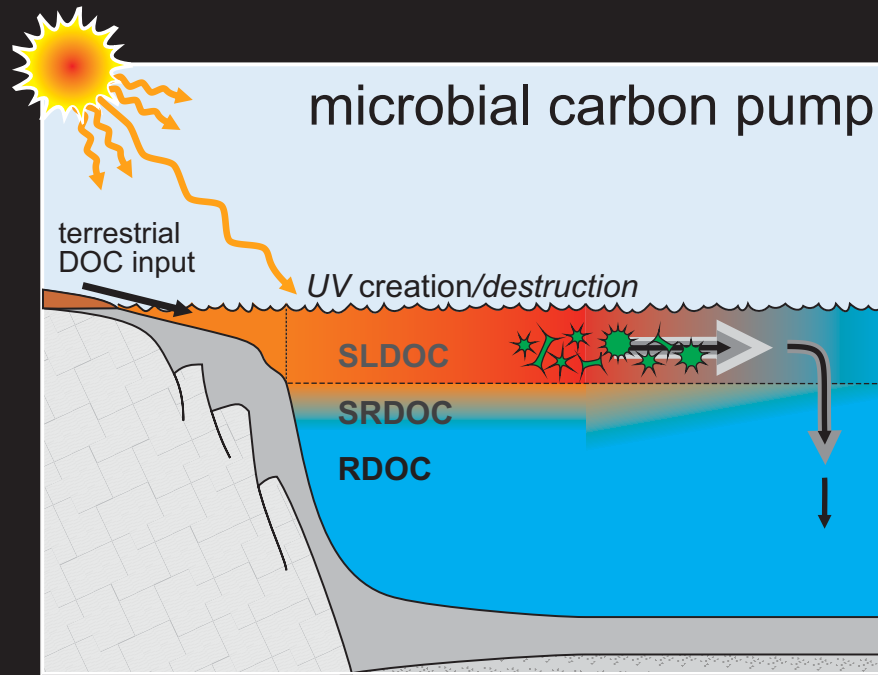
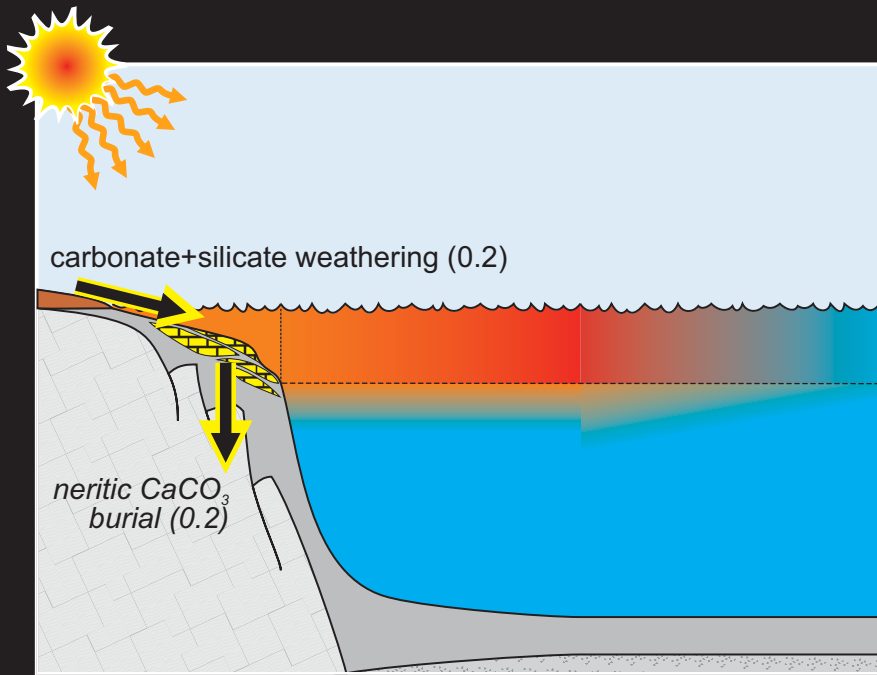
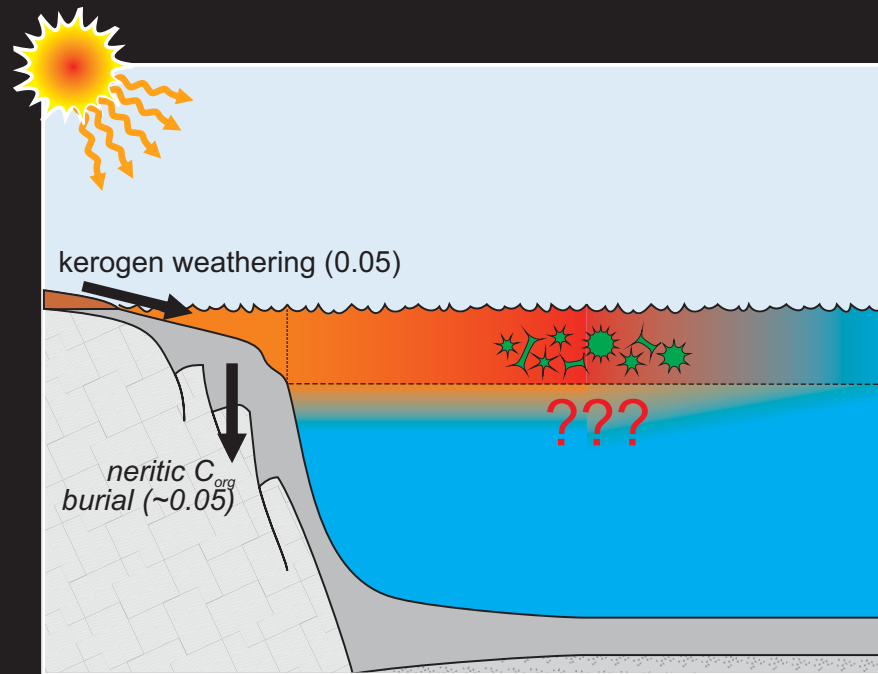
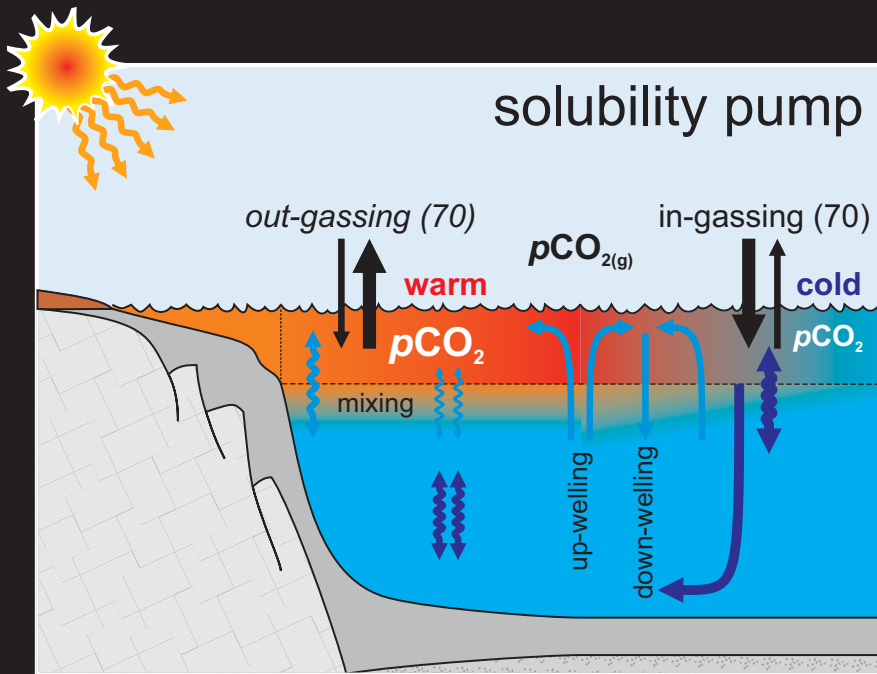
Eukaryotes [Knoll, 2014]

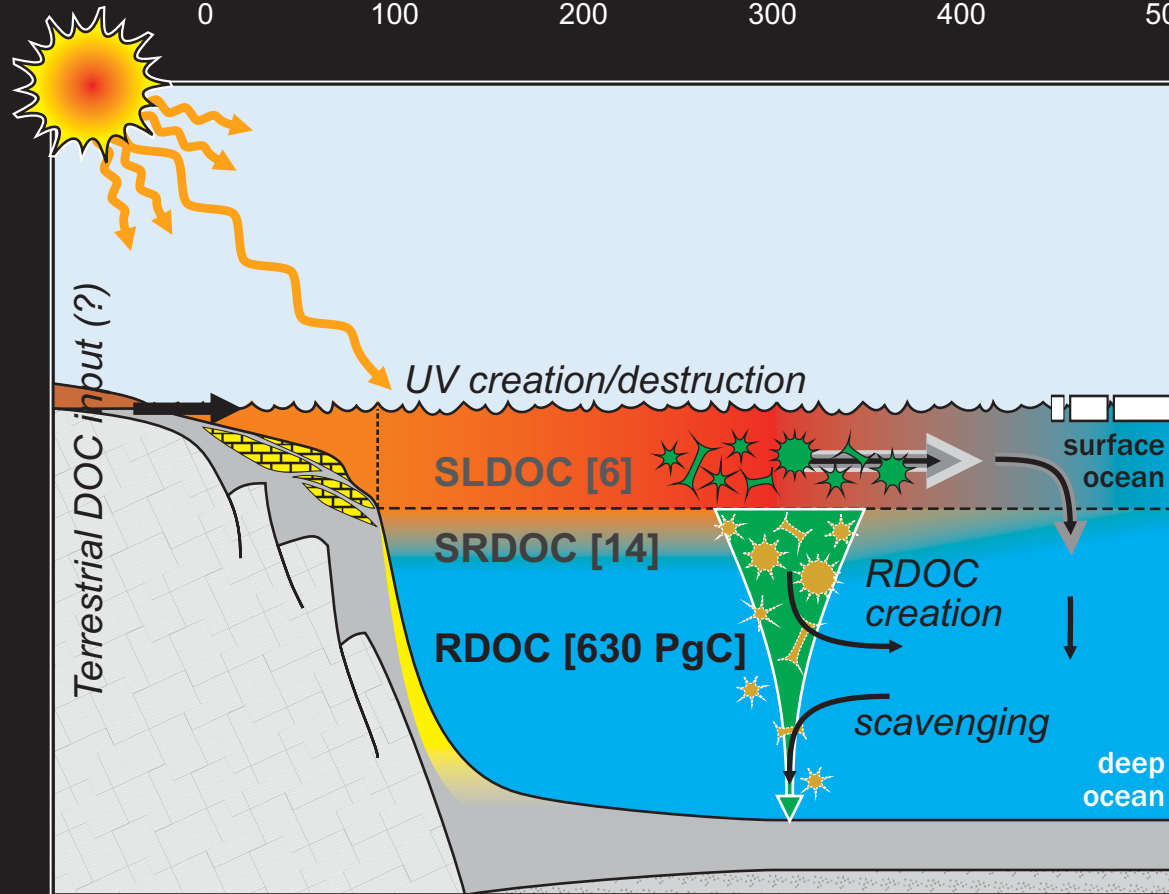
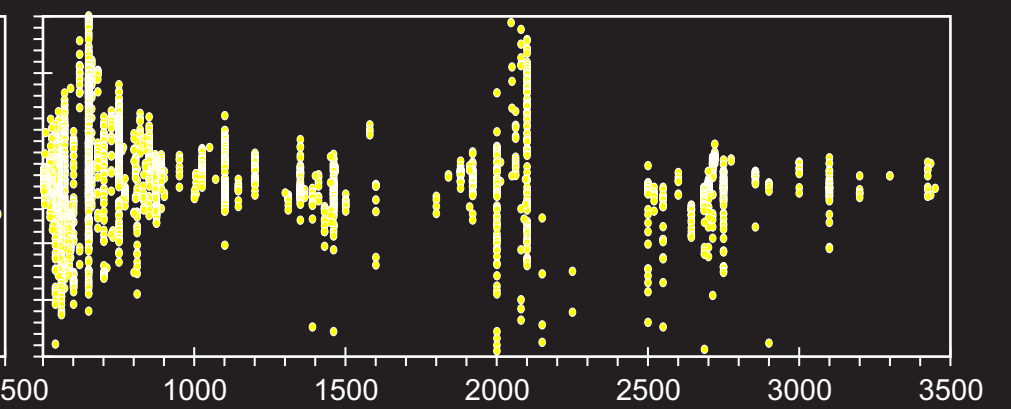
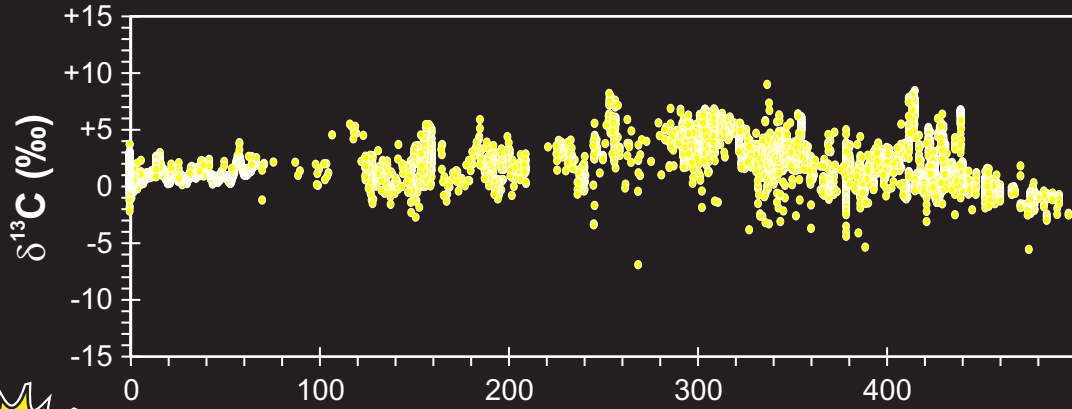
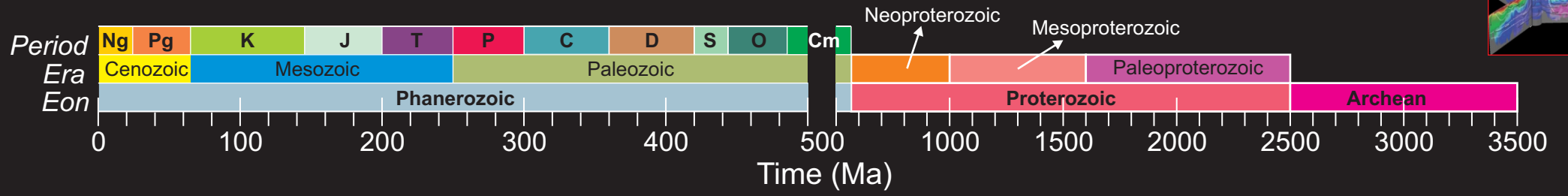
Cyanobacteria (planktonic) [Sánchez-Baracaldo, 2015]

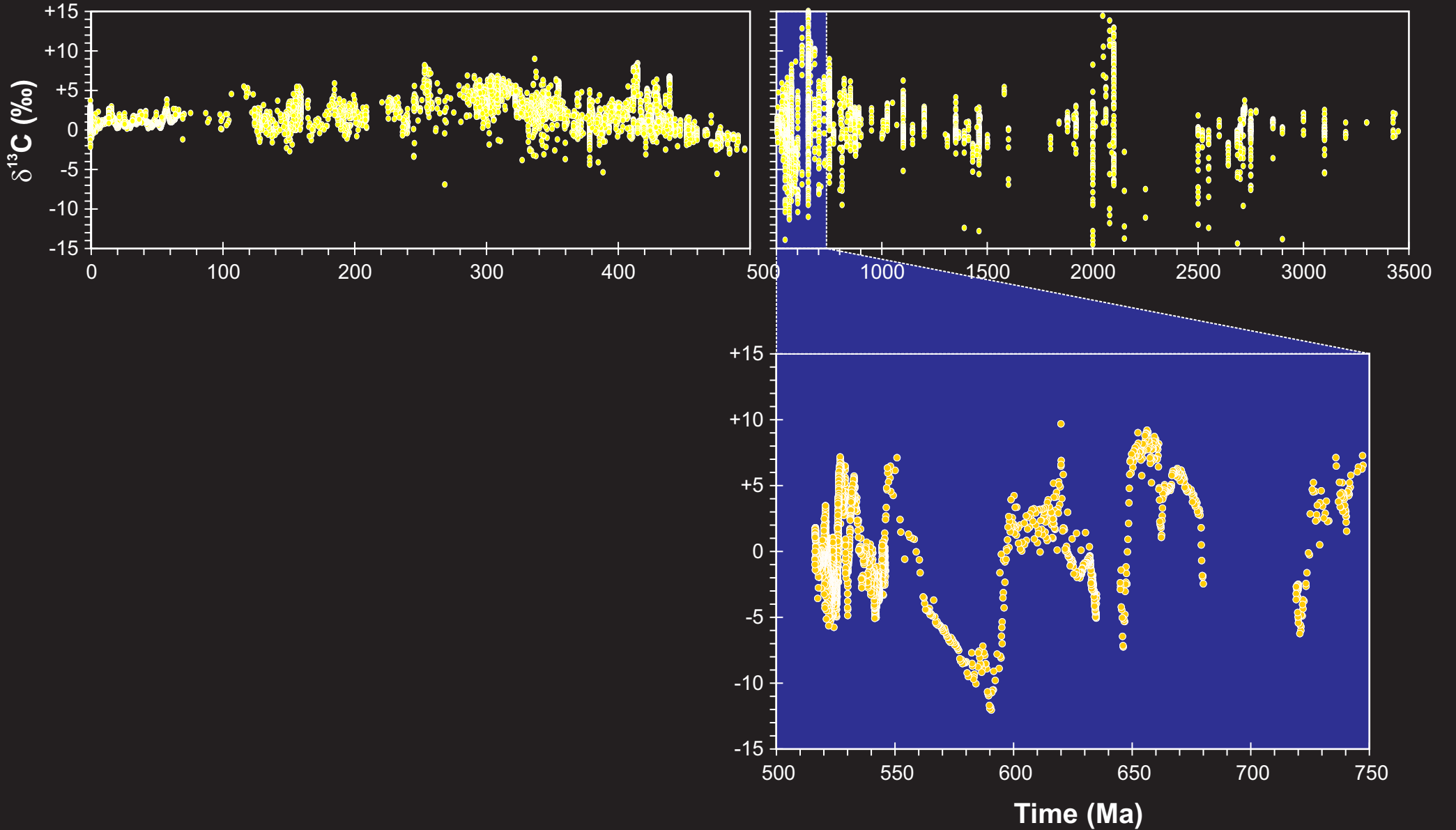
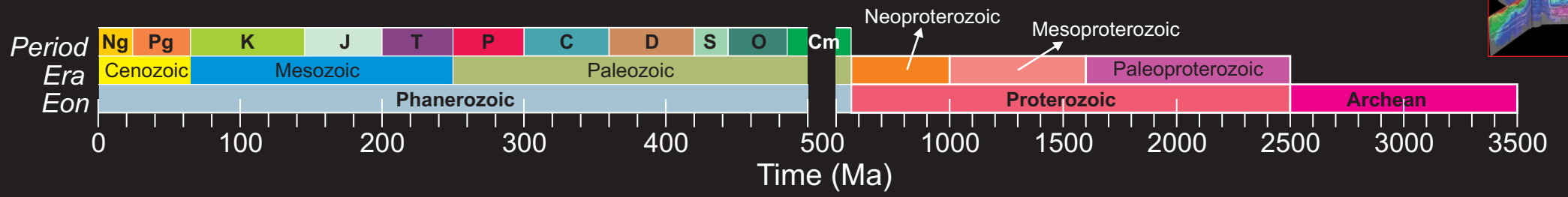
Cyanobacteria (benthic) [Sánchez-Baracaldo, 2015]



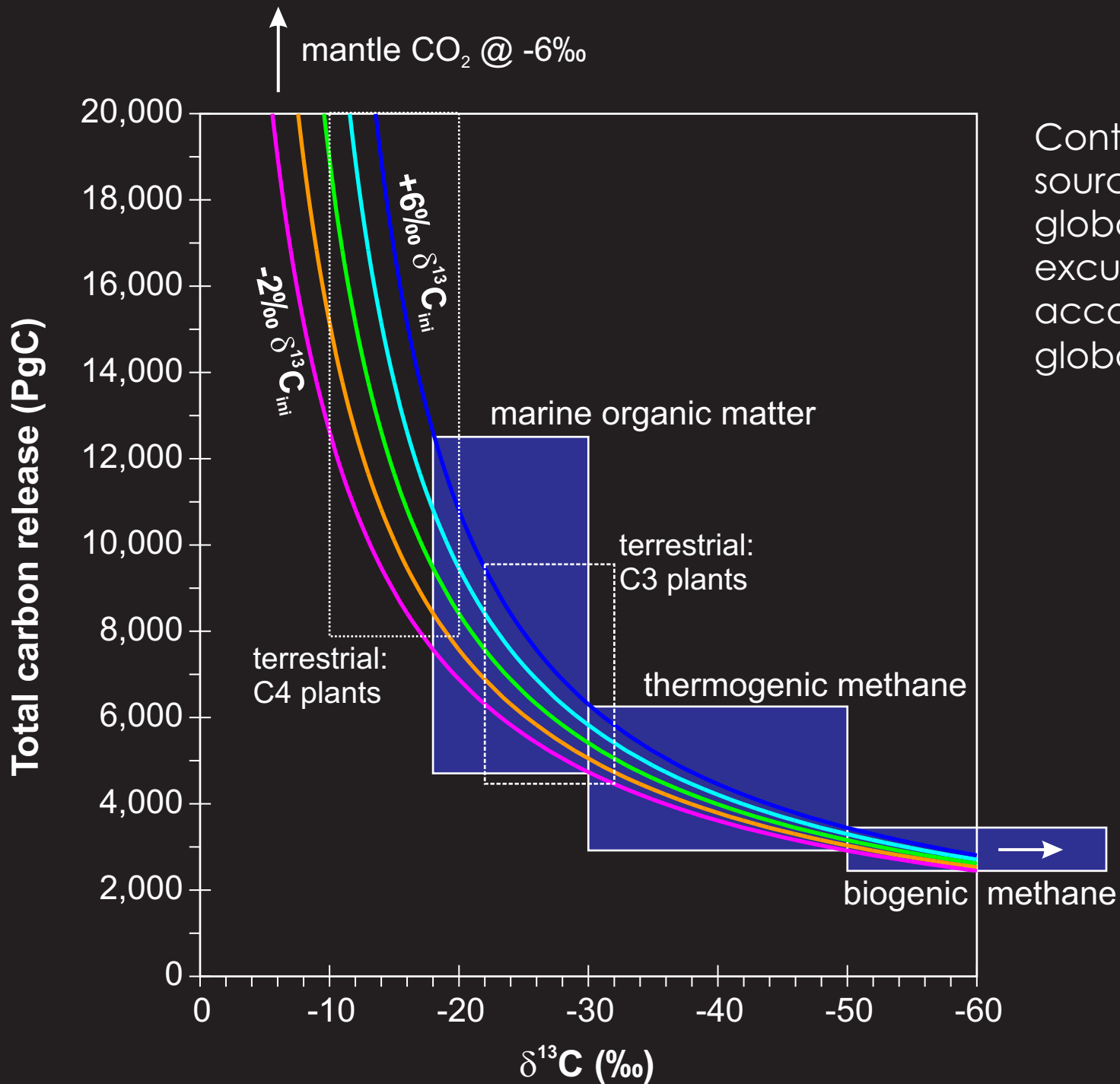
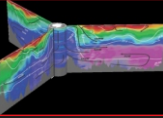






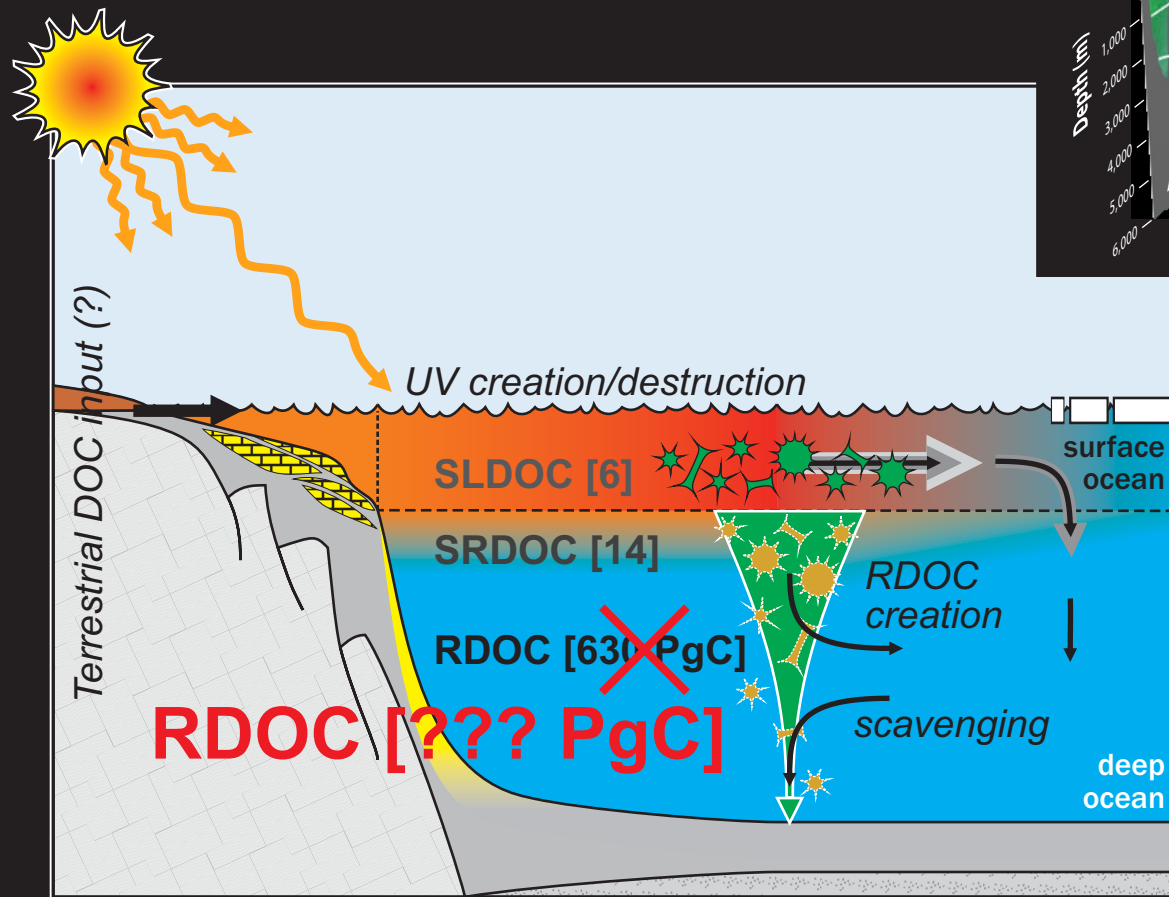
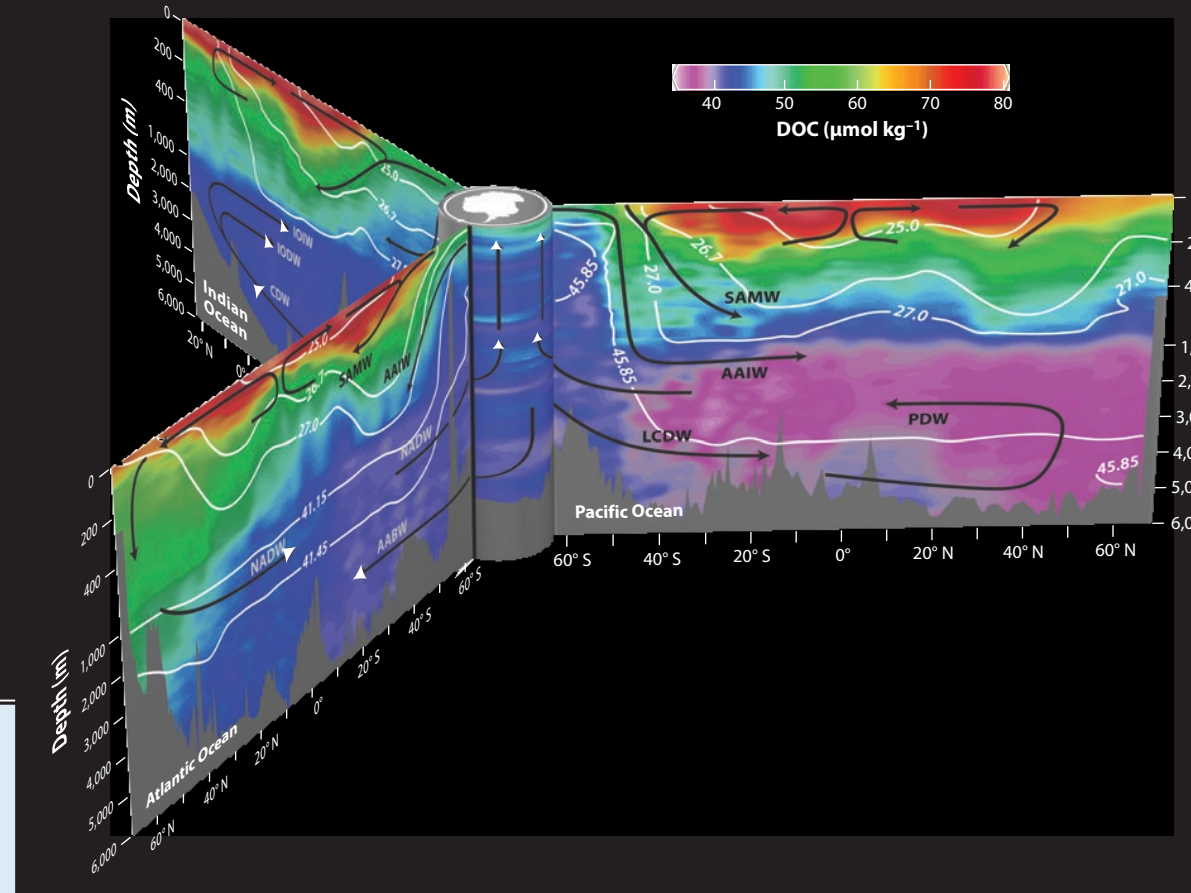
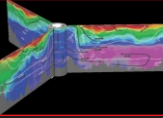


When RDOM ruled the World(?)

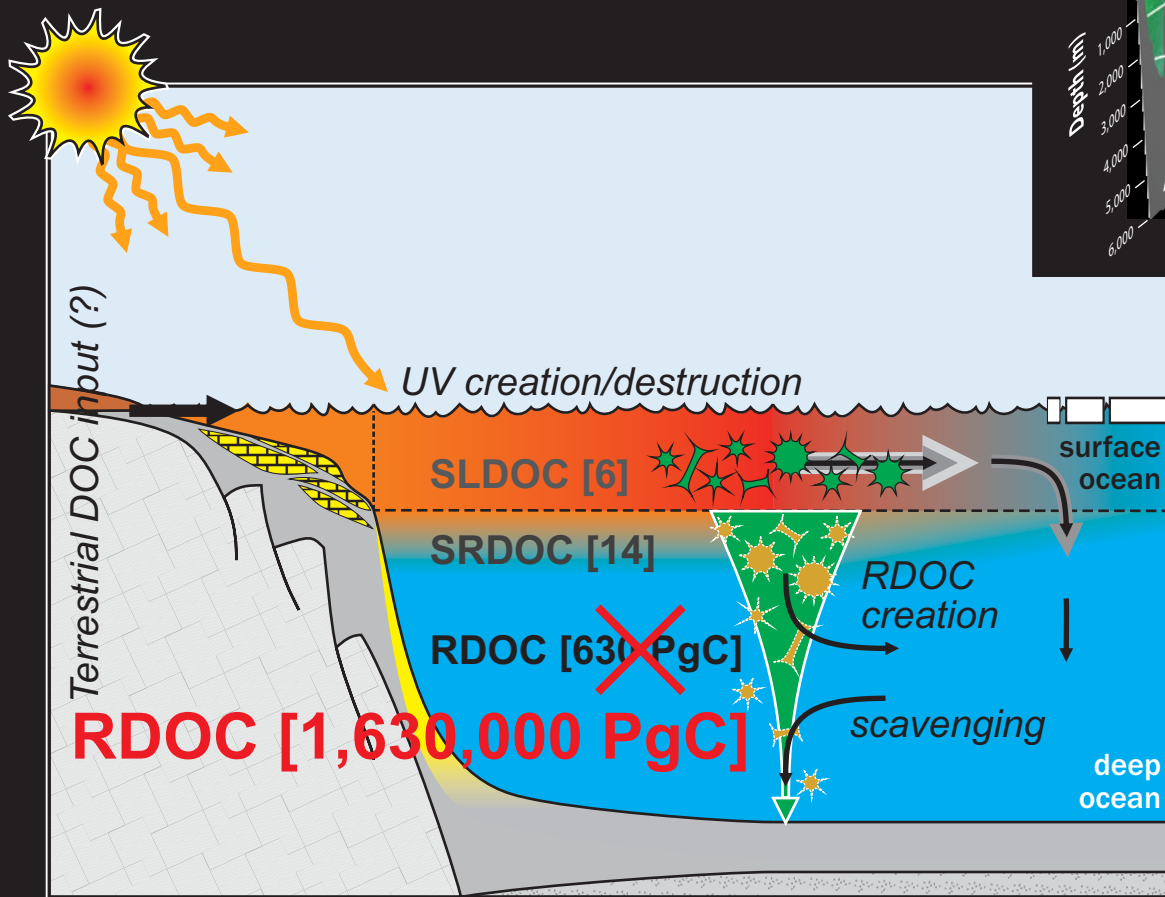
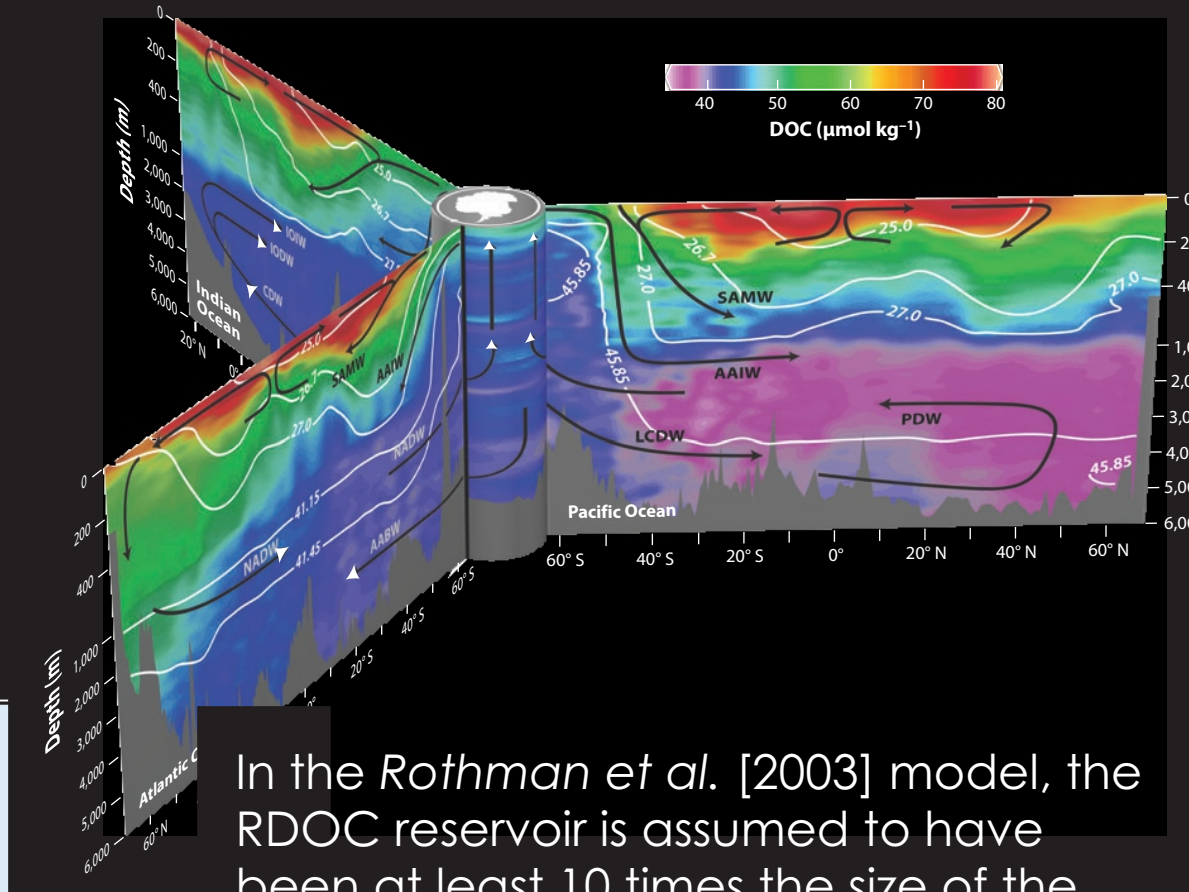
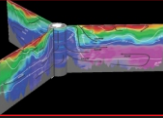


Contours of carbon release vs. source isotopic signature for a global -4‰ carbon isotopic excursion. Contours differ according to the initial mean global $\delta^{13}\text{C}$.

When RDOM ruled the World(?)



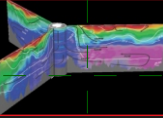
When RDOM ruled the World(?)



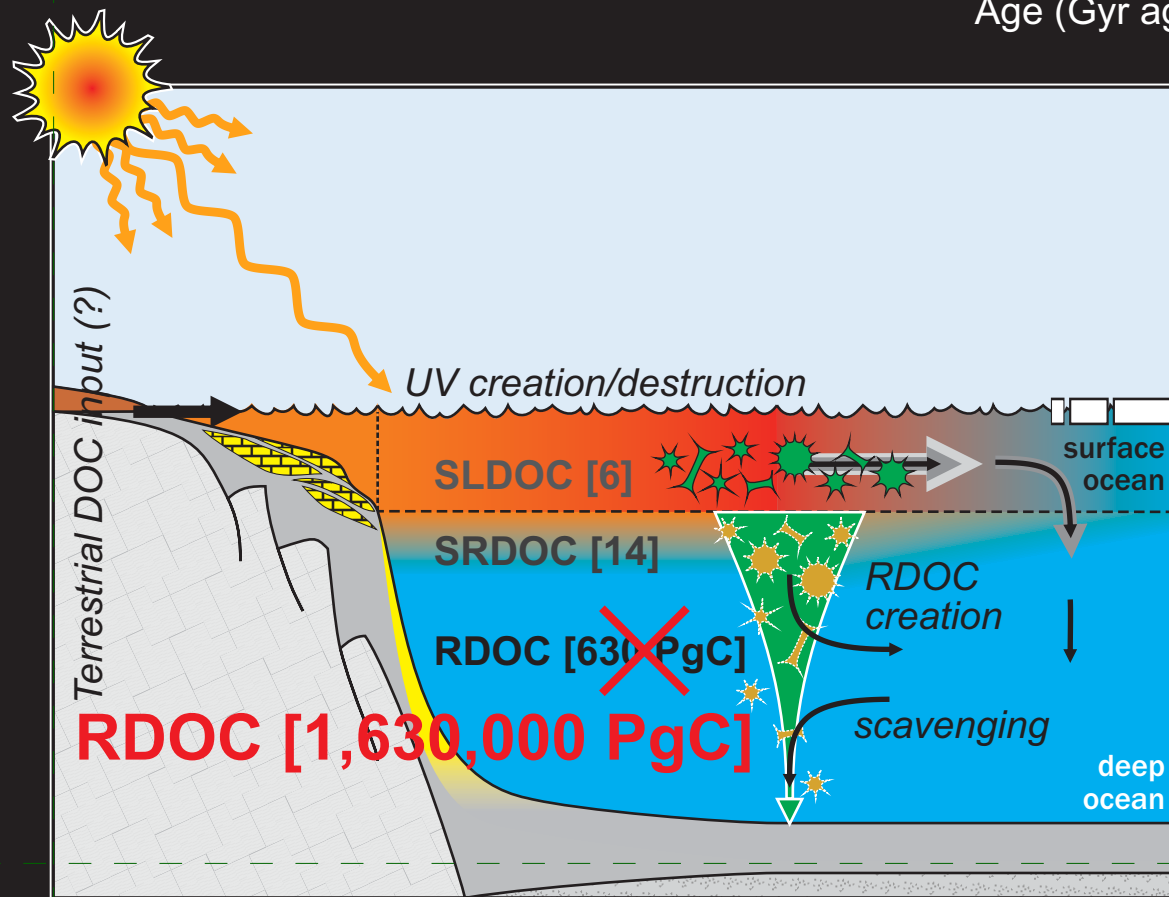
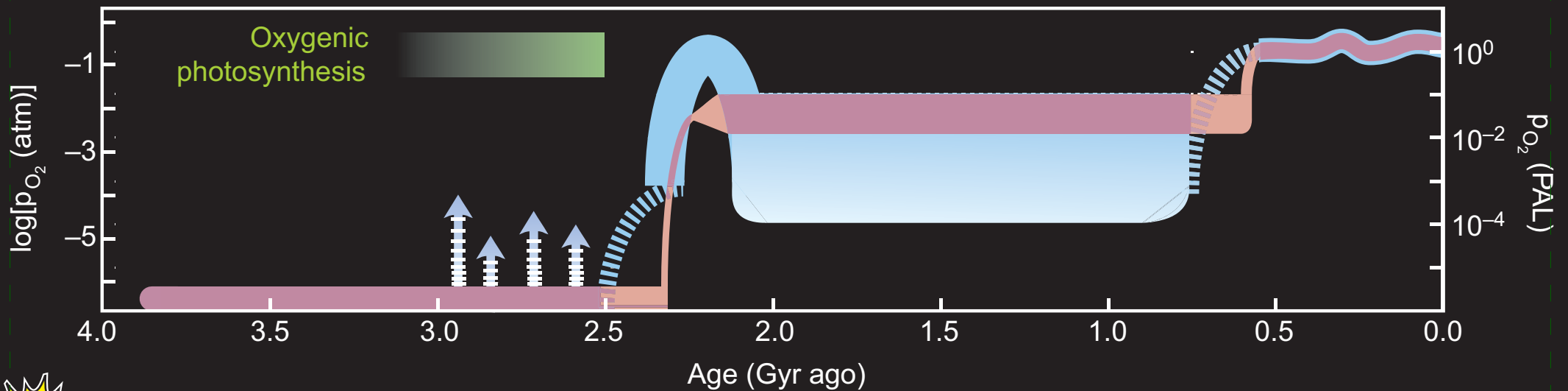
In the Rothman *et al.* [2003] model, the RDOC reservoir is assumed to have been at least 10 times the size of the inorganic (ocean DIC + atmospheric $p\text{CO}_2$) reservoir. For a modern DIC + $p\text{CO}_2$ reservoir of 39,000 PgC, this means 390,000 PgC of DOC – more than 500 times larger than modern).

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

When RDOM ruled the World(?)



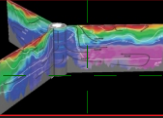
Lyons et al. [2014] (Nature 506)



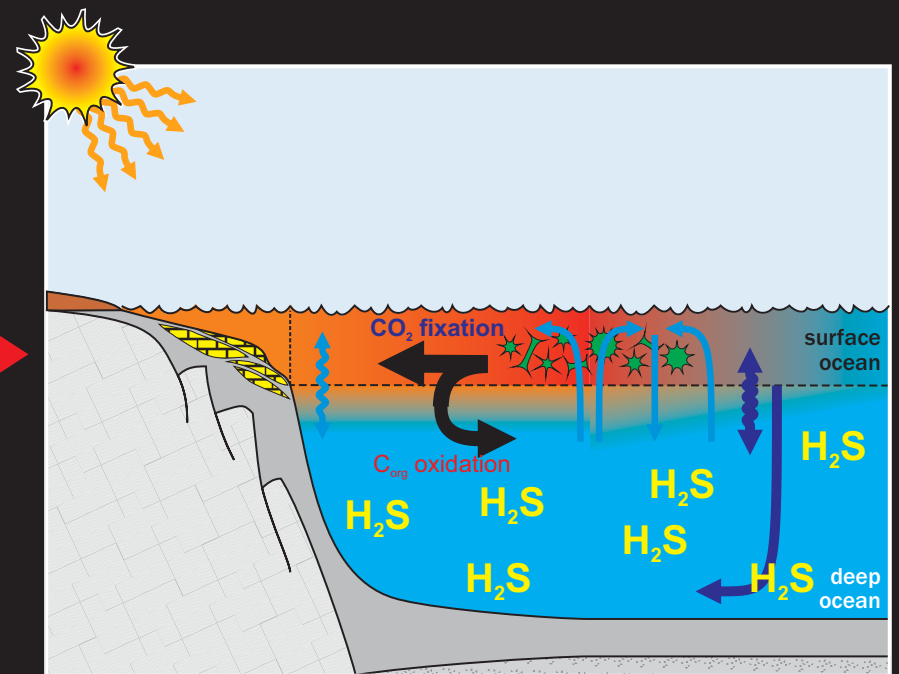
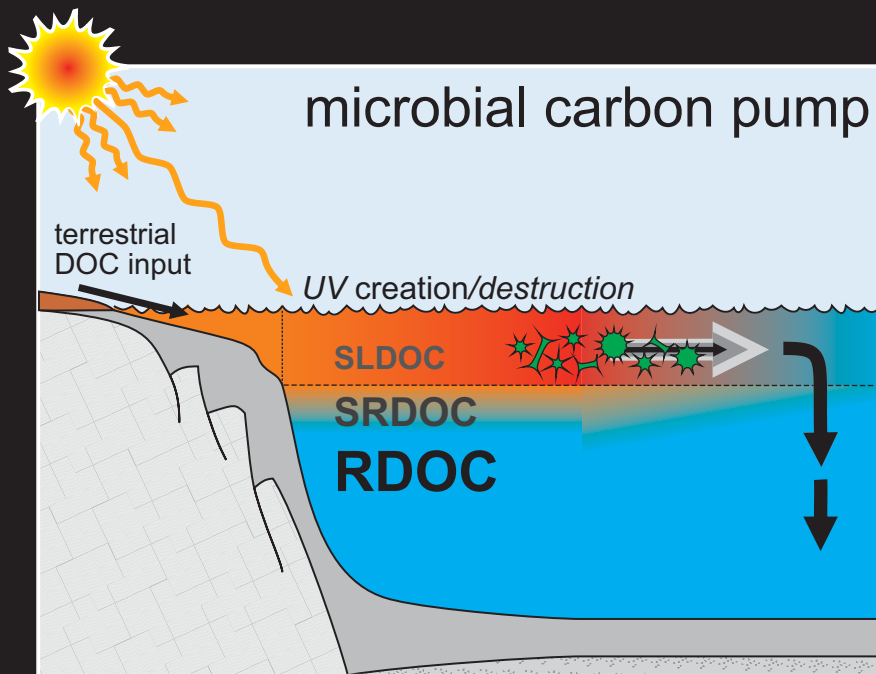
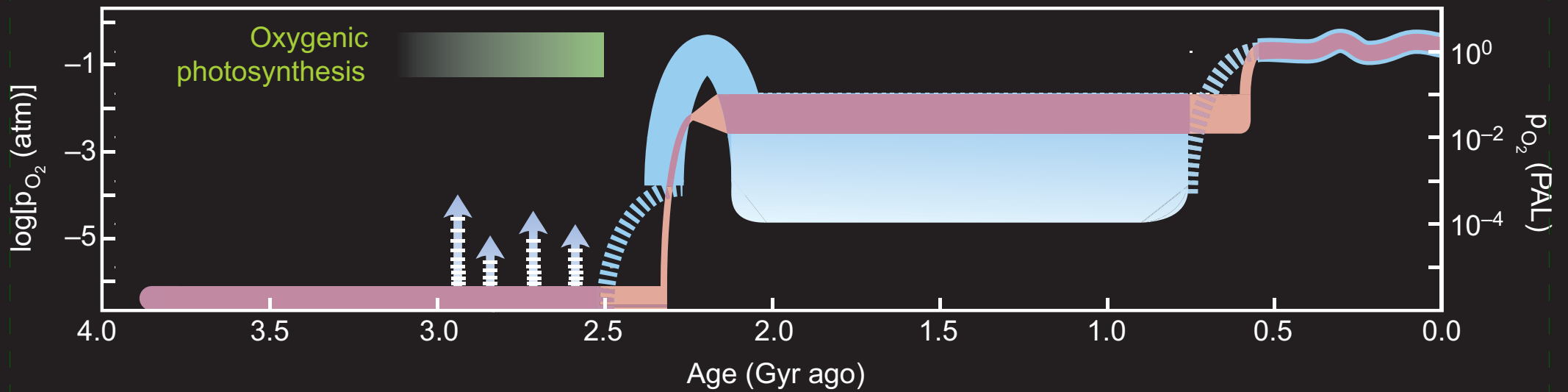
In the Rothman et al. [2003] model, the RDOC reservoir is assumed to have been at least 10 times the size of the inorganic (ocean DIC + atmospheric pCO_2) reservoir. For a modern DIC + pCO_2 reservoir of 39,000 PgC, this means 390,000 PgC of DOC – more than 500 times larger than modern).

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

When RDOM ruled the World(?)



Lyons et al. [2014] (Nature 506)



The Force awakens ... for sure this time ... ???



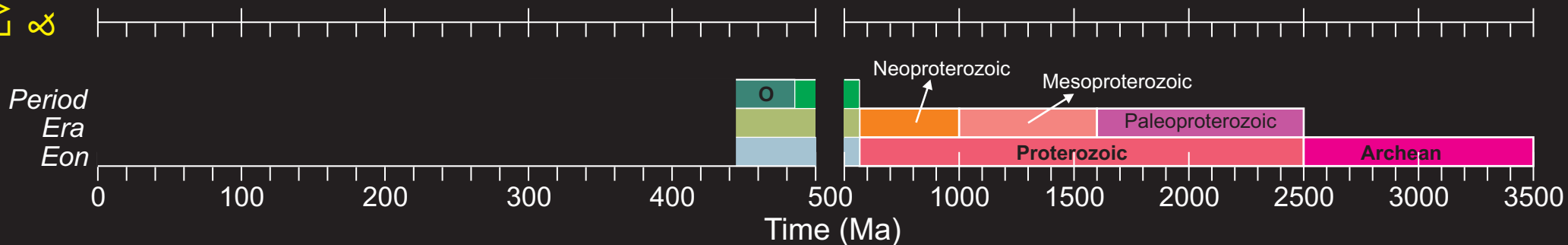
Evolutionary innovations & plankton assemblage

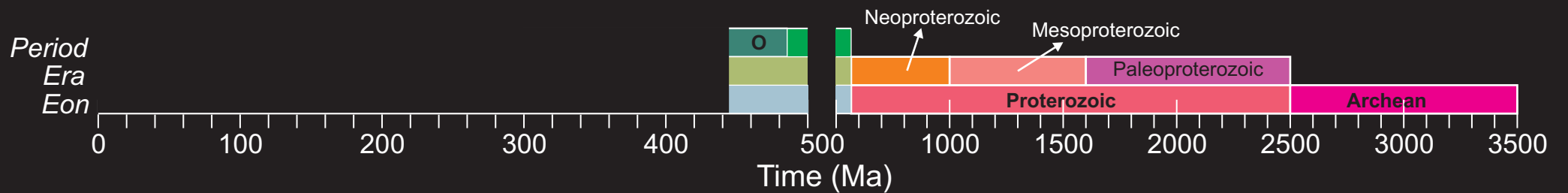
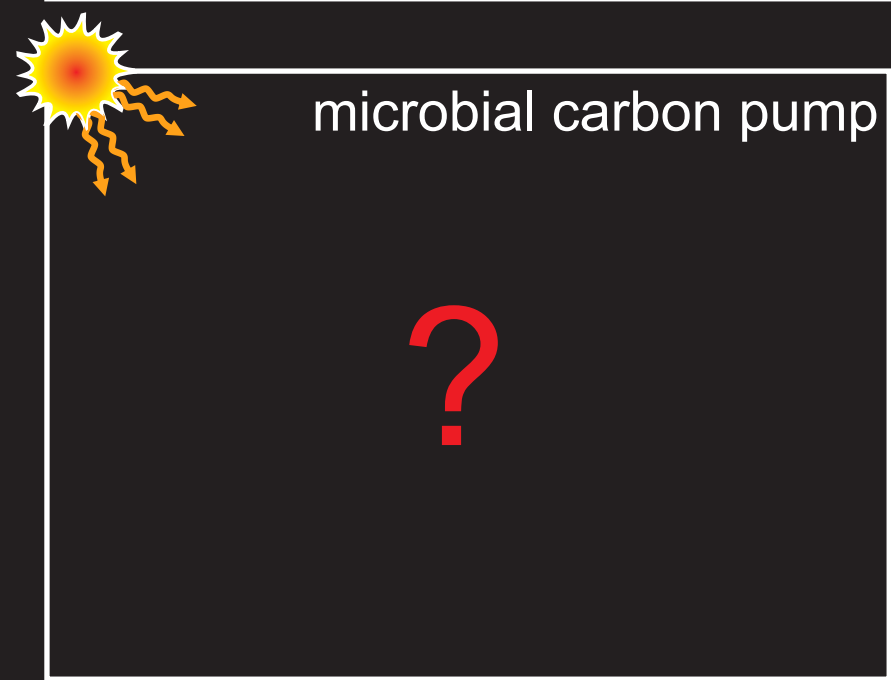
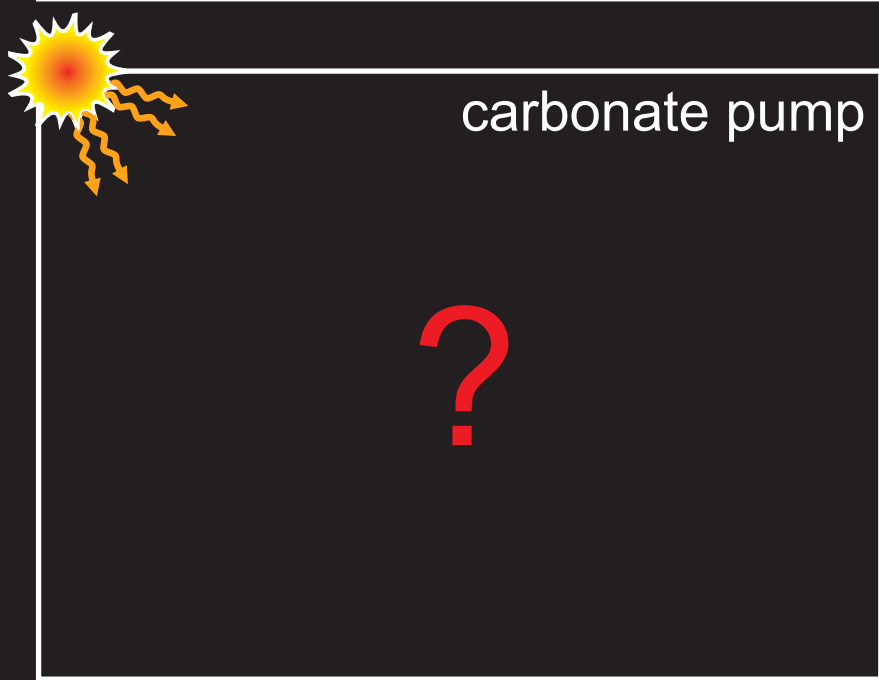
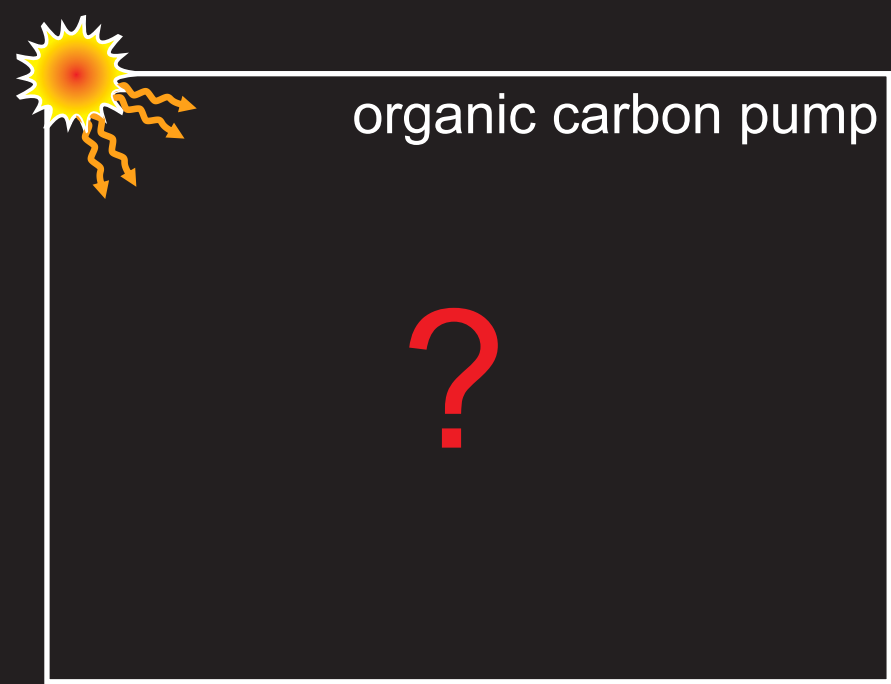
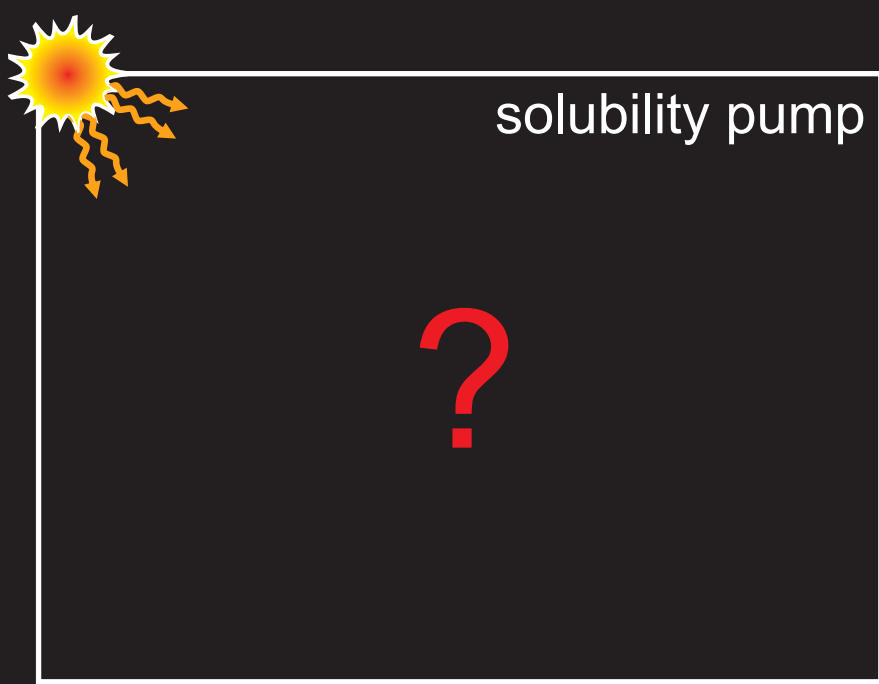
Animals! (metzoans)

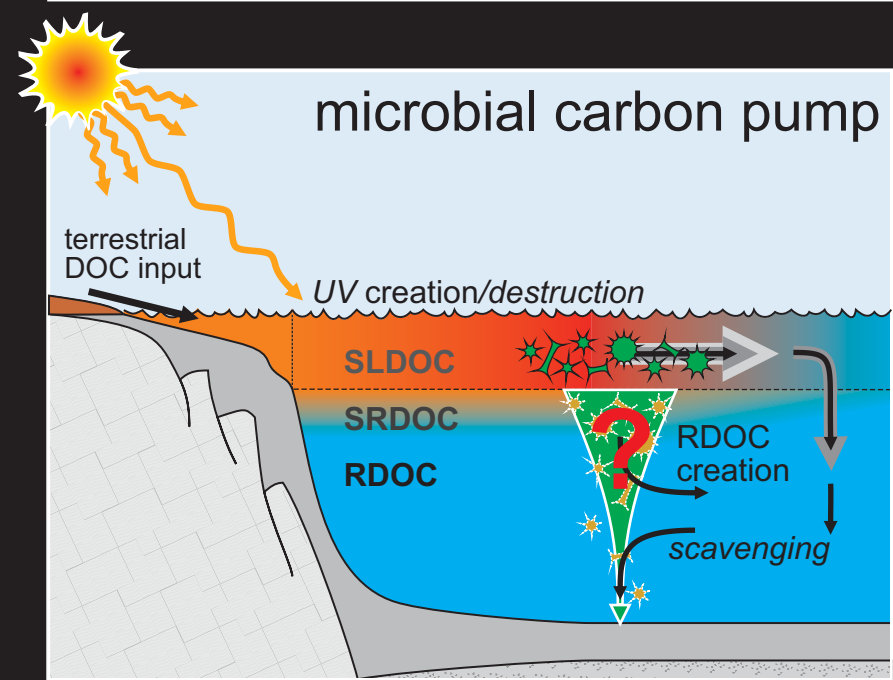
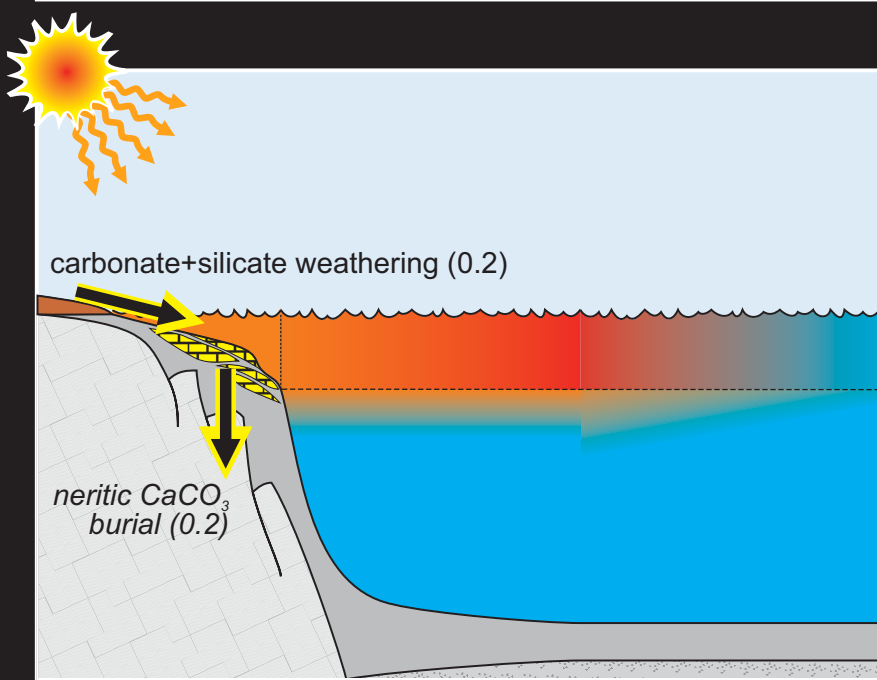
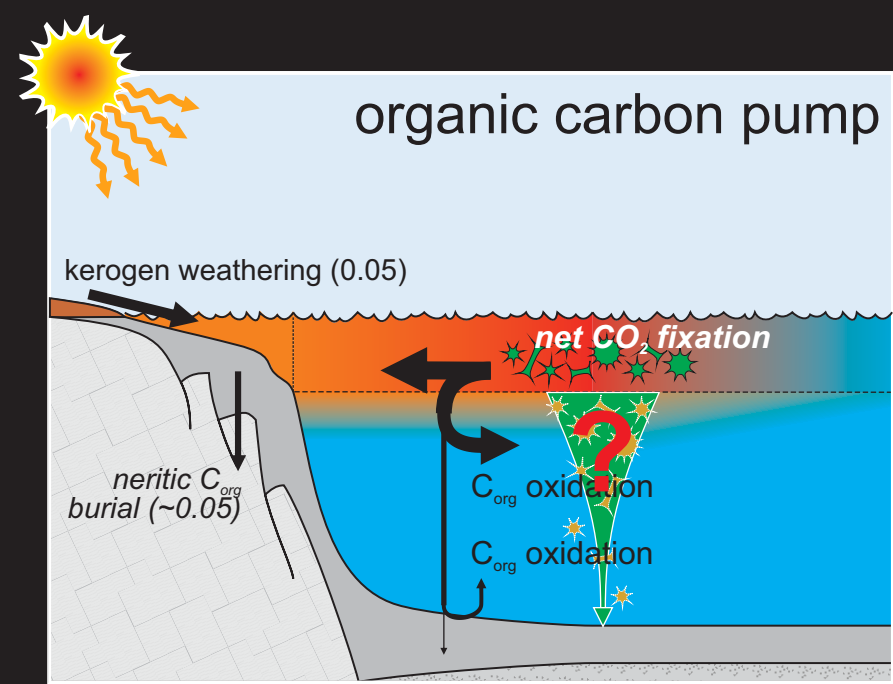
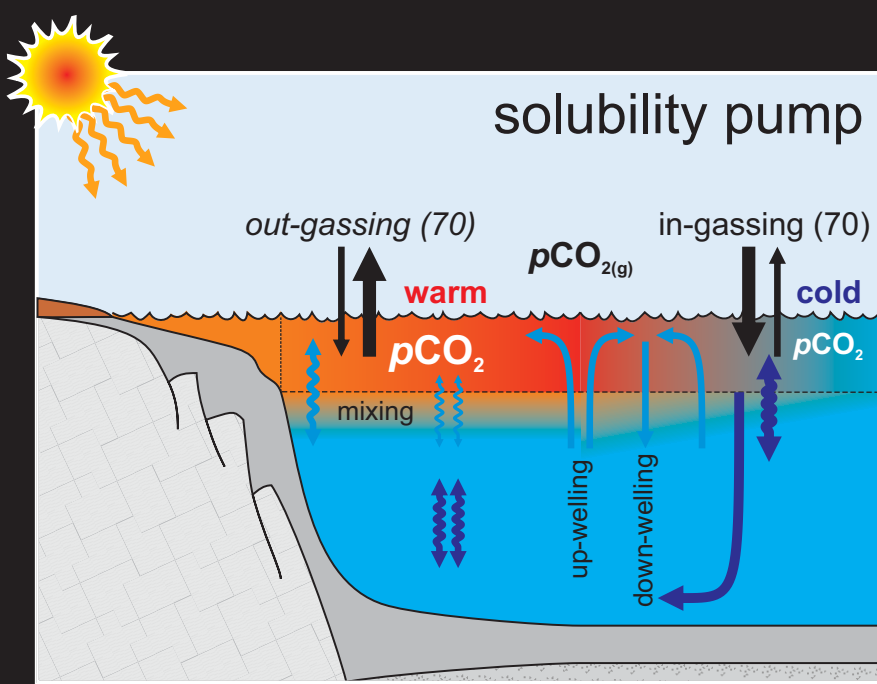
Eurkaryotes [Knoll, 2014]

Cyanobacteria (planktonic) [Sánchez-Baracaldo, 2015]

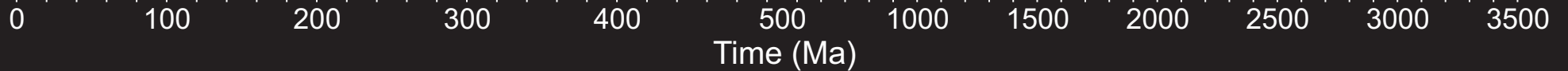
Cyanobacteria (benthic) [Sánchez-Baracaldo, 2015]

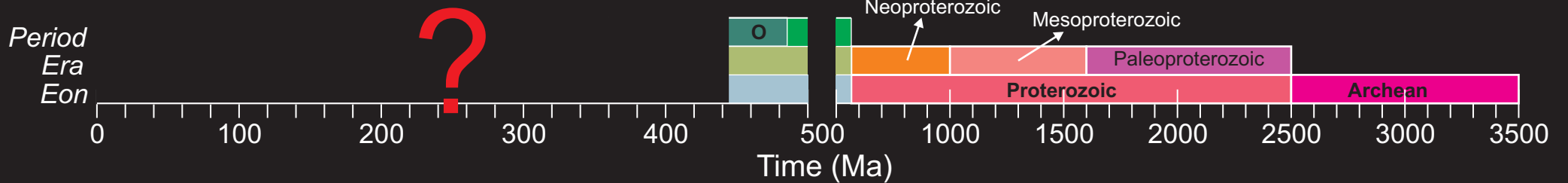
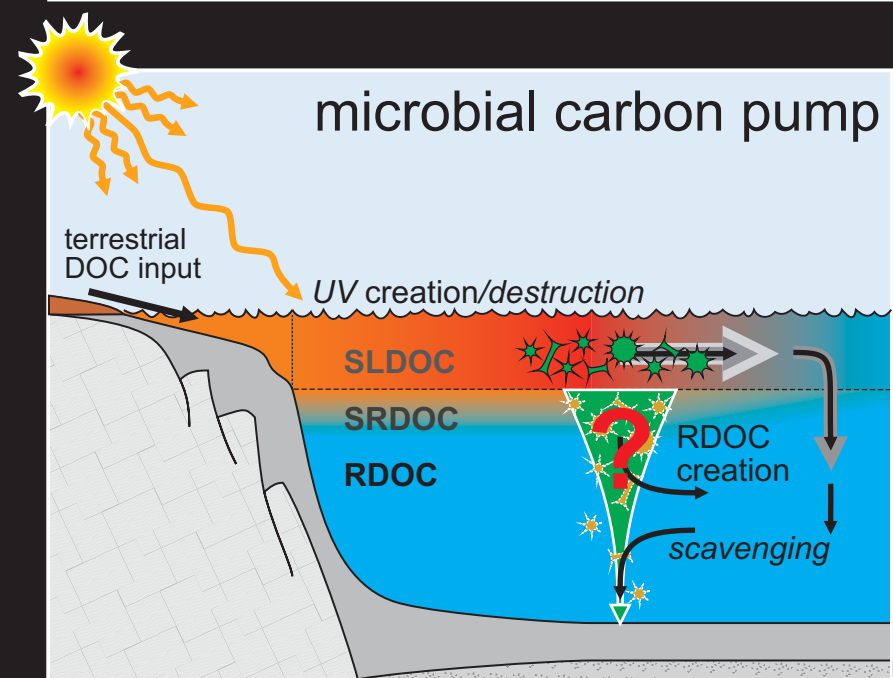
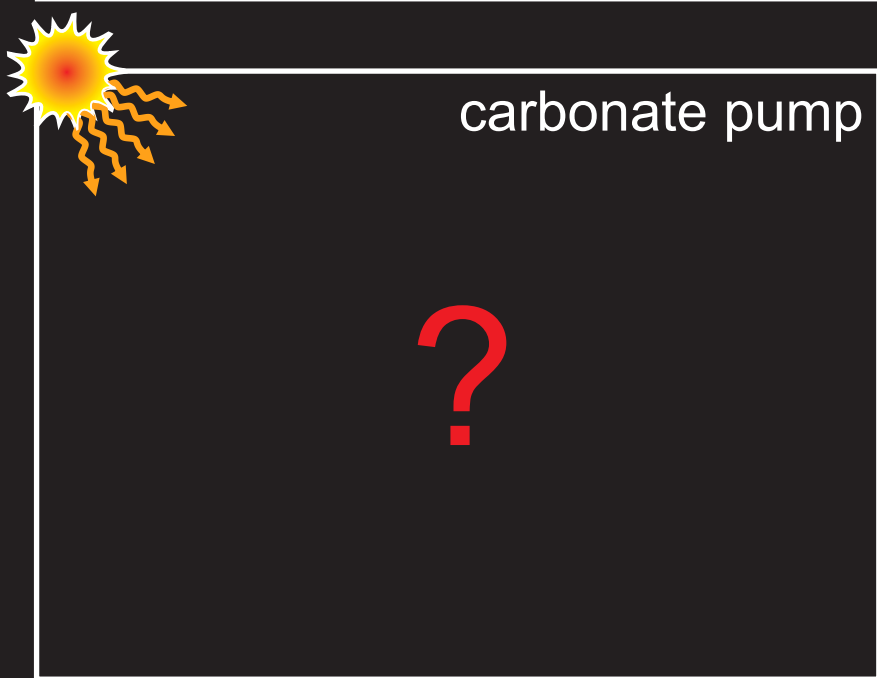
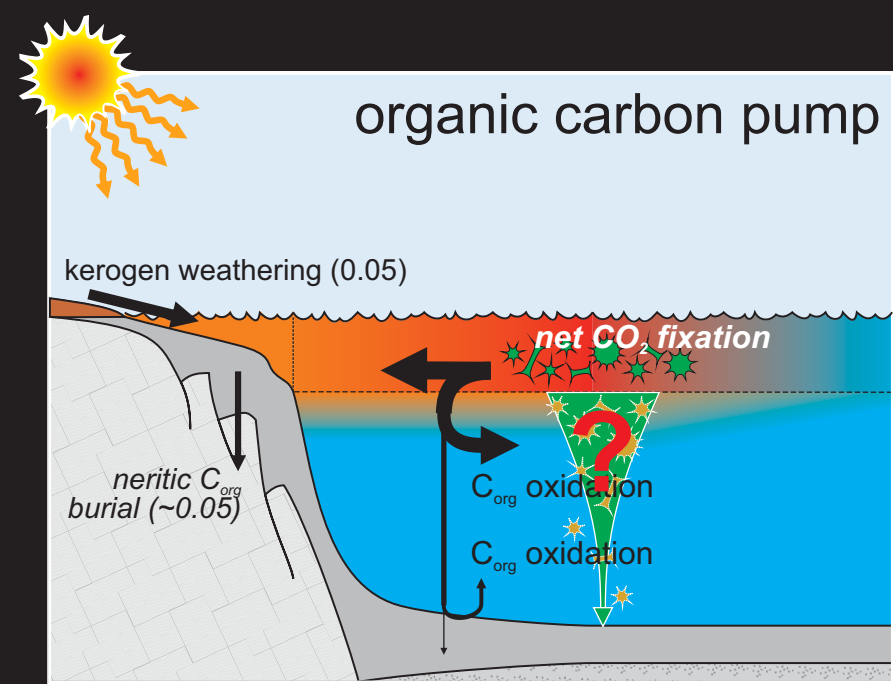
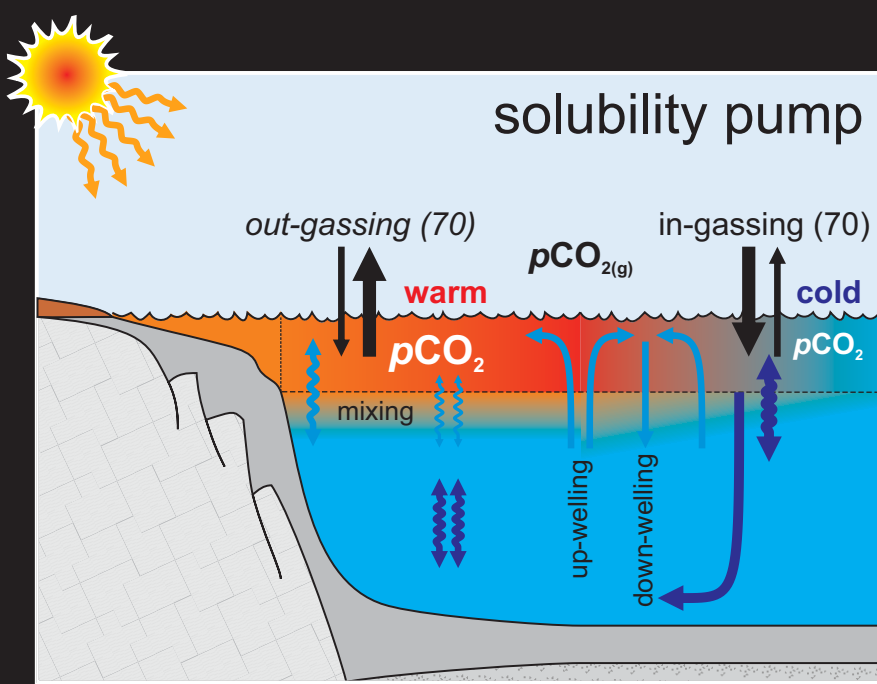




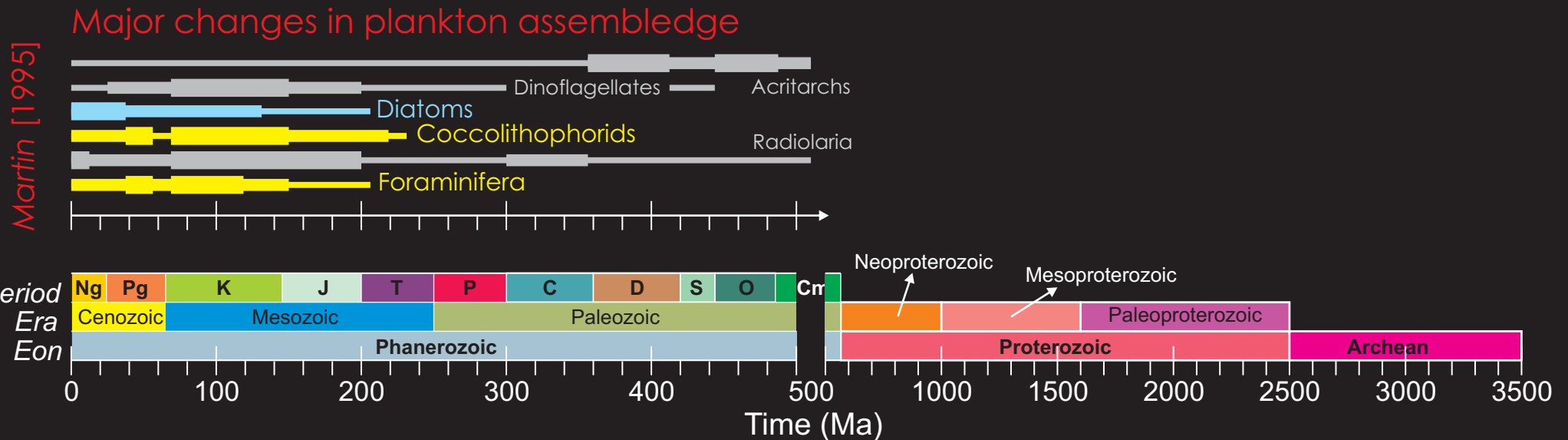
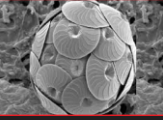


Period
Era
Eon

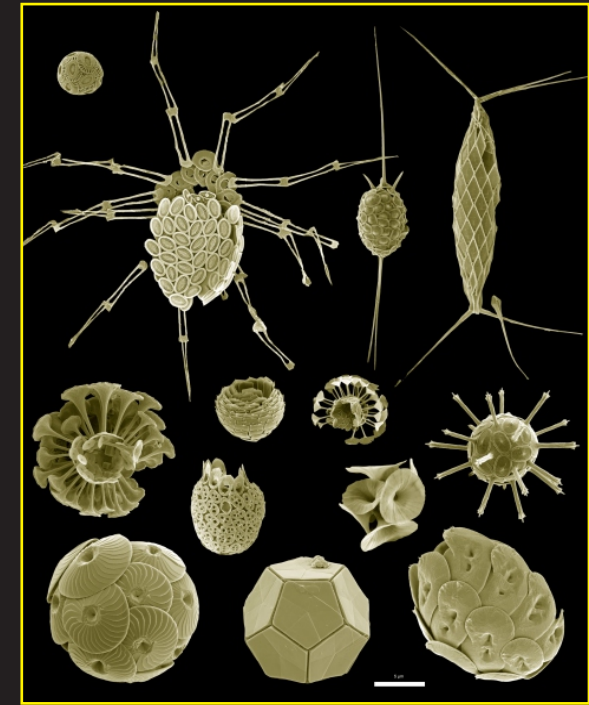
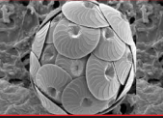




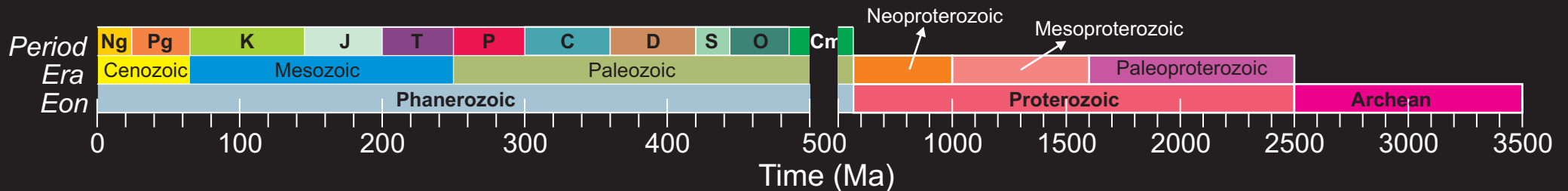
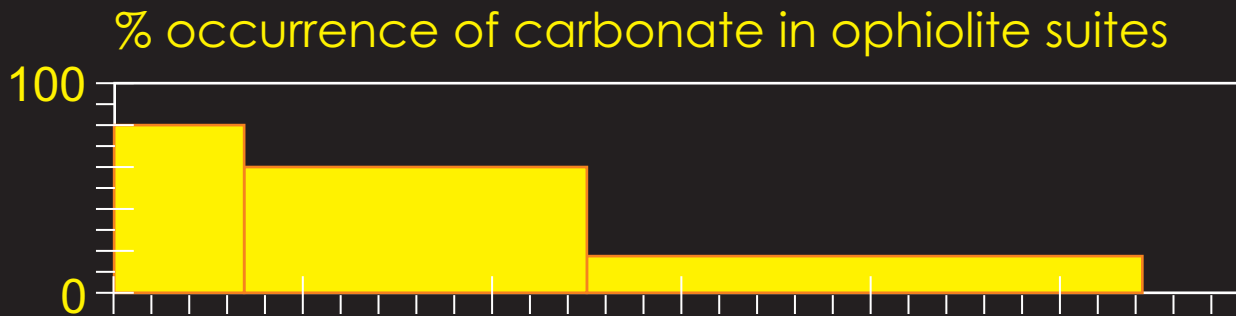
The Force awakens!

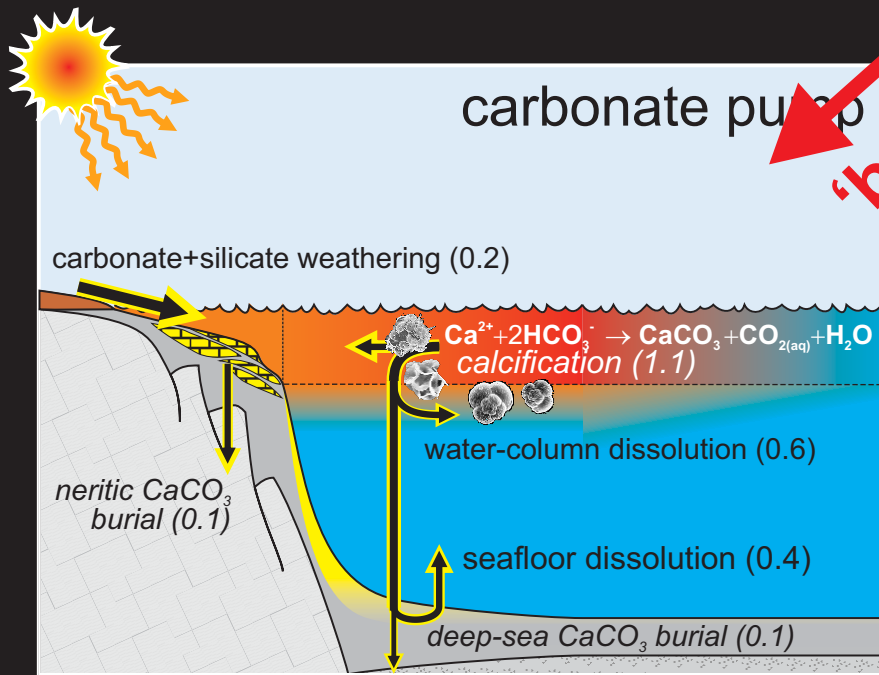
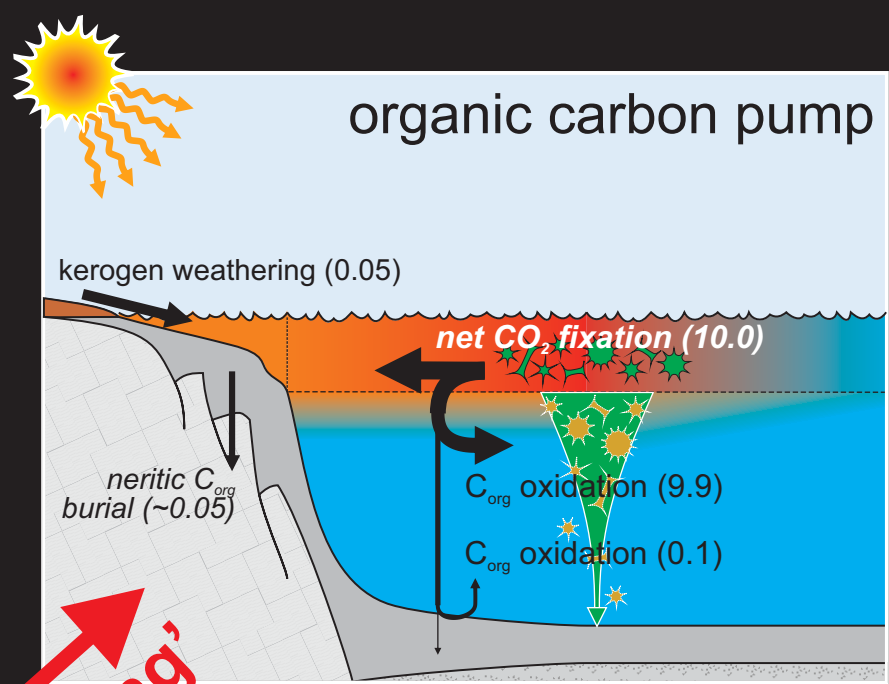
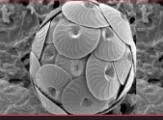


The Force awakens!

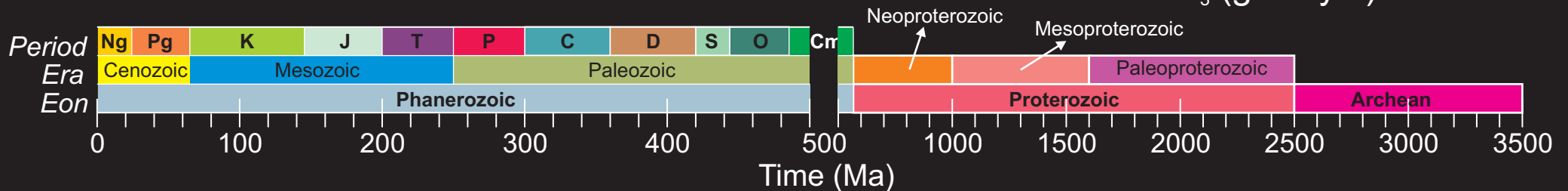
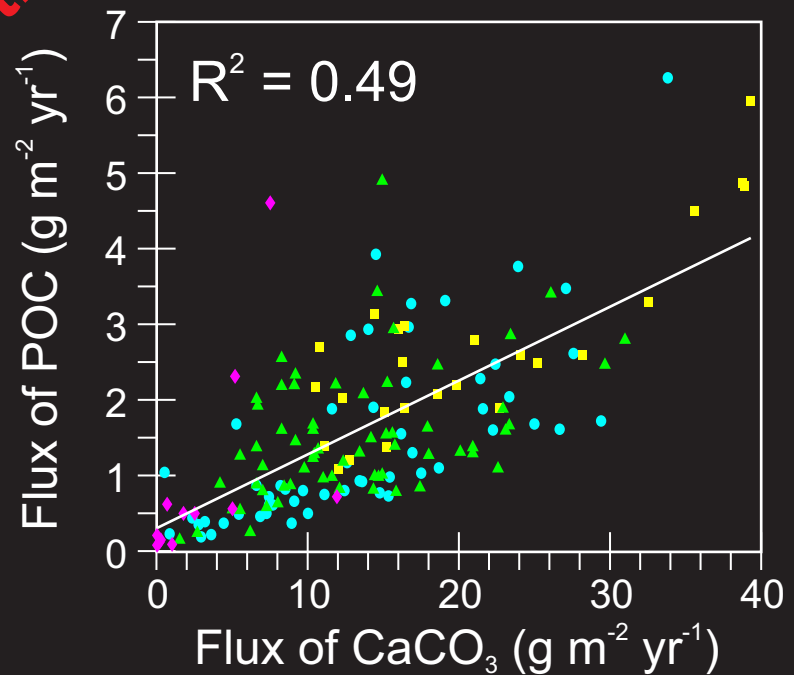


Boss and Wilkinson [1991]

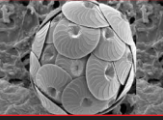




‘ballasting’

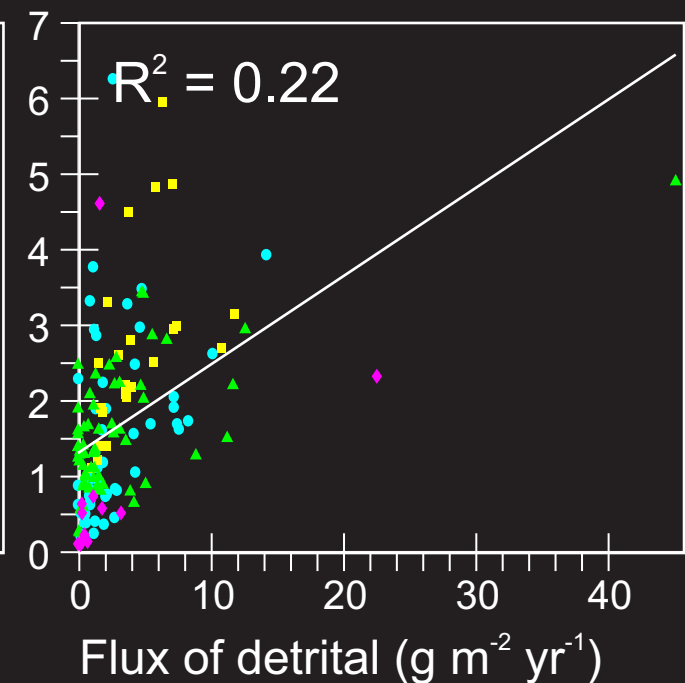
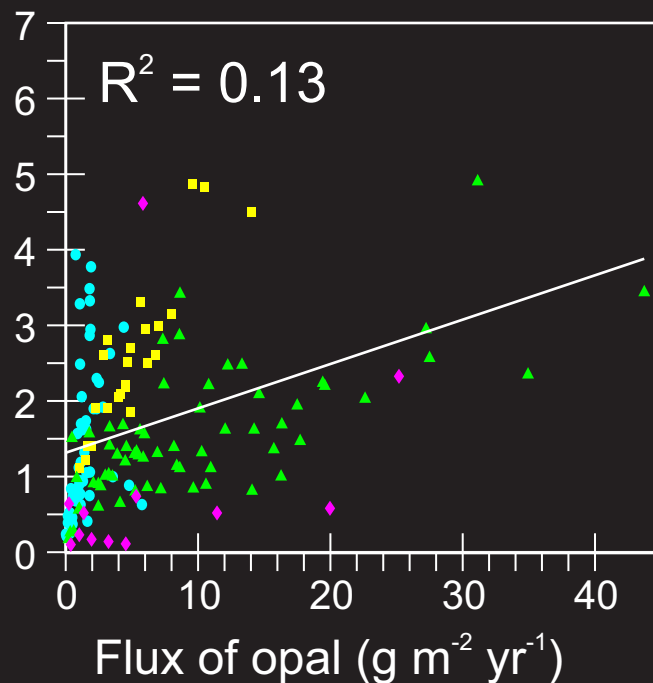
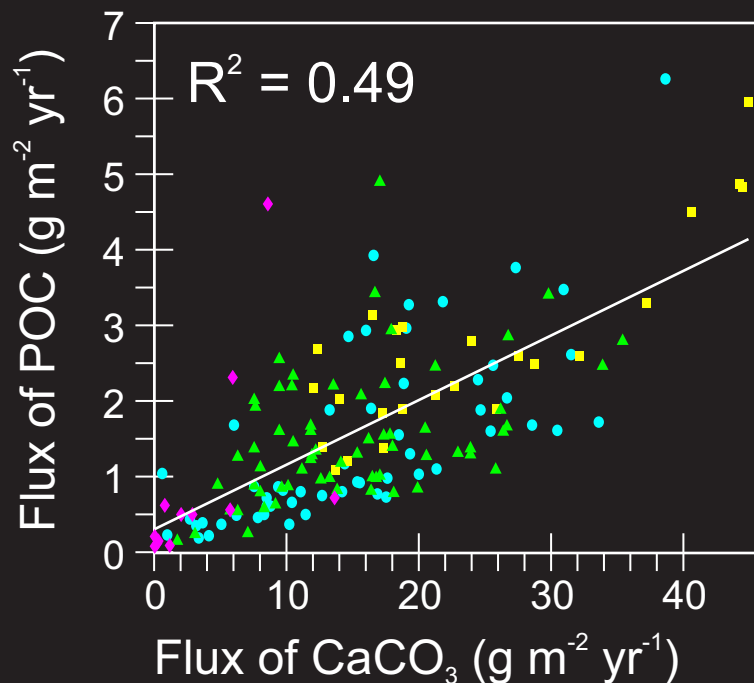


The Force awakens???

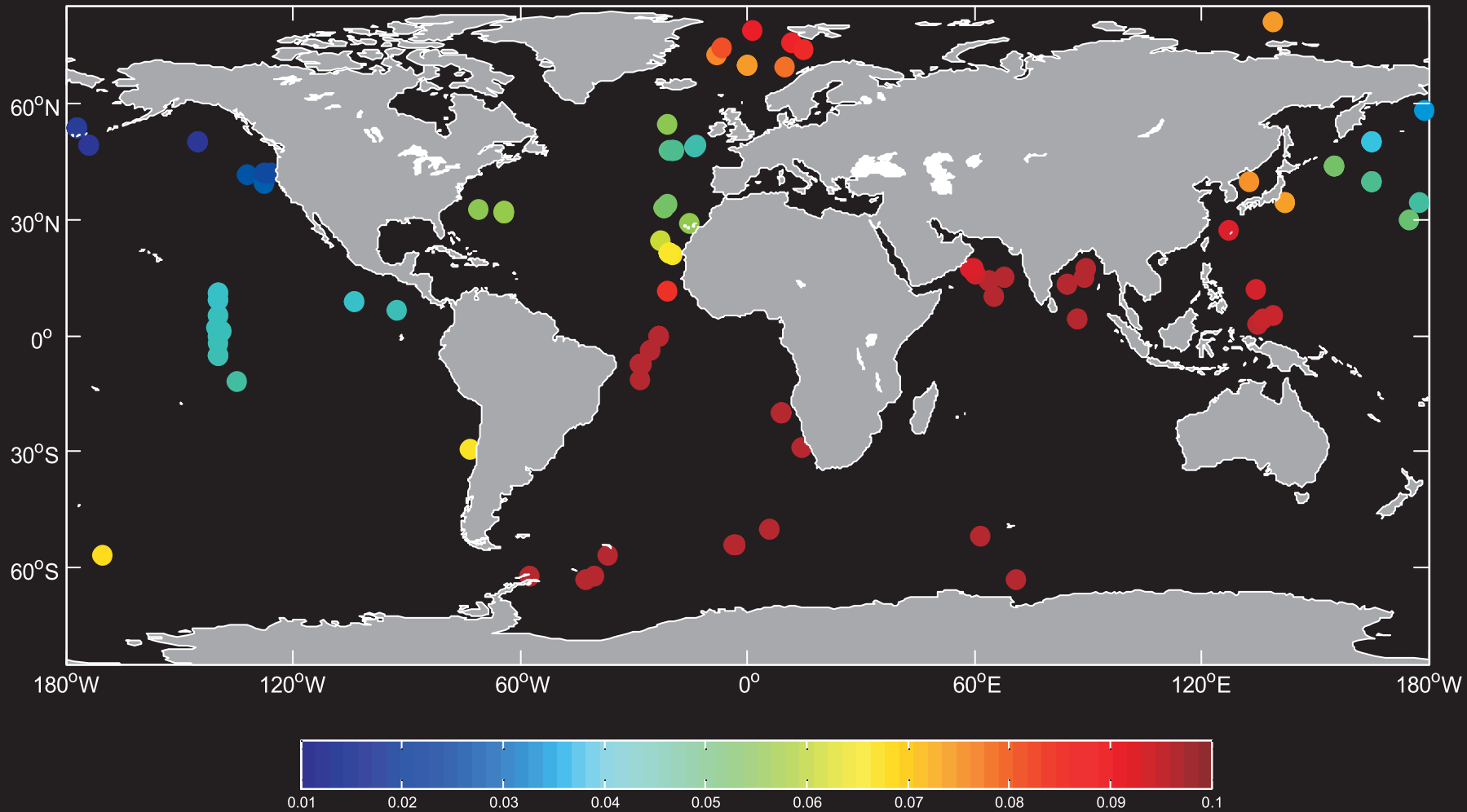
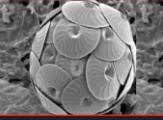


Compilation of sediment trap observations:
depths ≥ 2000 m (to exclude hydrodynamically distorted
fluxes and relationships) and differentiated by basin:
cyan == Atl, yellow == Ind, green == Pac, magenta == SO.

[Wilson et al., 2012; GBC 26, doi:10.1029/2012GB004398]

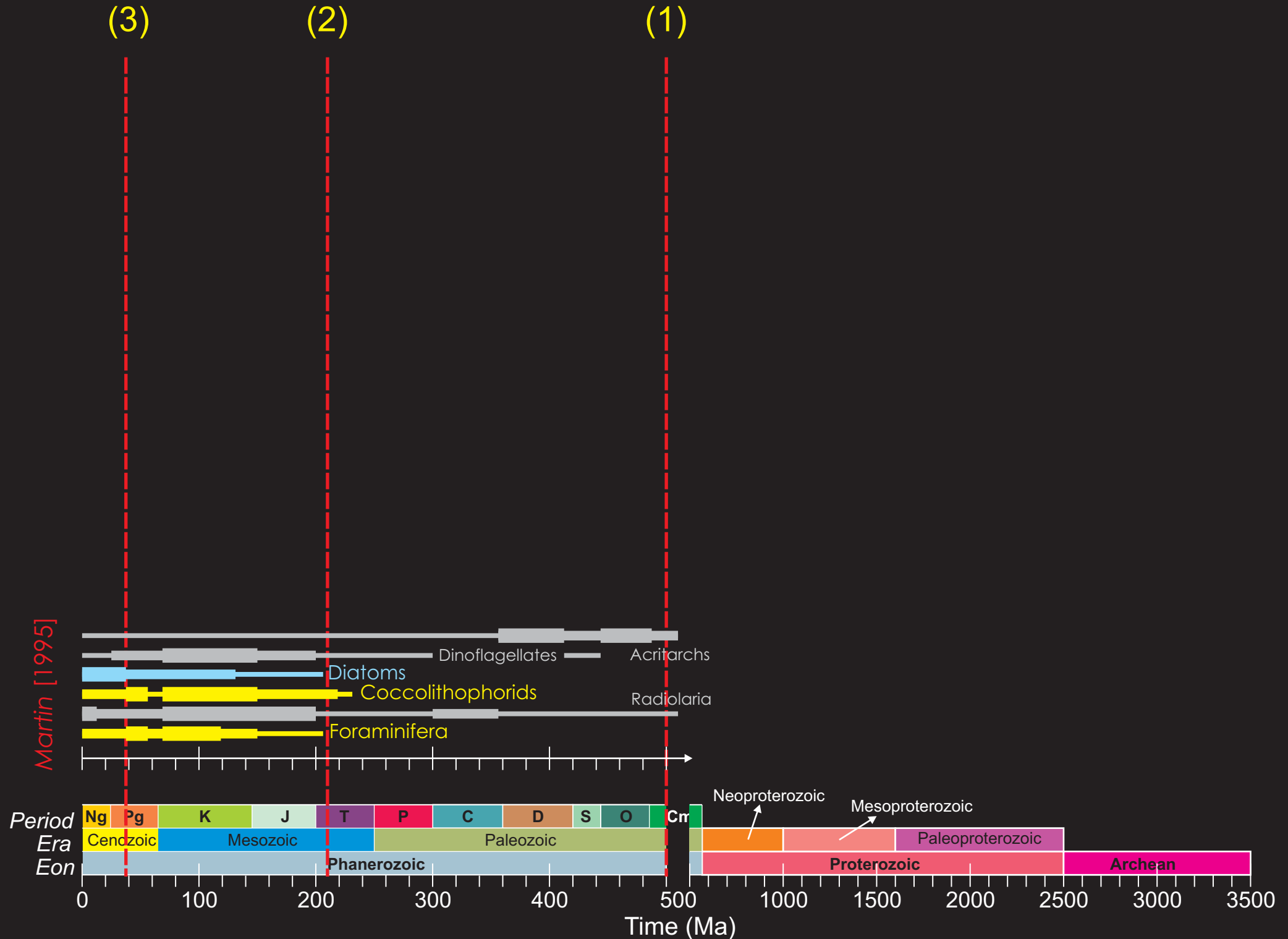
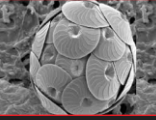


The Force awakens???

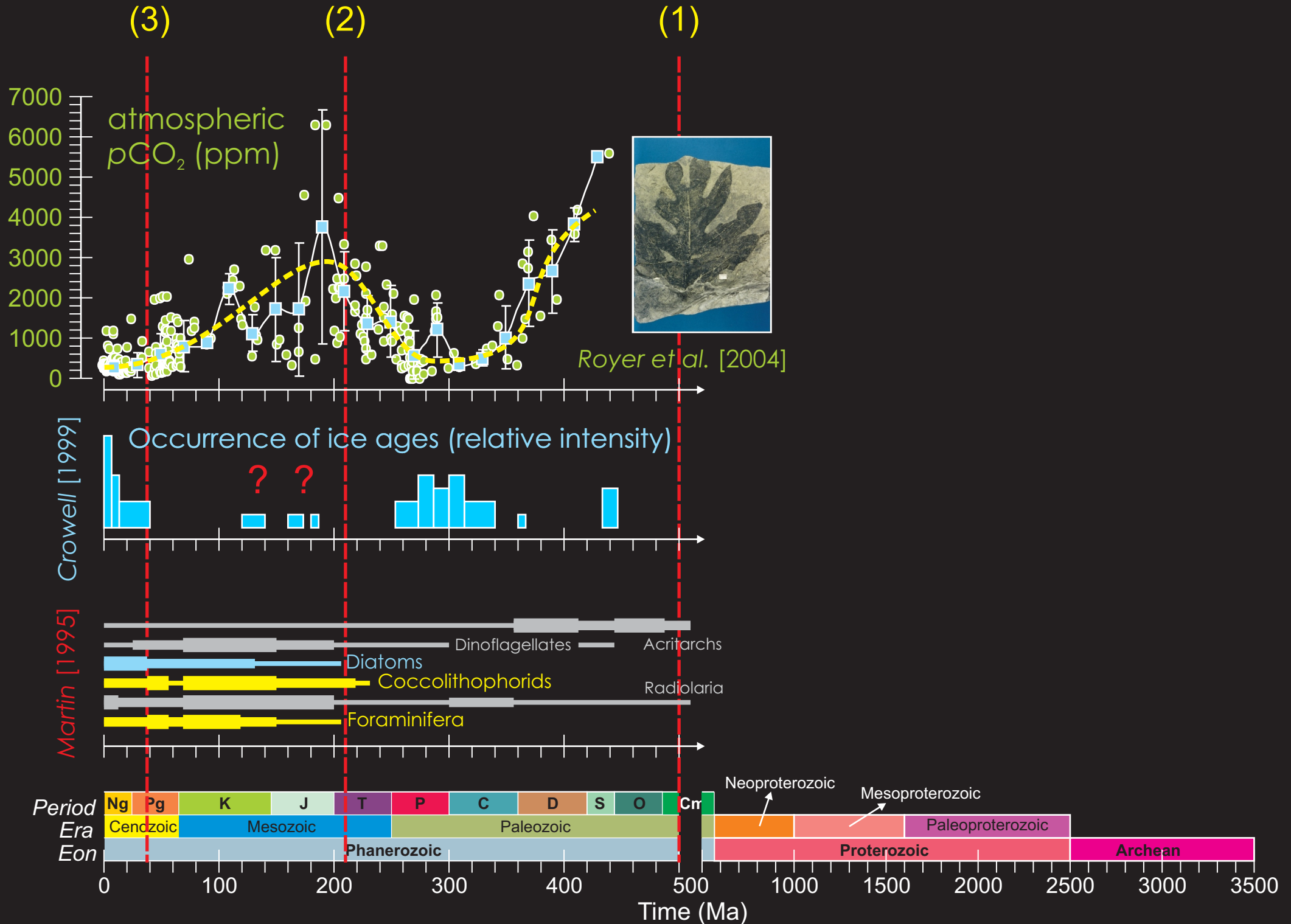
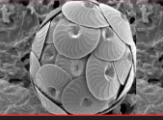


Spatial distribution of carrying capacity (ballasting) coefficients calculated using geographically weighted regression analysis for CaCO_3 .

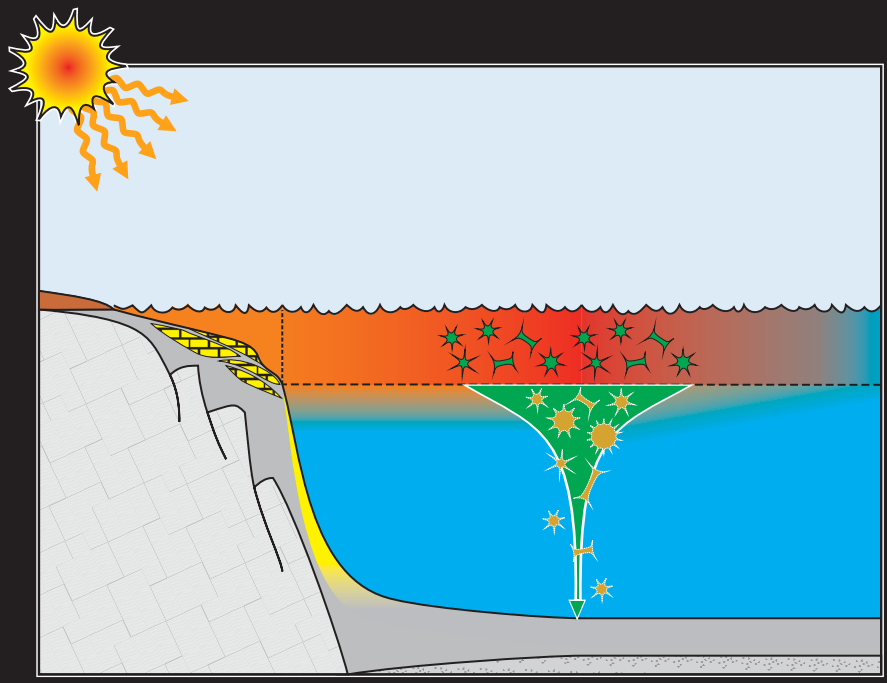
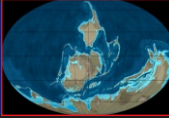
When did the Force awaken (modern biological pump form)?



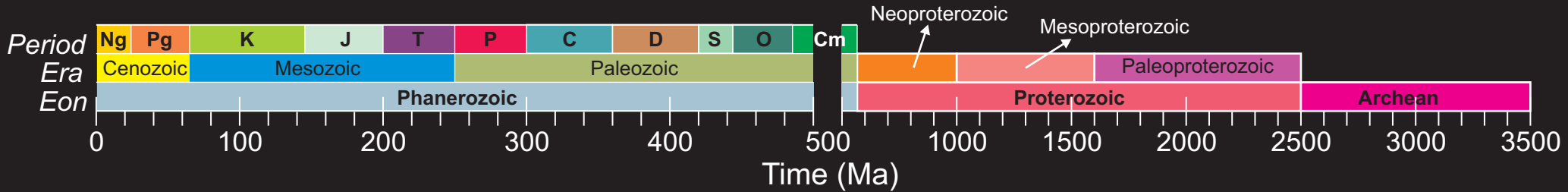
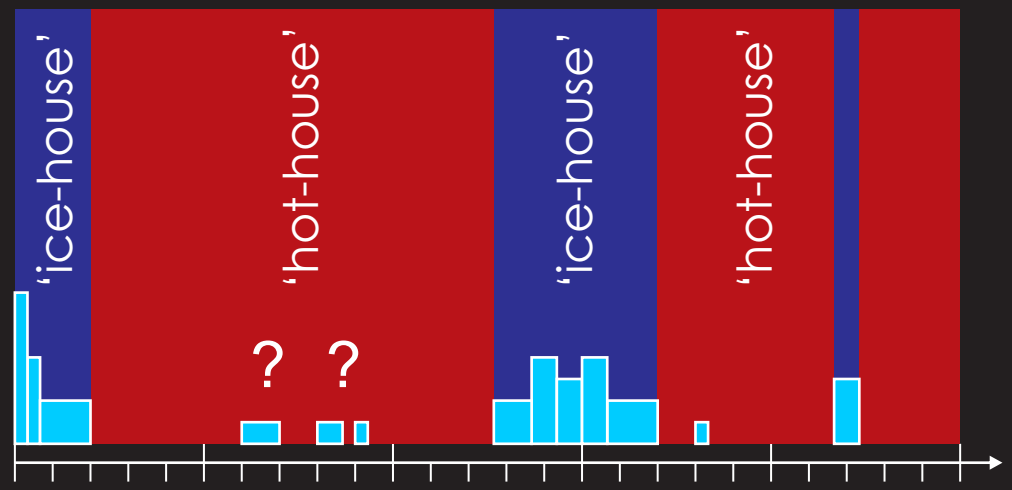
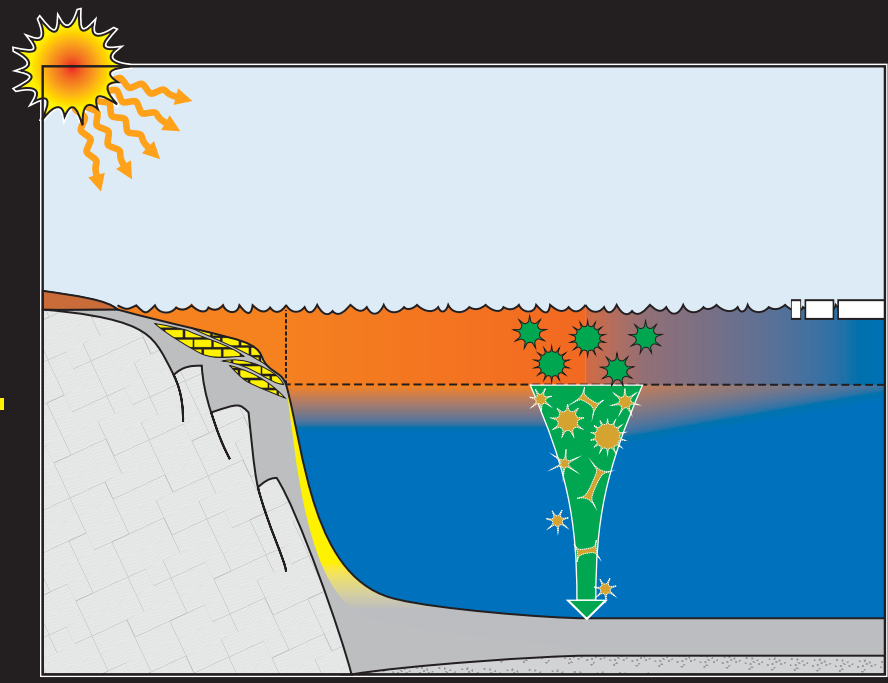
When did the Force awaken (modern biological pump form)?



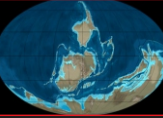
Paleo Perspectives – Extreme climate states



VS.

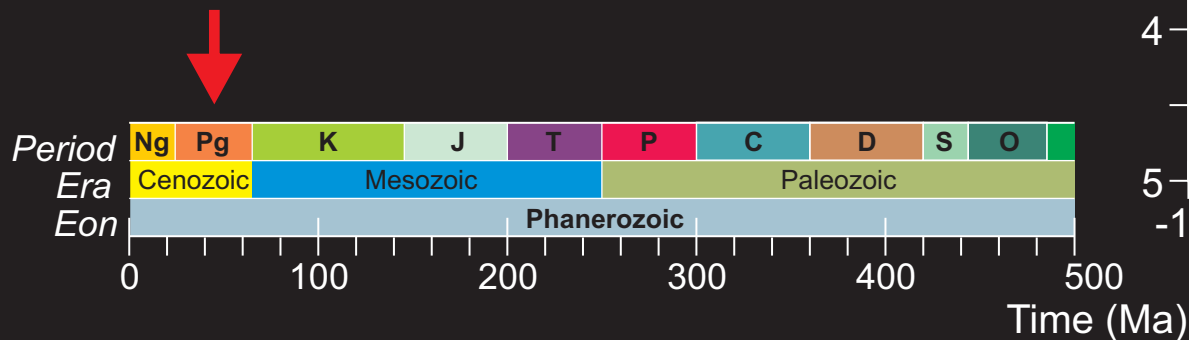
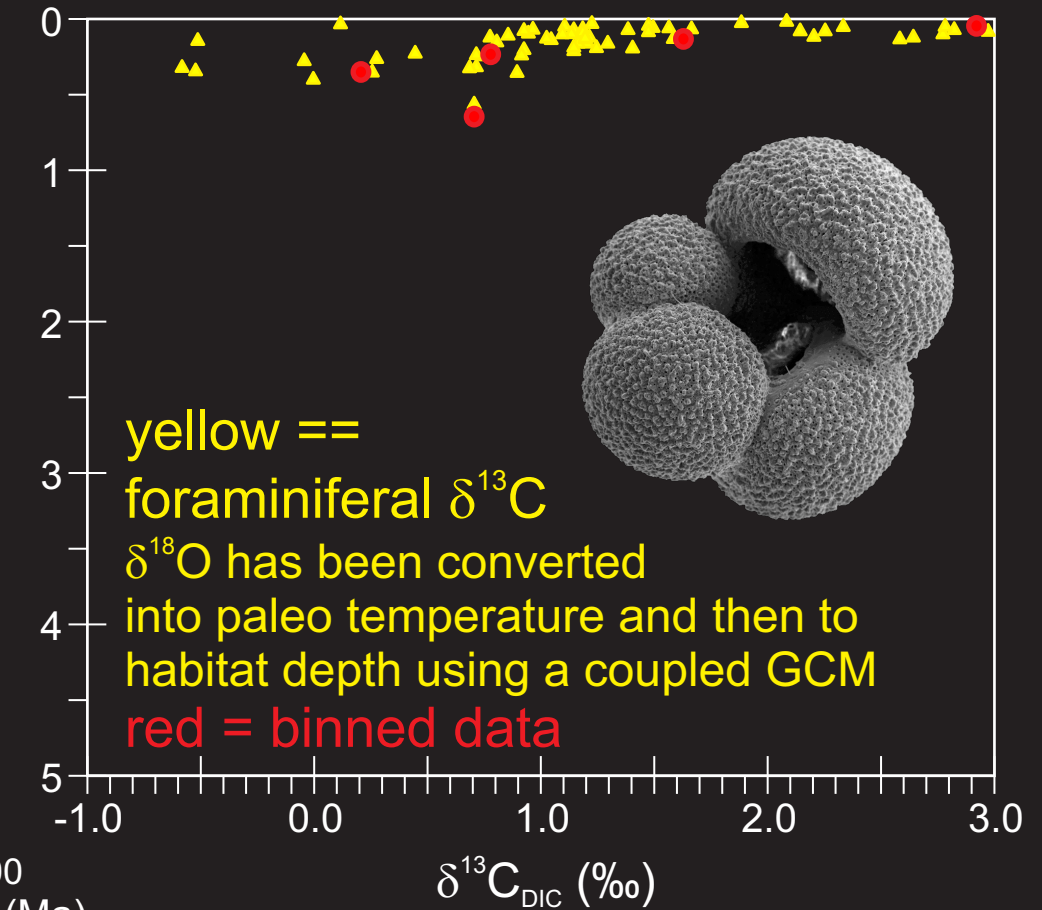
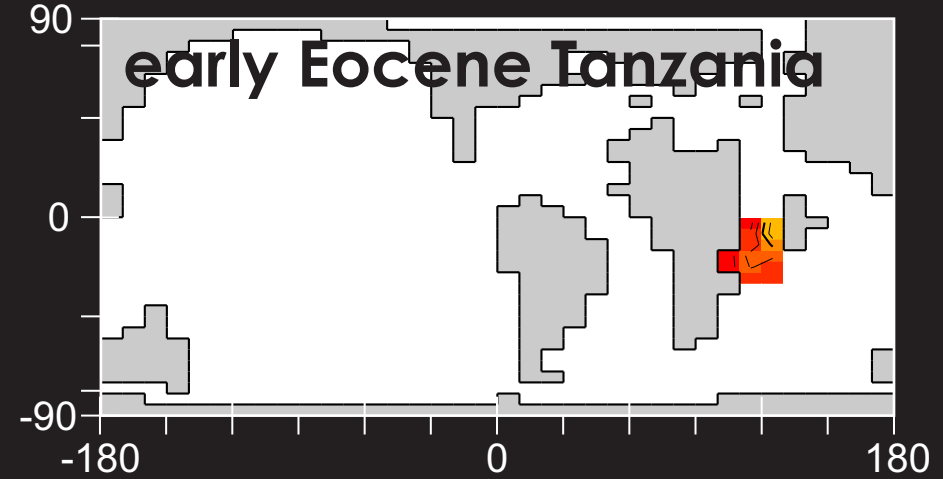


Paleo Perspectives – Testing the ‘metabolic’ hypothesis

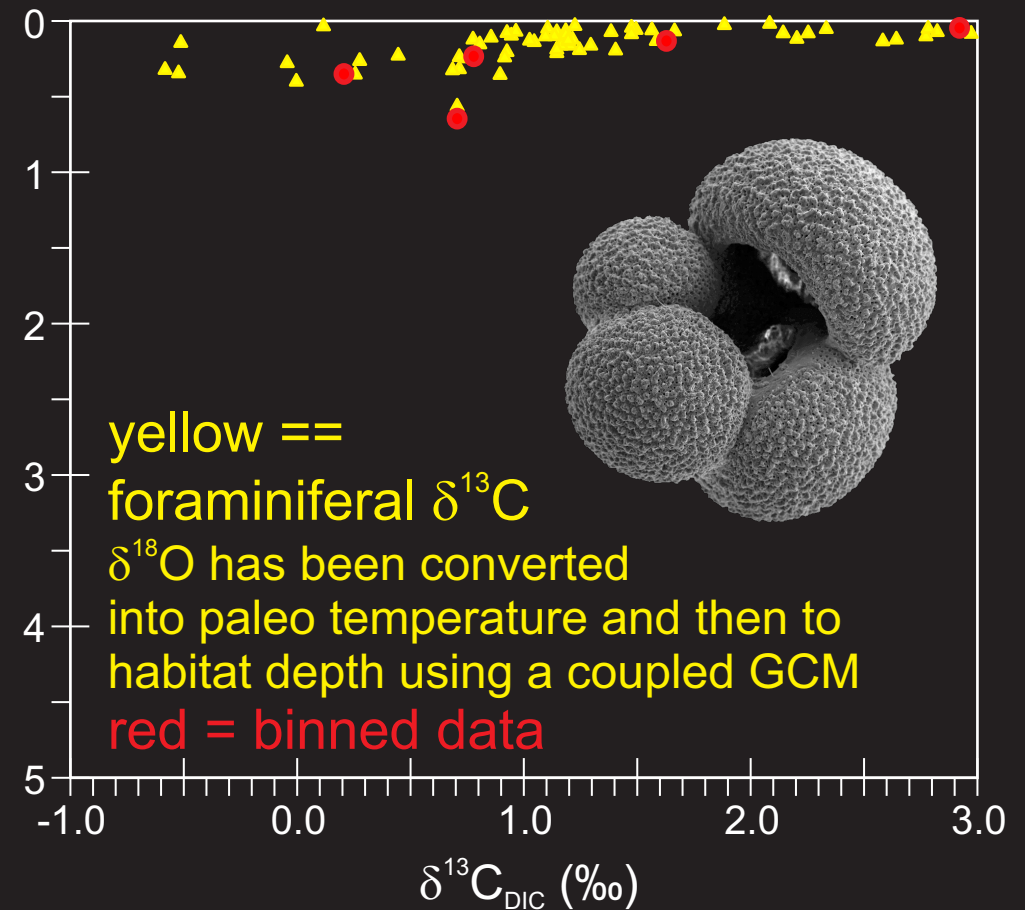
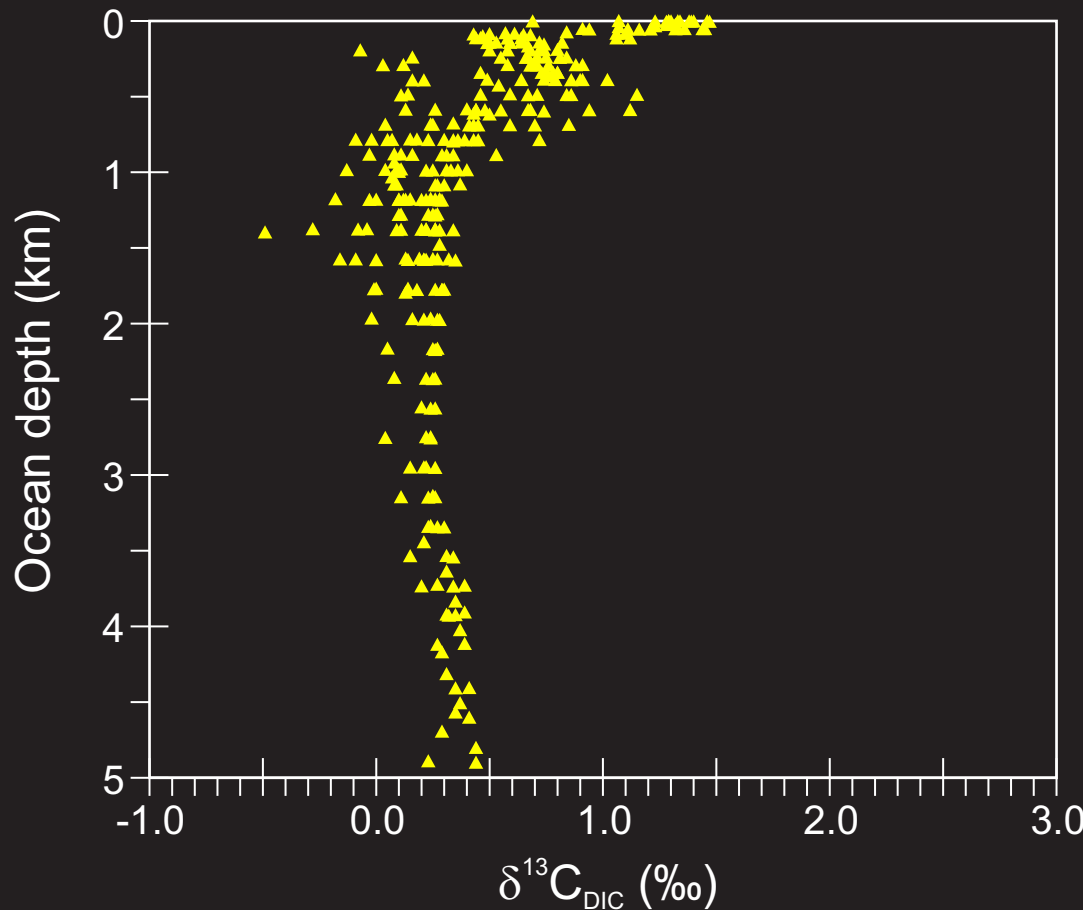
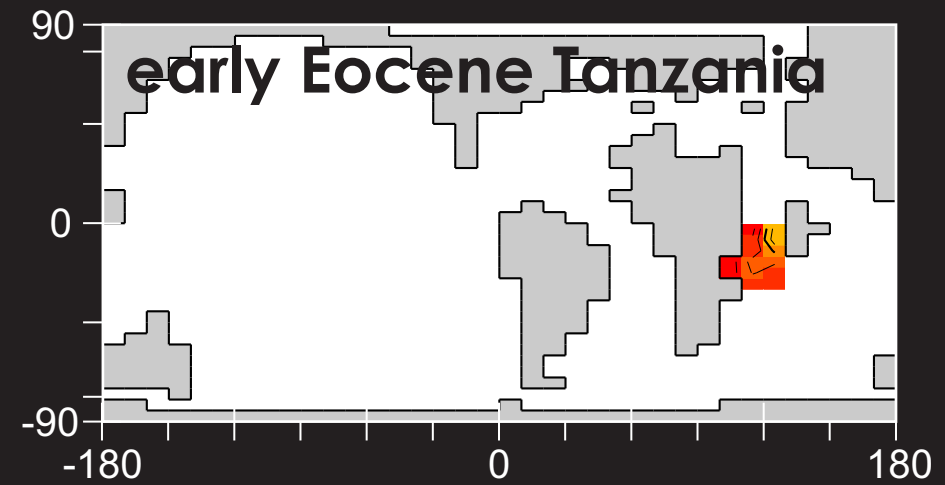
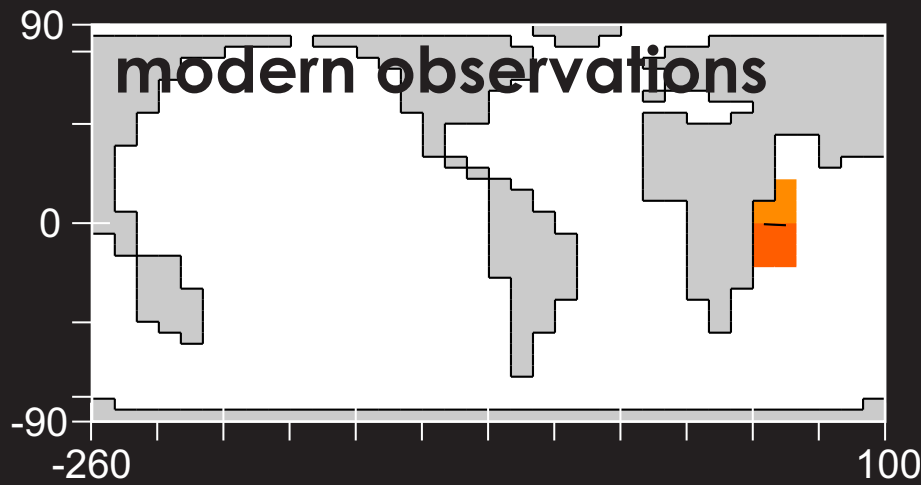
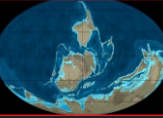


(for water column POC remineralization)

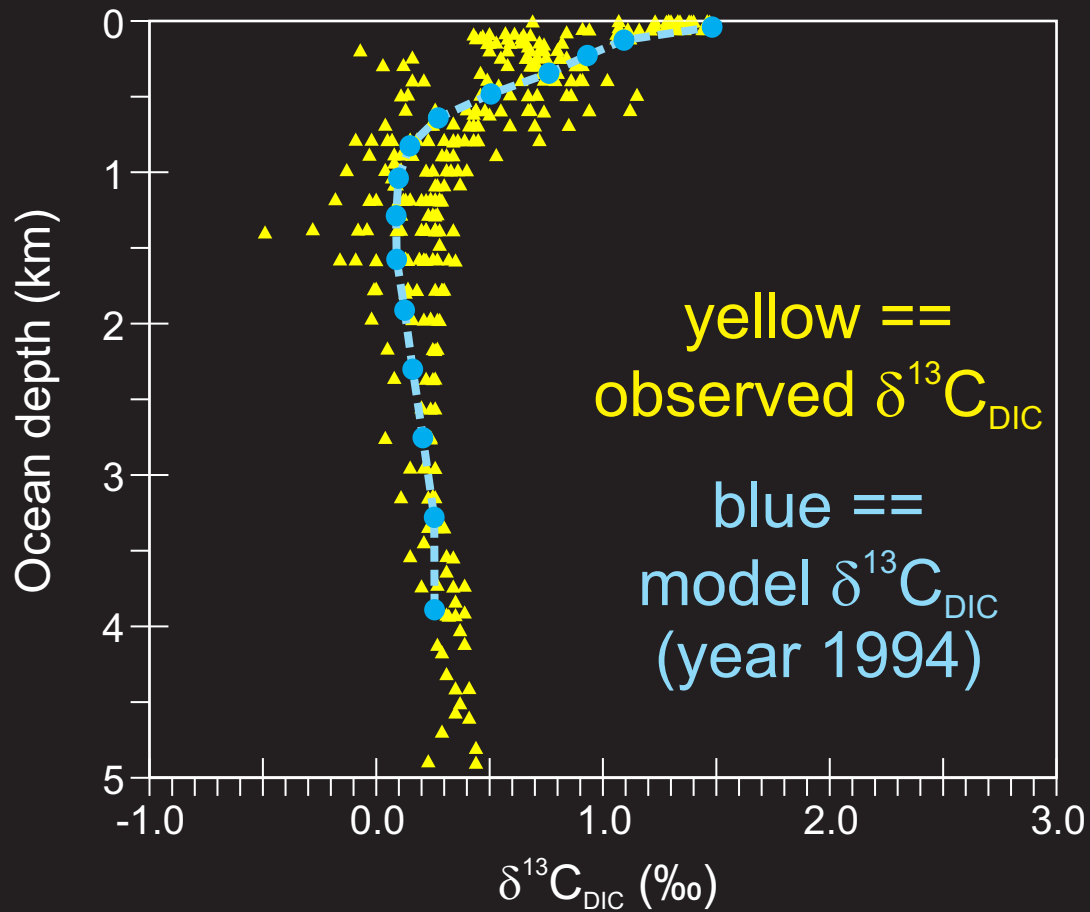
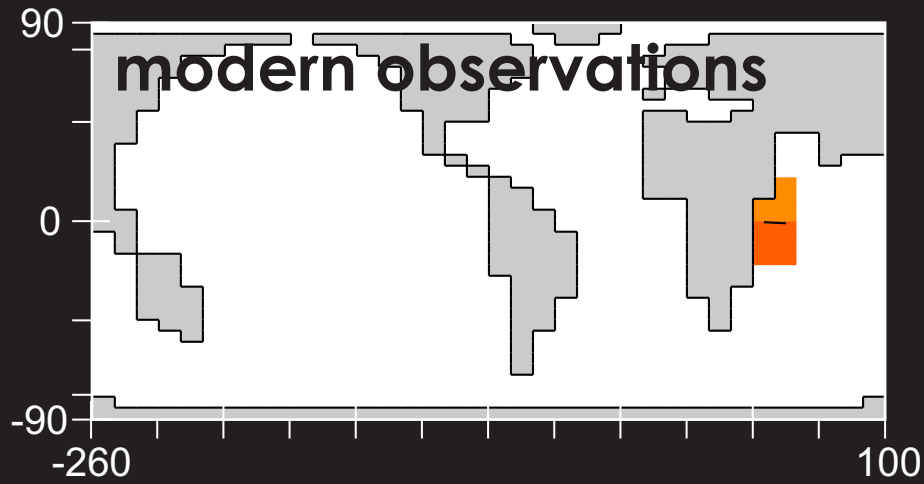
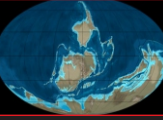
John et al. [2014] (PPP 413)



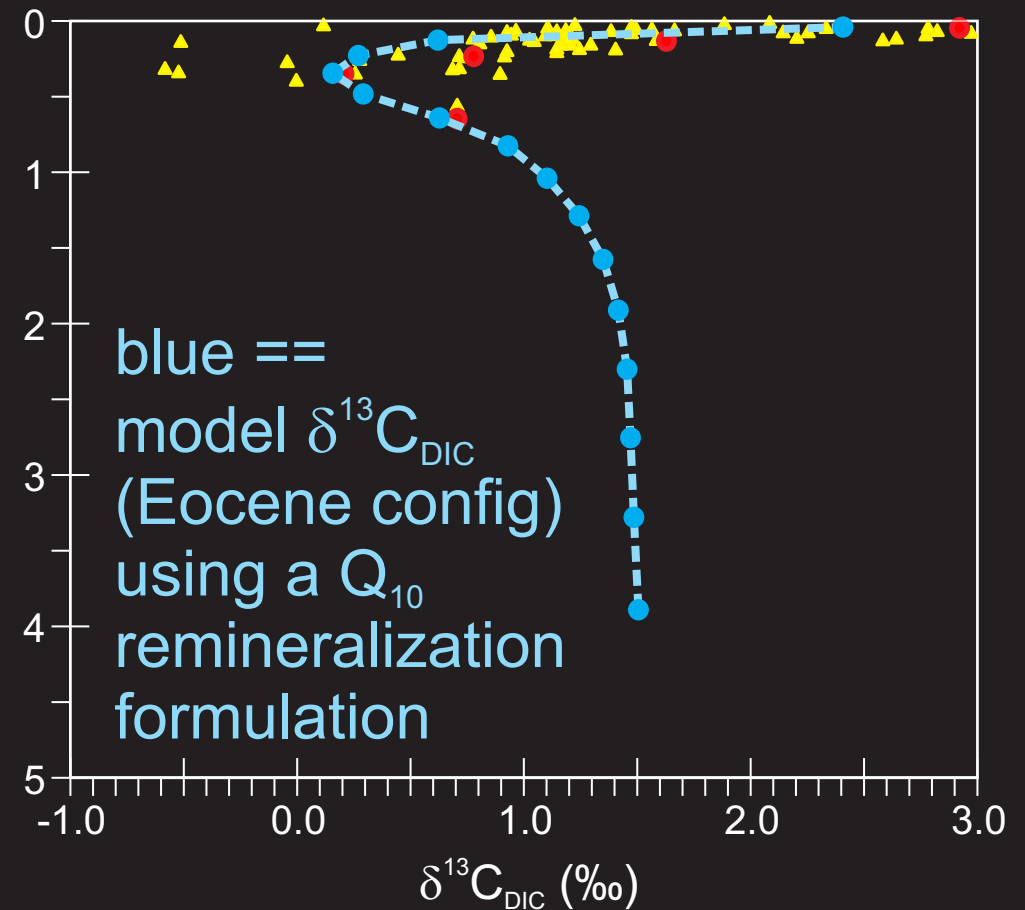
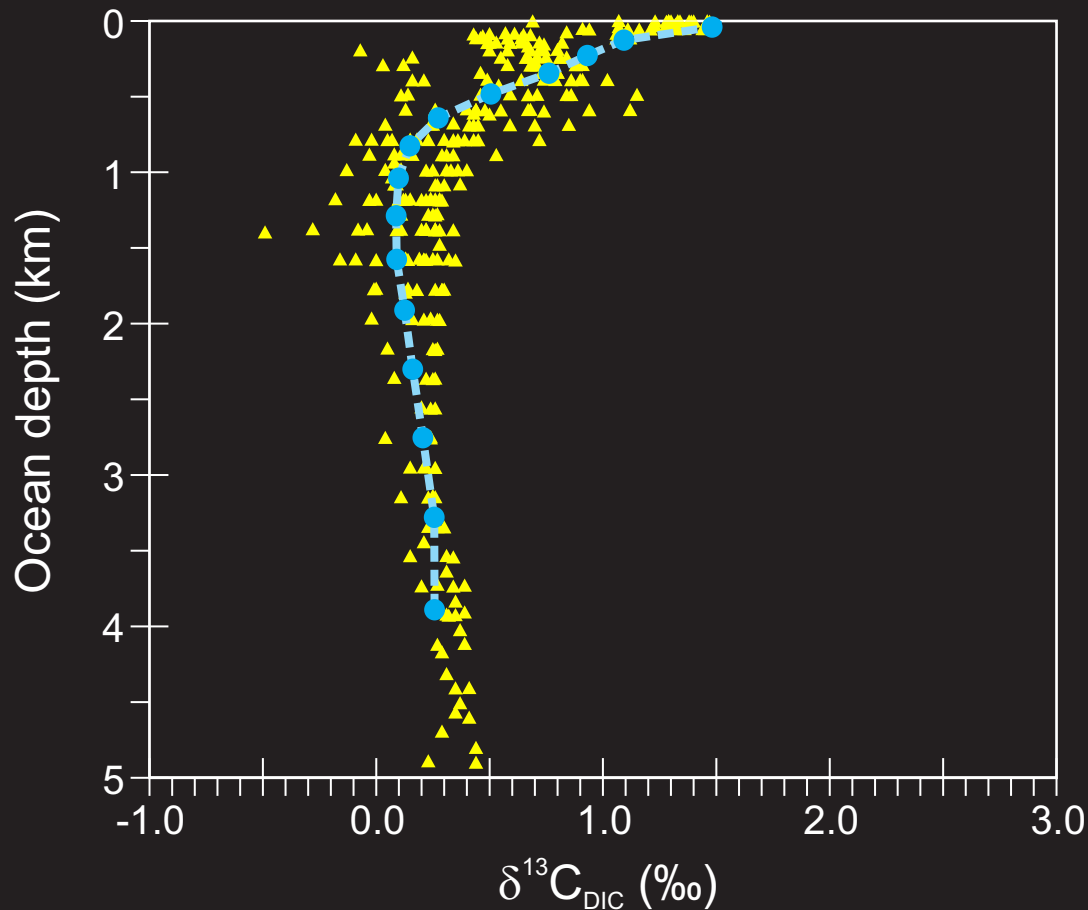
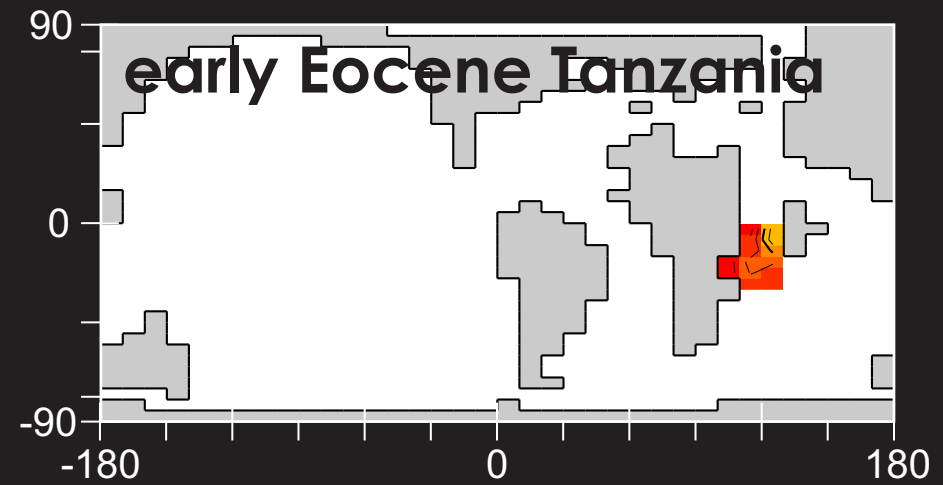
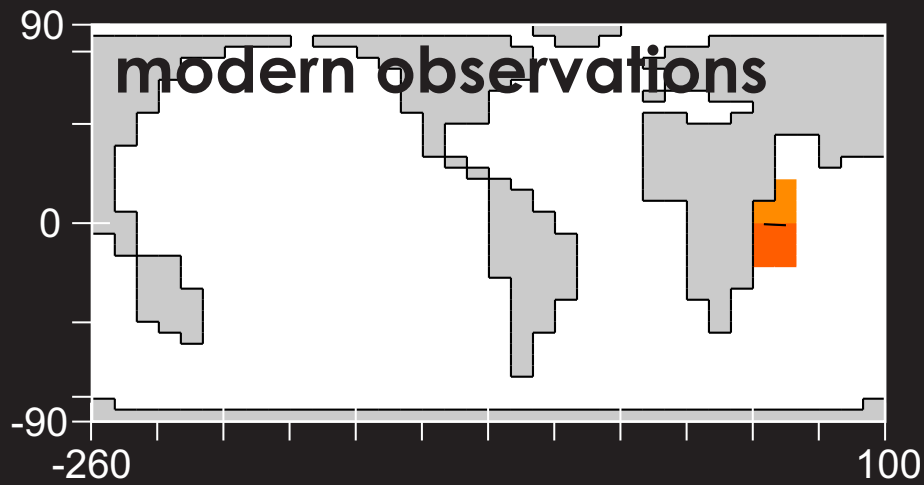
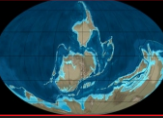
Paleo Perspectives – Testing the ‘metabolic’ hypothesis



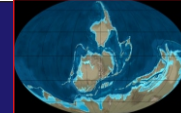
Paleo Perspectives – Testing the ‘metabolic’ hypothesis



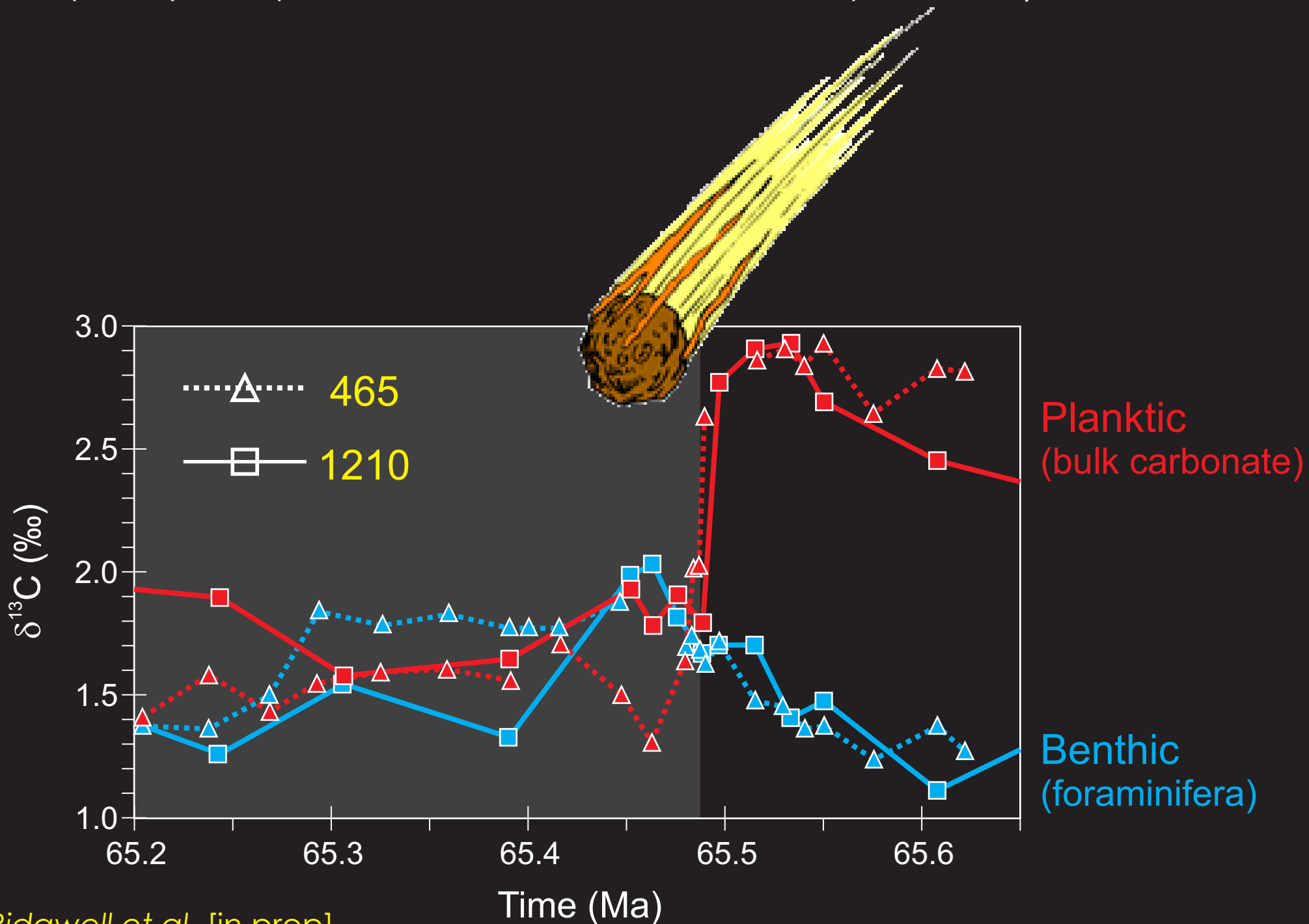
Paleo Perspectives – Testing the ‘metabolic’ hypothesis



Paleo Perspectives – ‘Hiccups’



(temporary disruption or removal of one or more processes)



Evolution of the Biological Pump

Chicheley Hall Royal Society

Evolution of Carbon Pumping for Dummies

