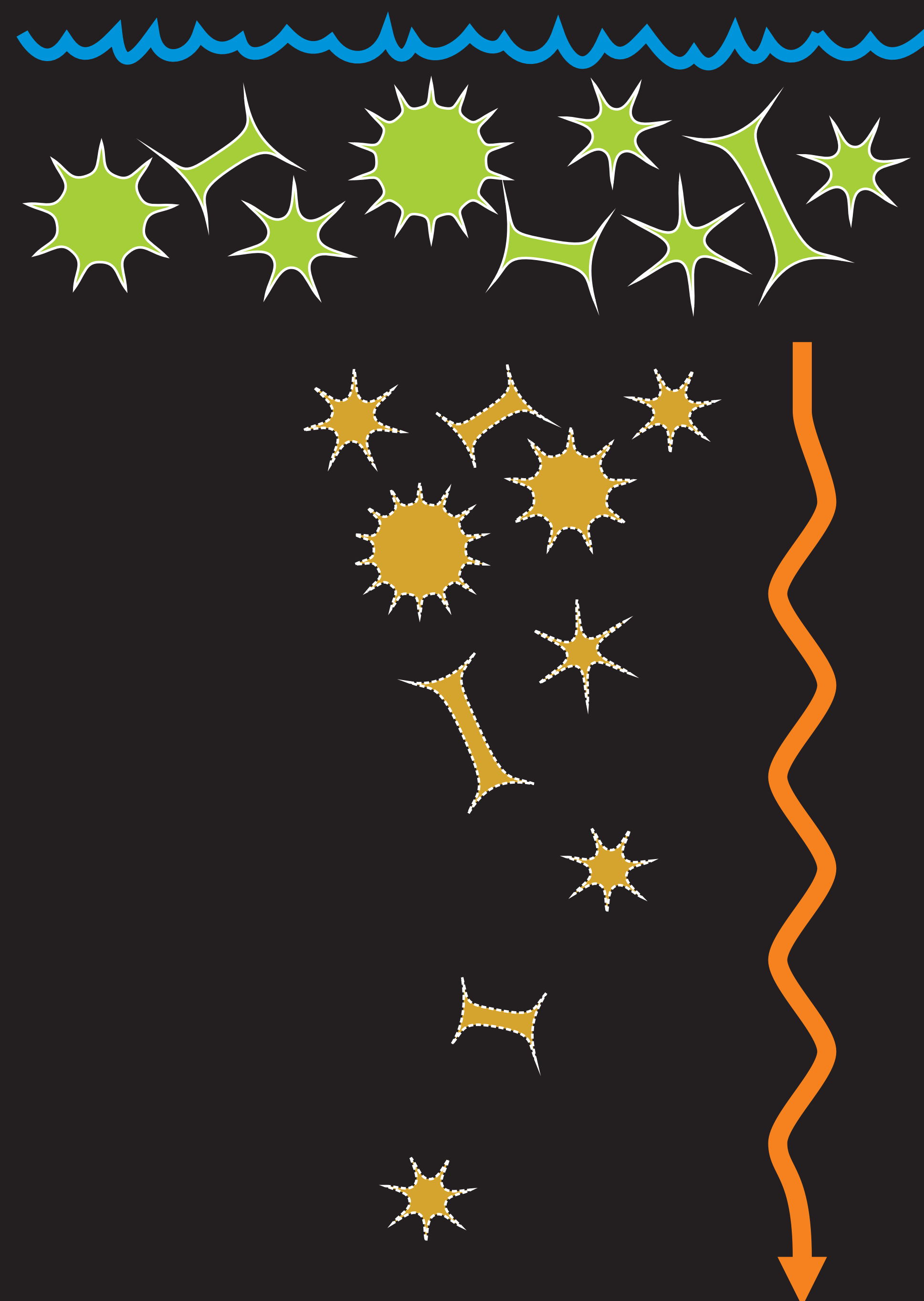
Evolution of the Biological Pump

Andy Ridgwell



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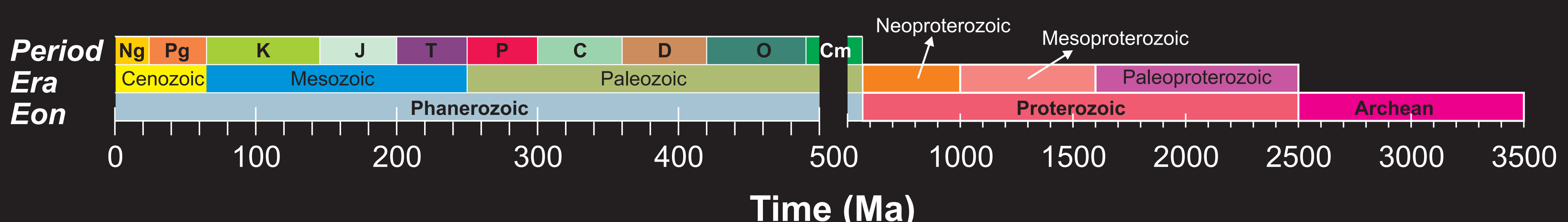
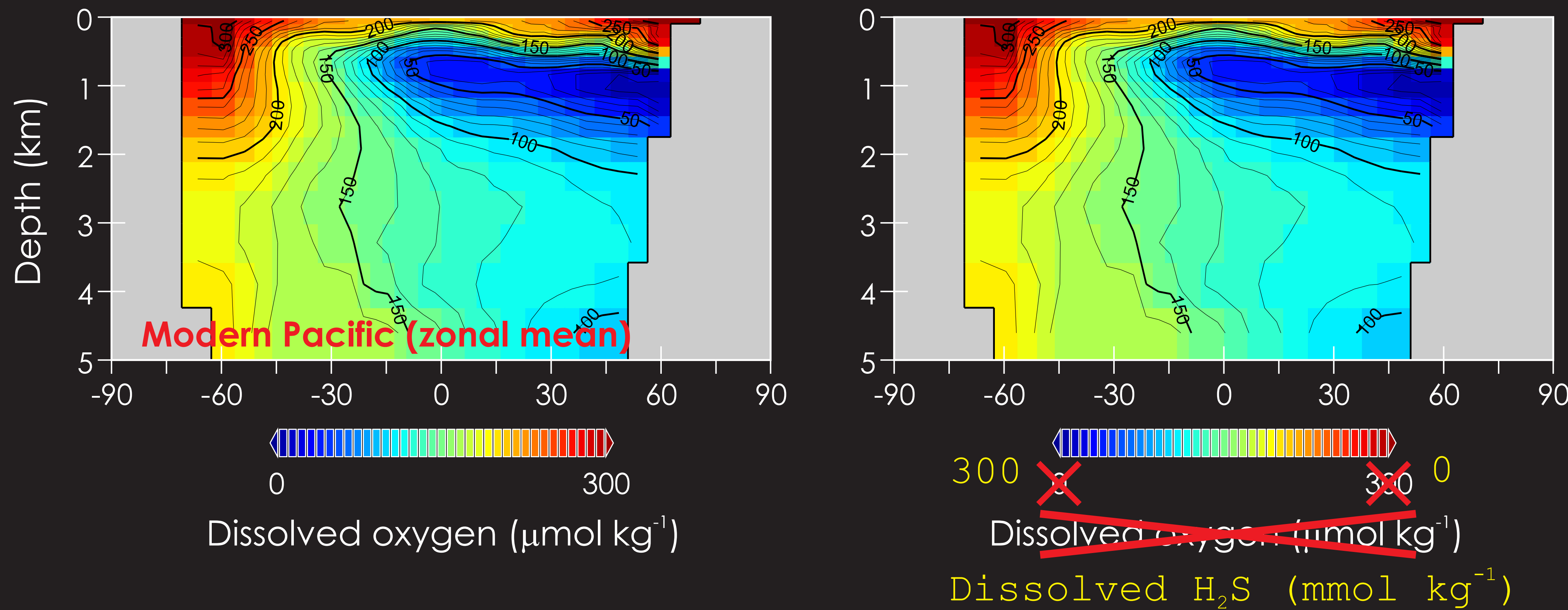
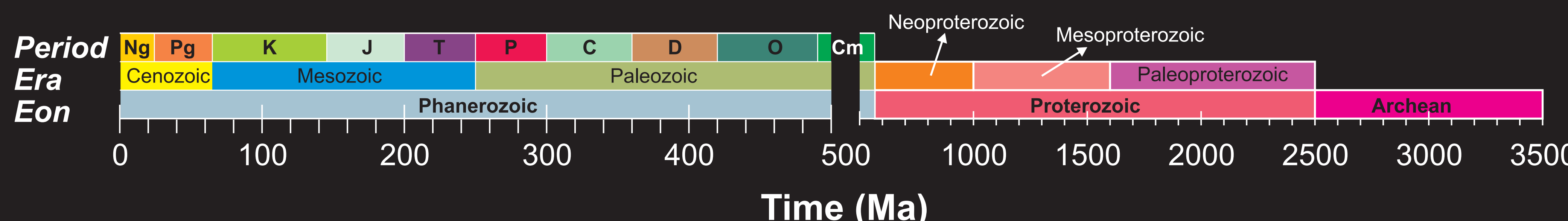
Evolution of the Biological Pump



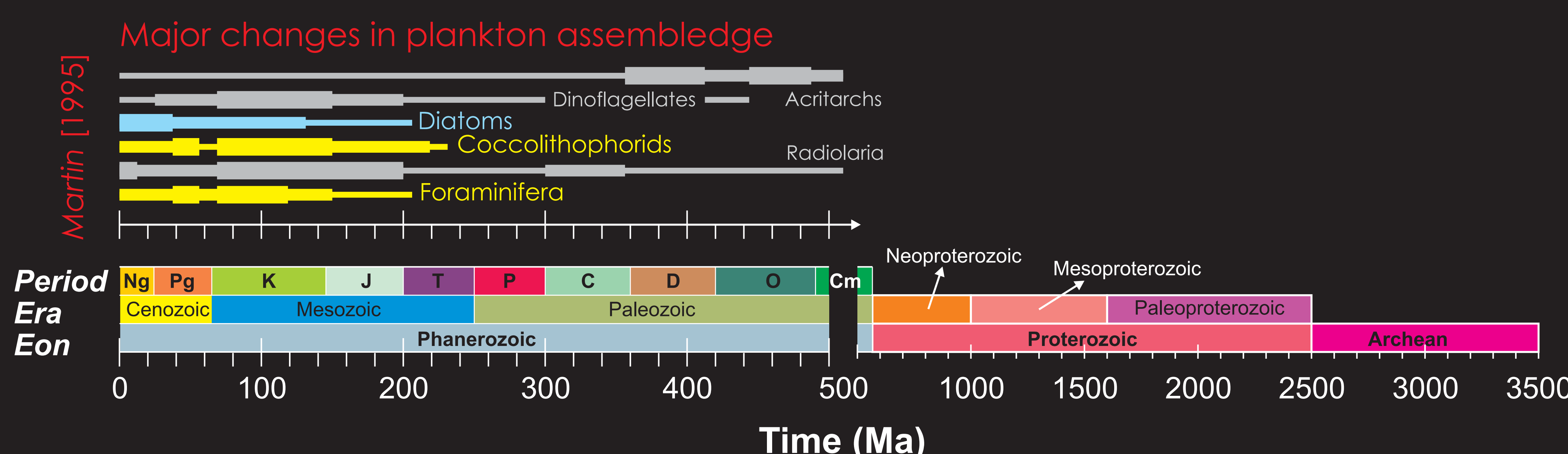
Evolution of the Biological Pump

Decreased atmospheric pO_2





Evolution of the Biological Pump



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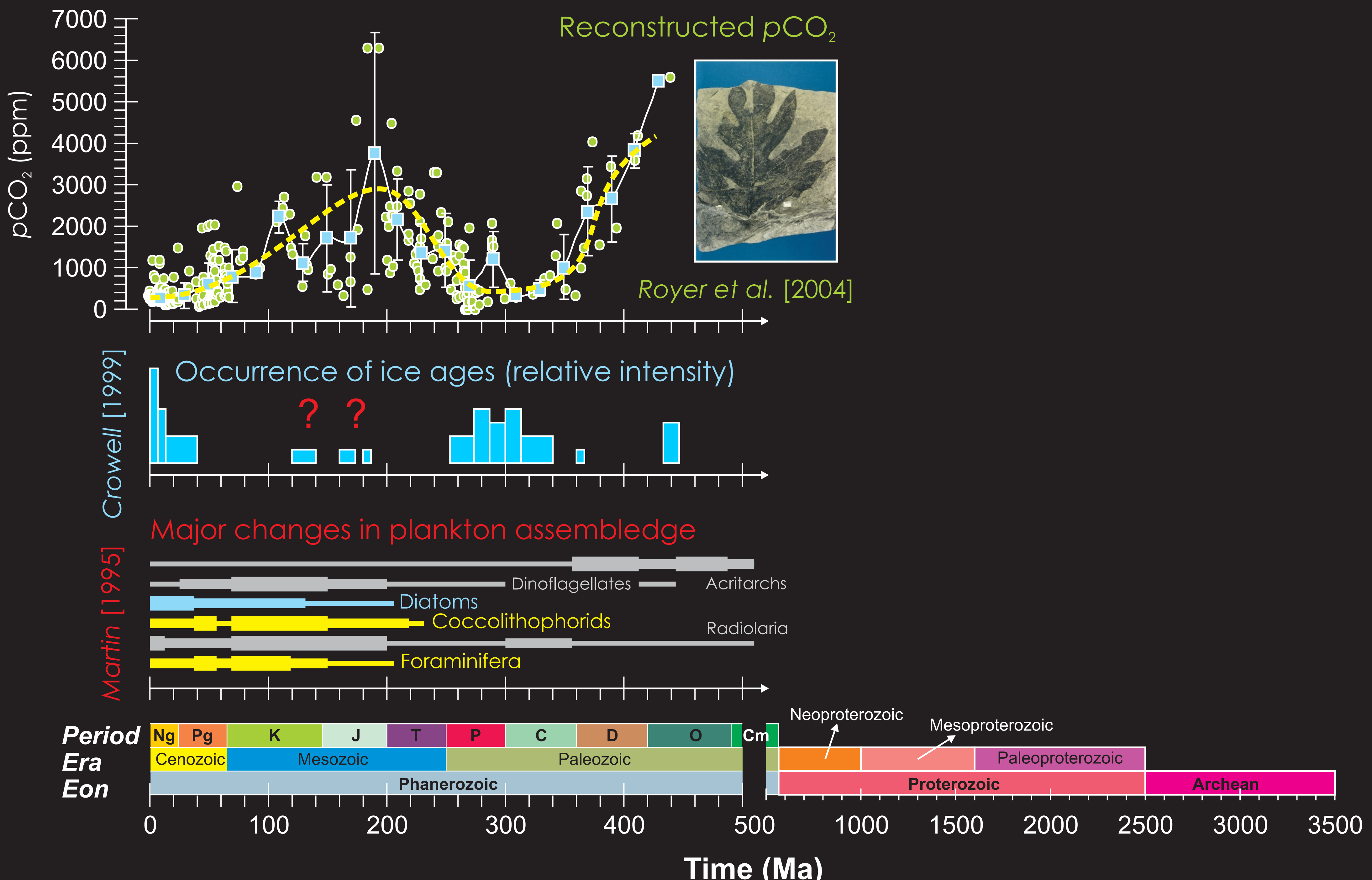
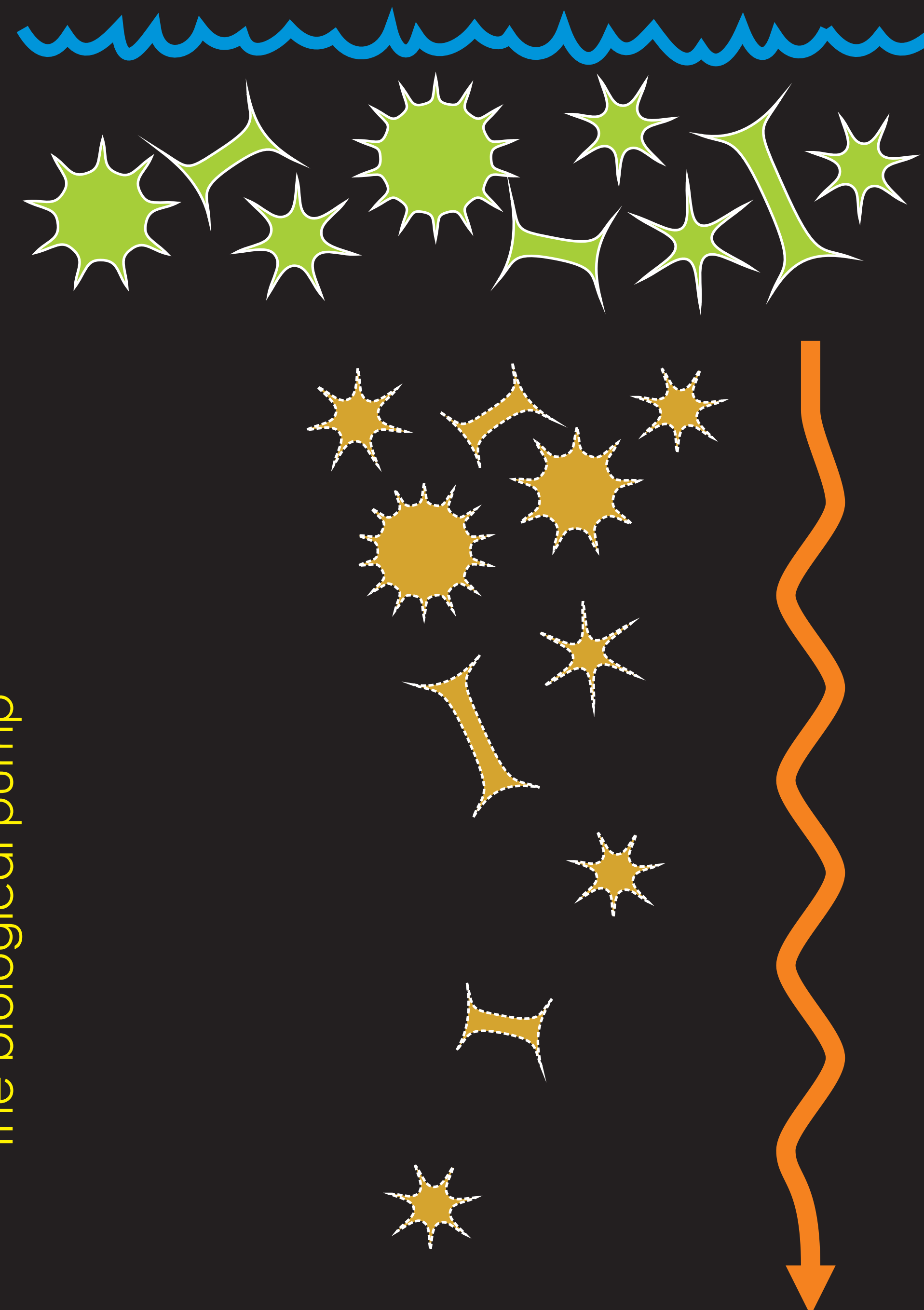


Evolution of the Biological Pump



The processes that govern the partitioning of carbon (and alkalinity) between the surface ocean (and hence atmosphere) and ocean interior, are traditionally described in terms of three conceptual 'pumps':

(1) the 'solubility' pump

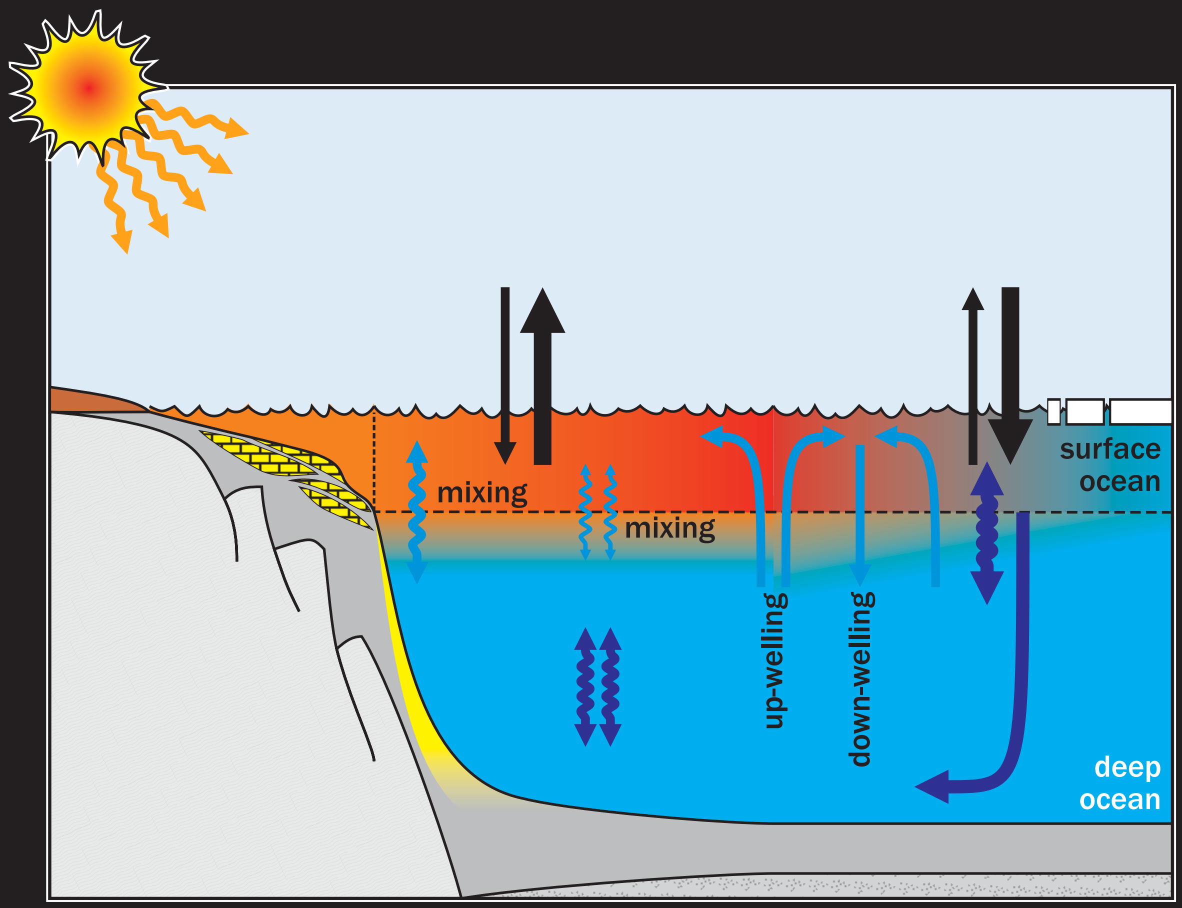
(2) the 'organic matter' (or 'soft tissue') pump, and

(3) the 'carbonate' (or 'counter') pump.

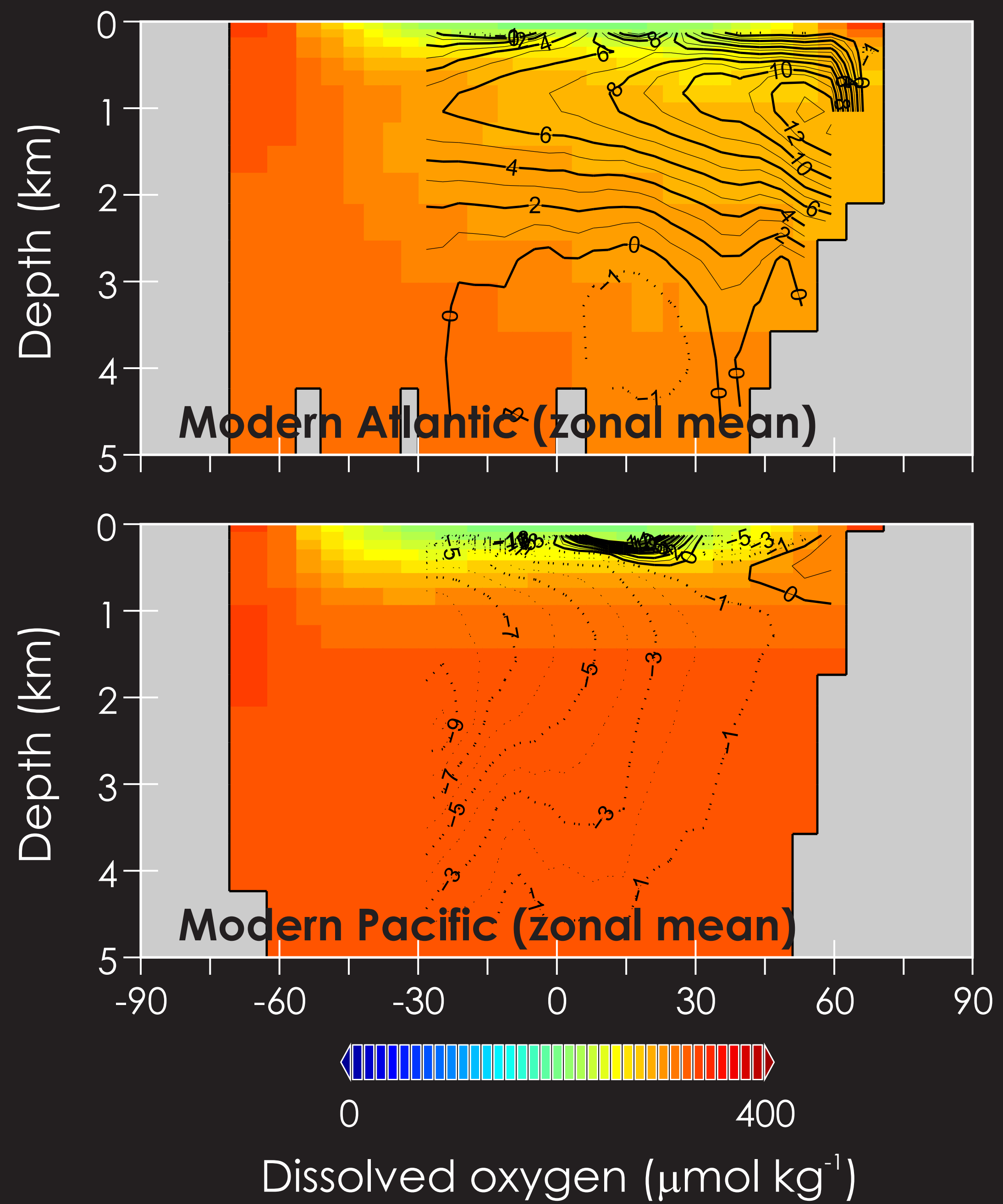
This conceptual framework has more recently extended by a fourth component:
(4) the microbial carbon pump.

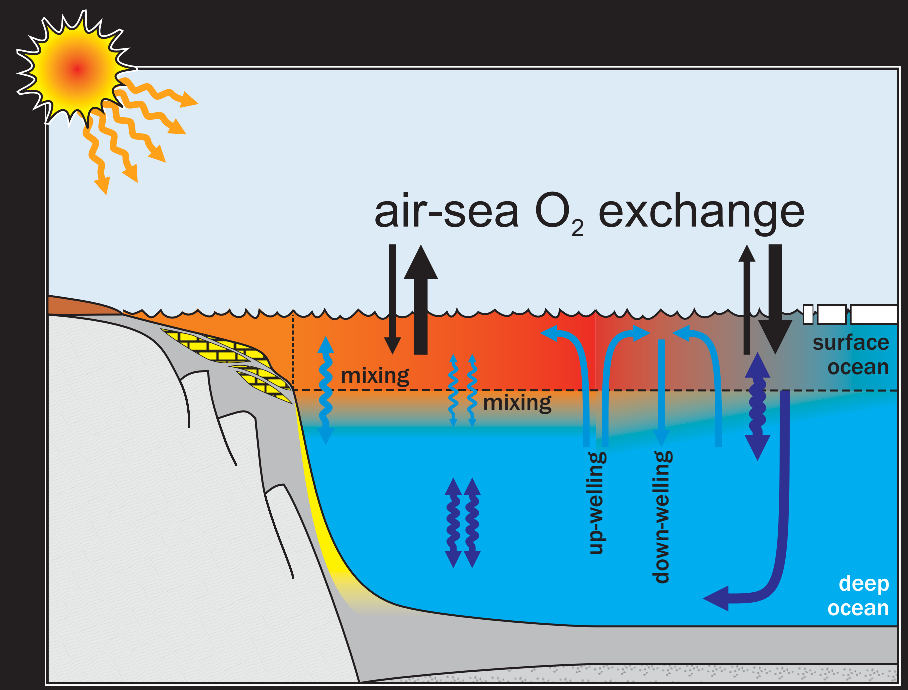
'the biological pump'

(1) The solubility pump



(1) The solubility pump





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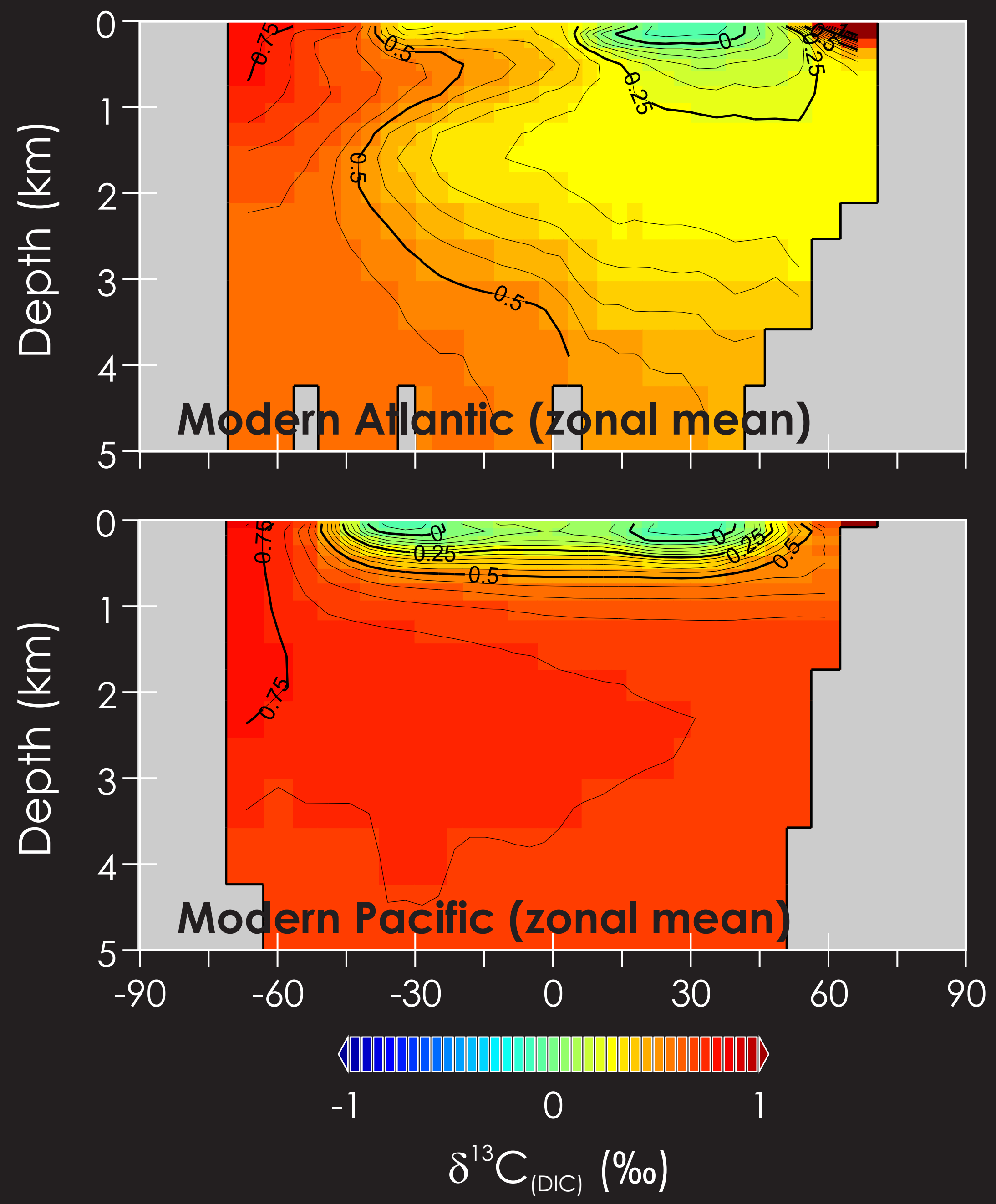
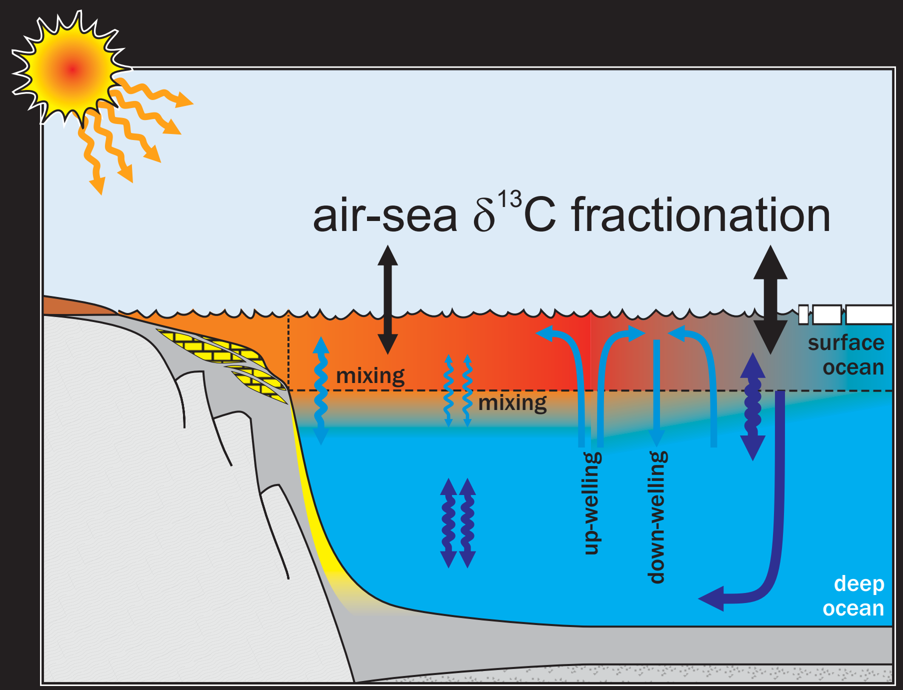
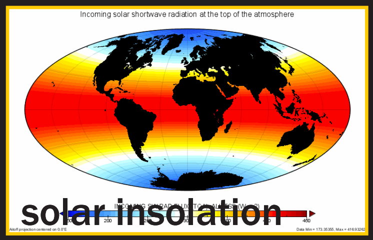
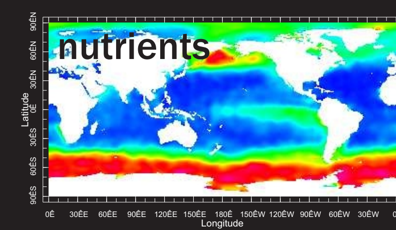


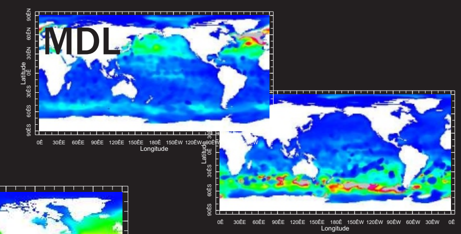


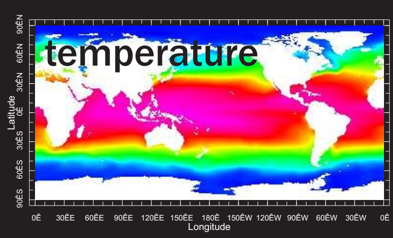
(2) The organic matter (soft-tissue) pump

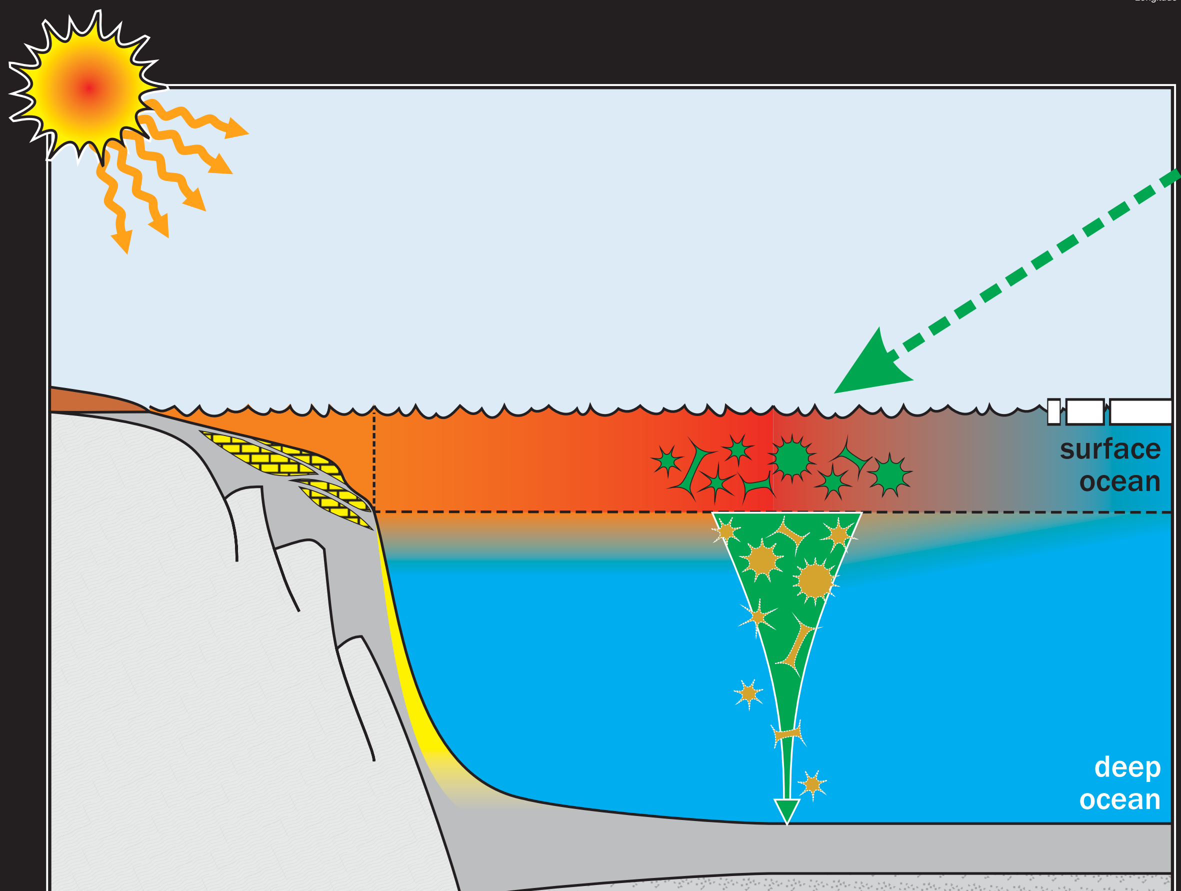
The <u>strength </u>of the biological pump is dictated by biological export production and all the processes (e.g. nutrient availability) that govern that.





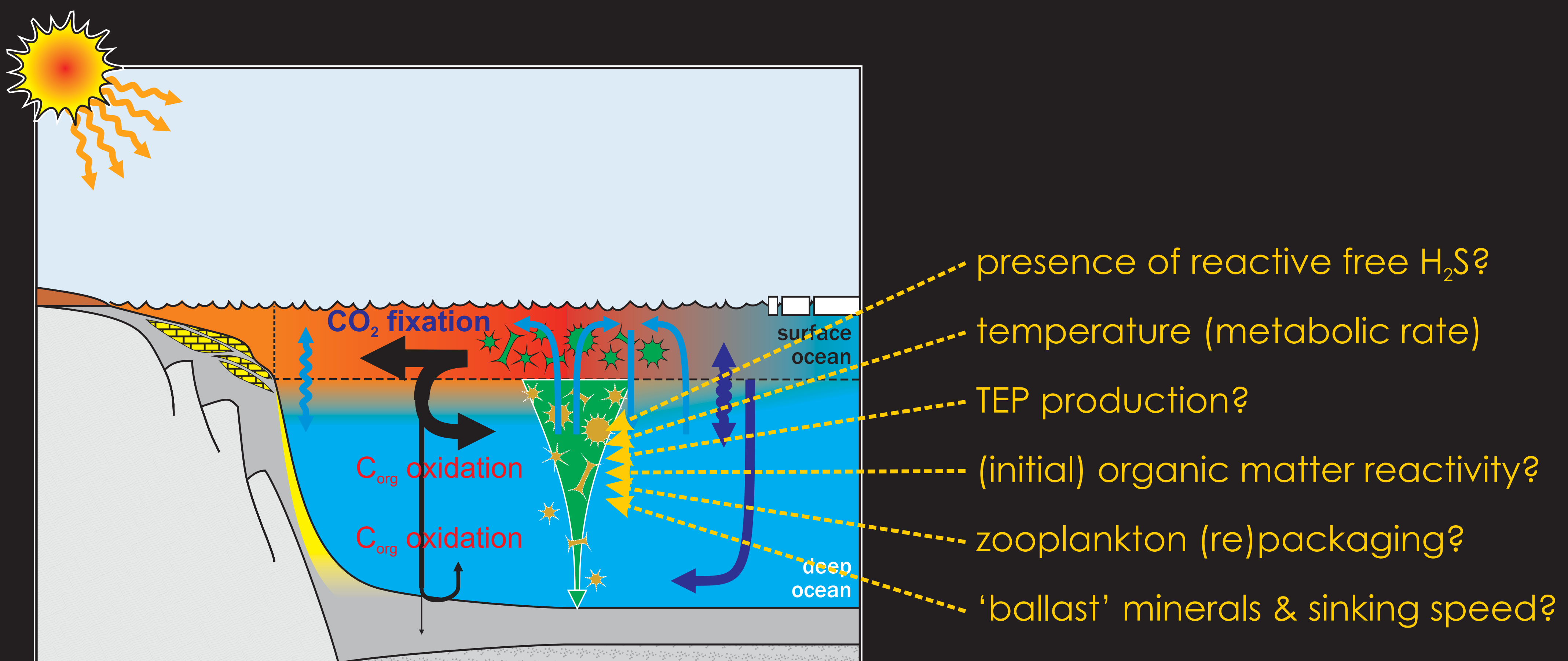






(2) The organic matter (soft-tissue) pump

The efficiency of the biological pump is dictated by the depth at which organic matter is remineralized and carbon (and nutrients) released into the water column together with the large-scale circulation of the ocean which sets the rate and location of carbon (and nutrient) return to the surface.



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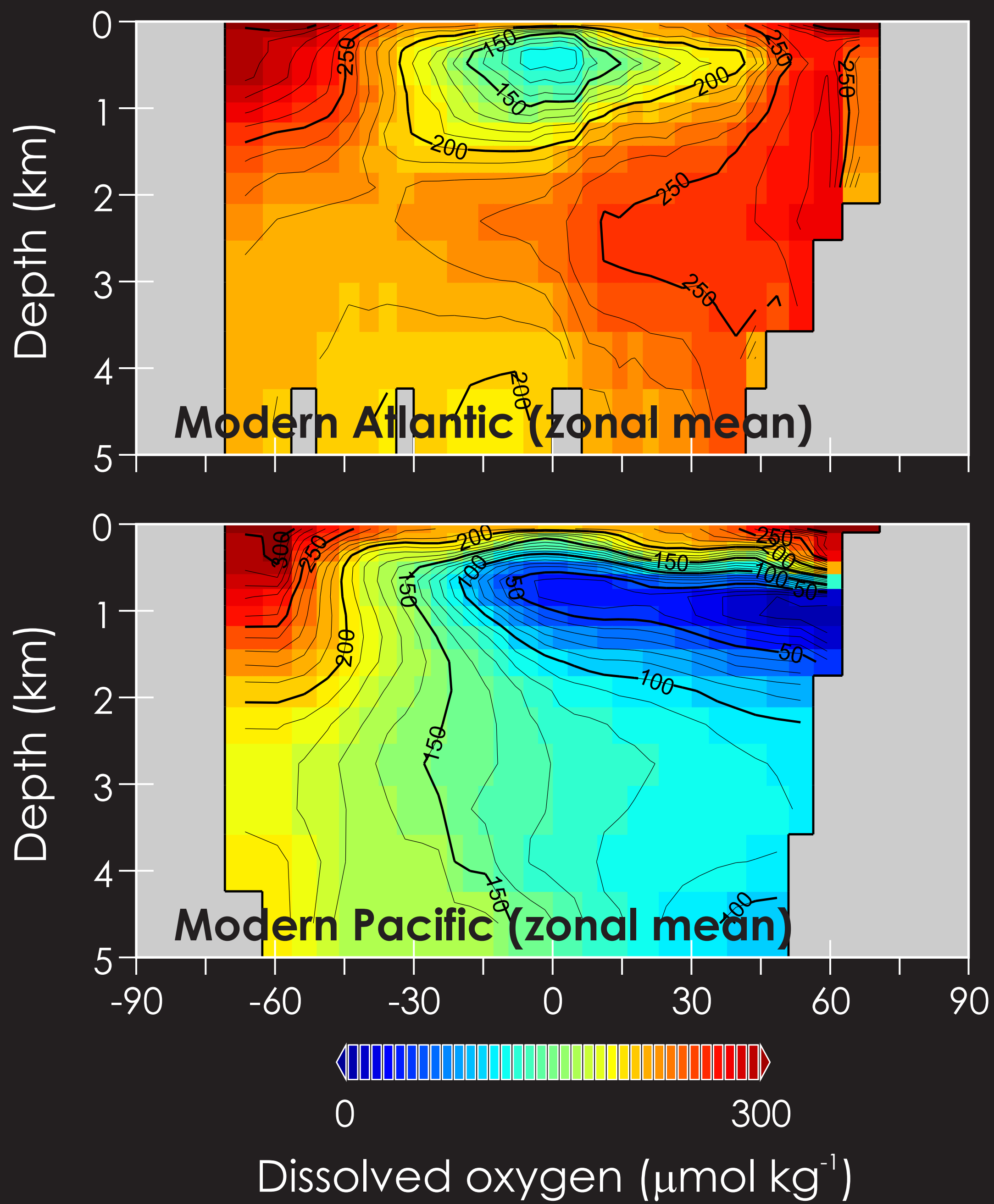
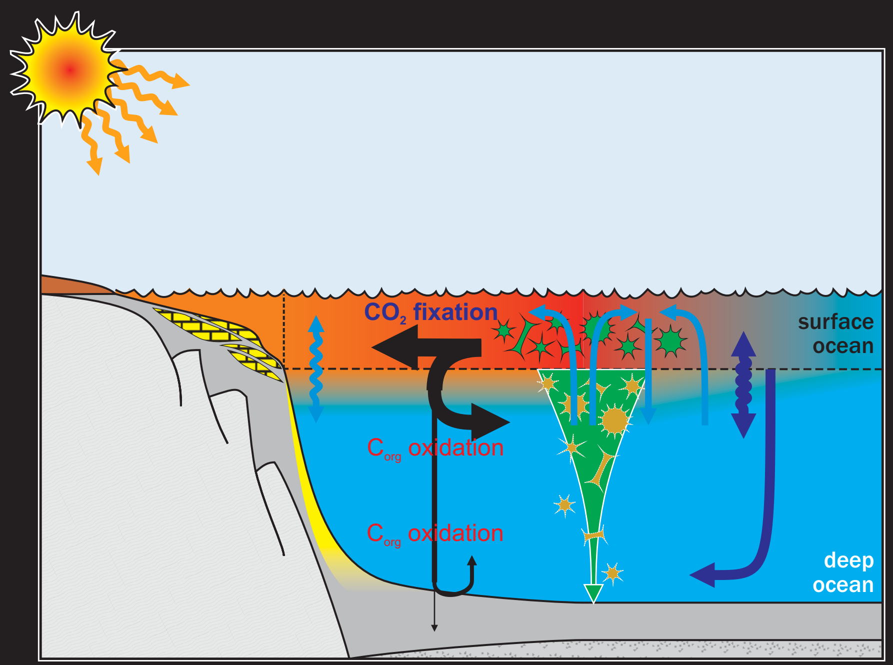
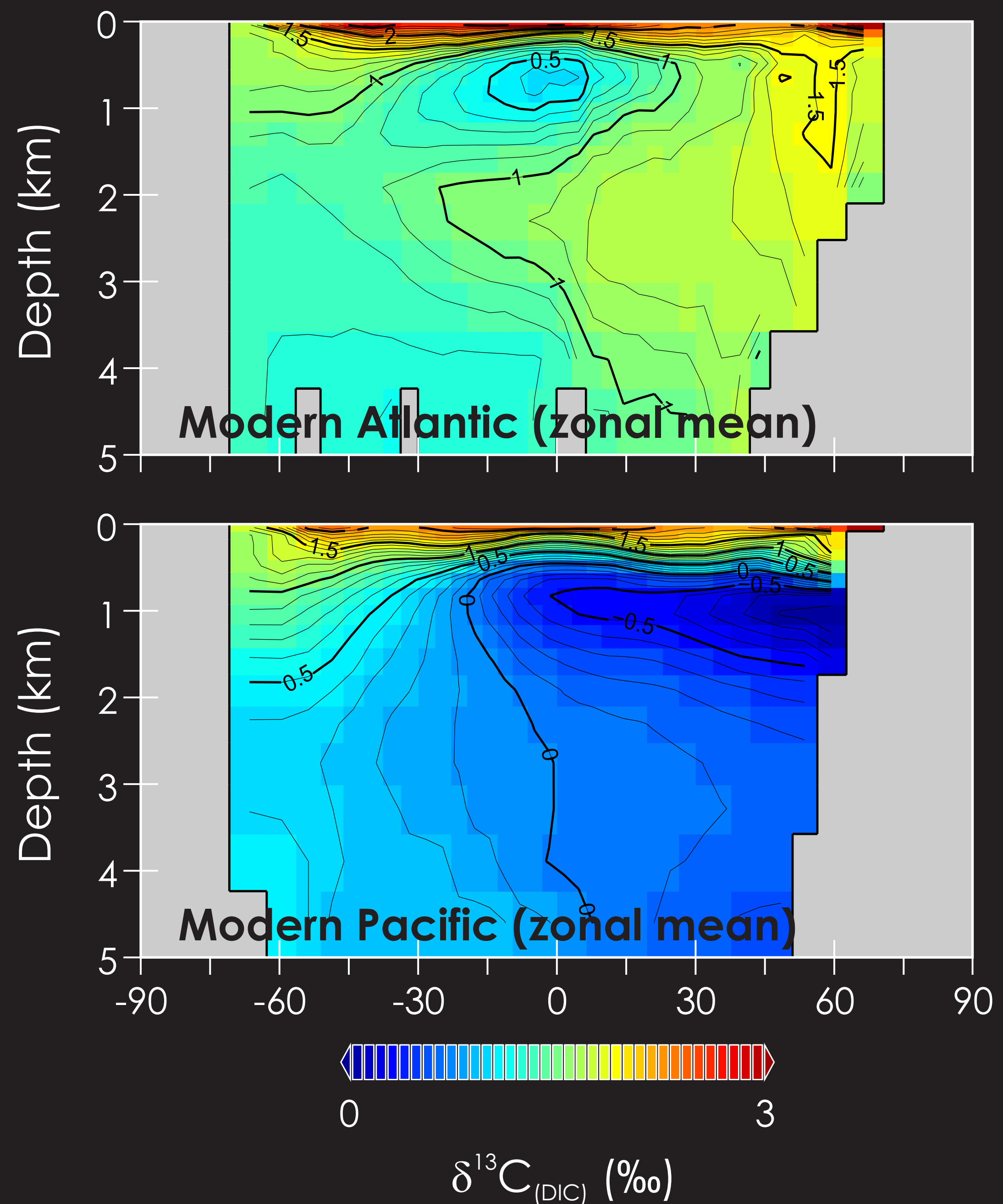
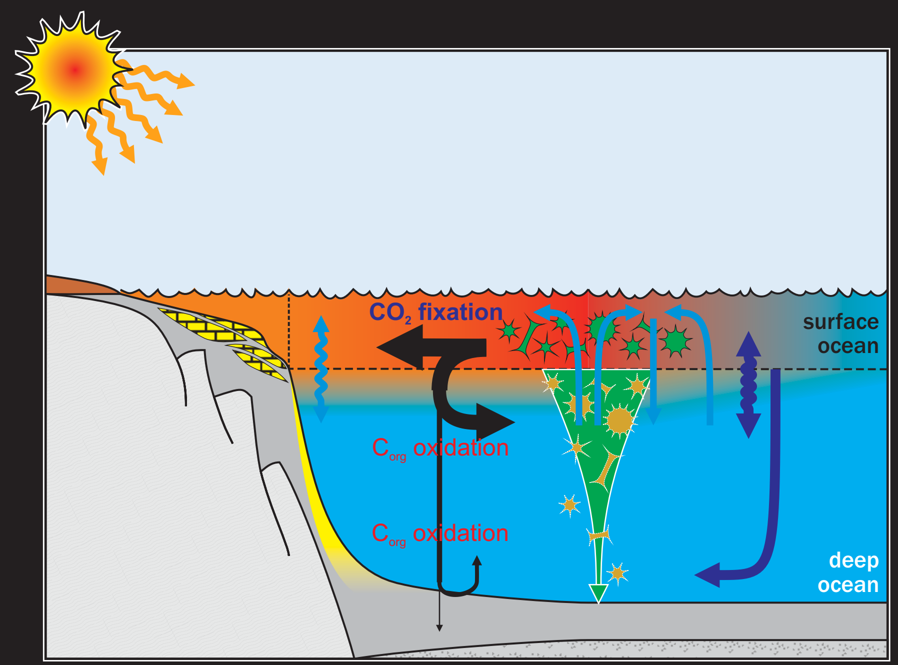


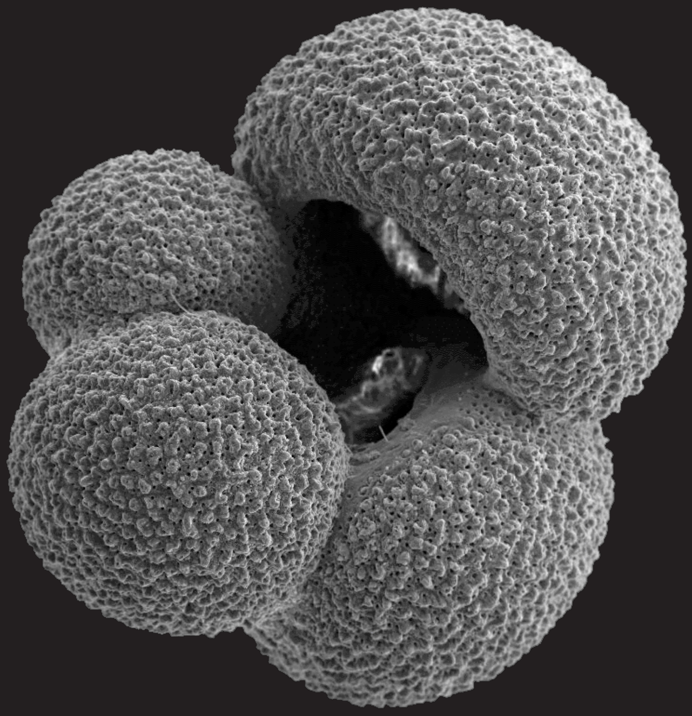


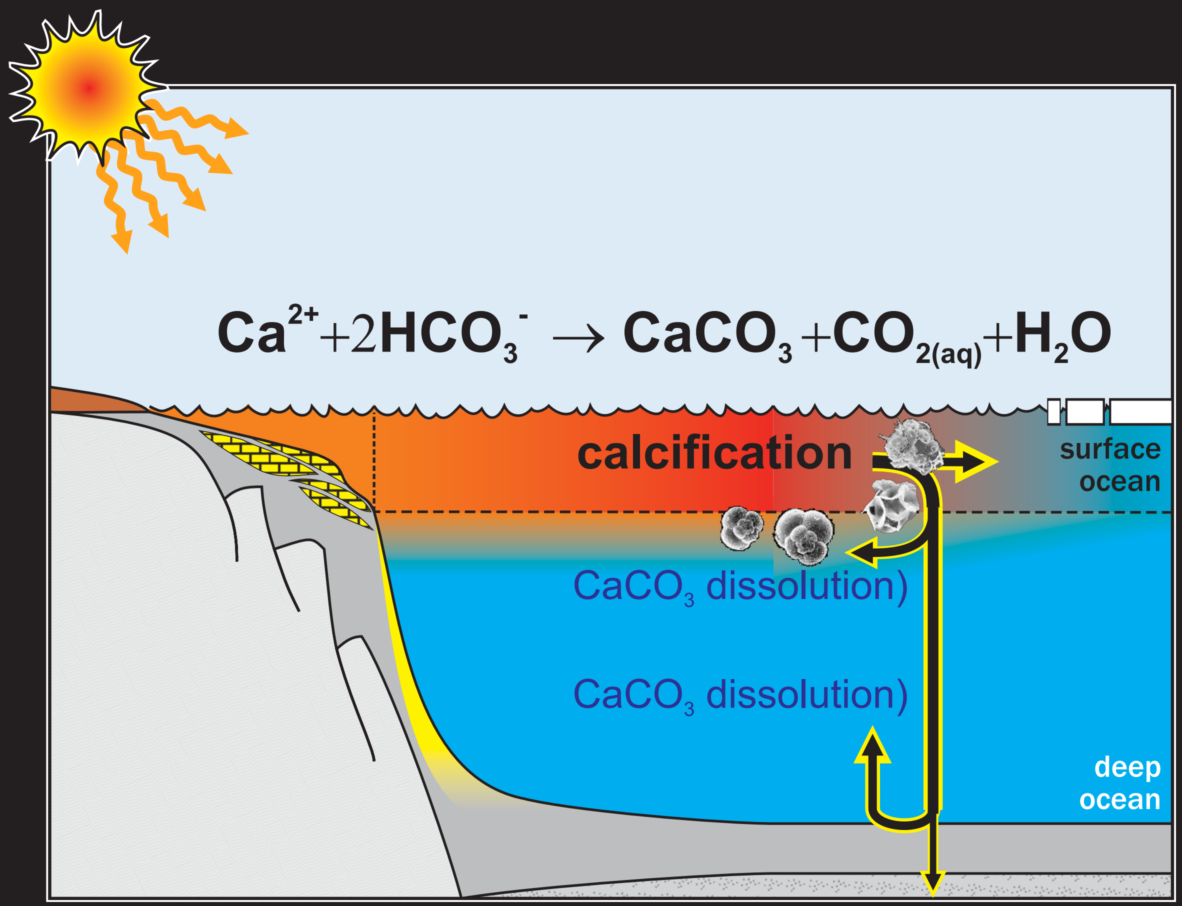
(2) The organic matter (soft-tissue) pump



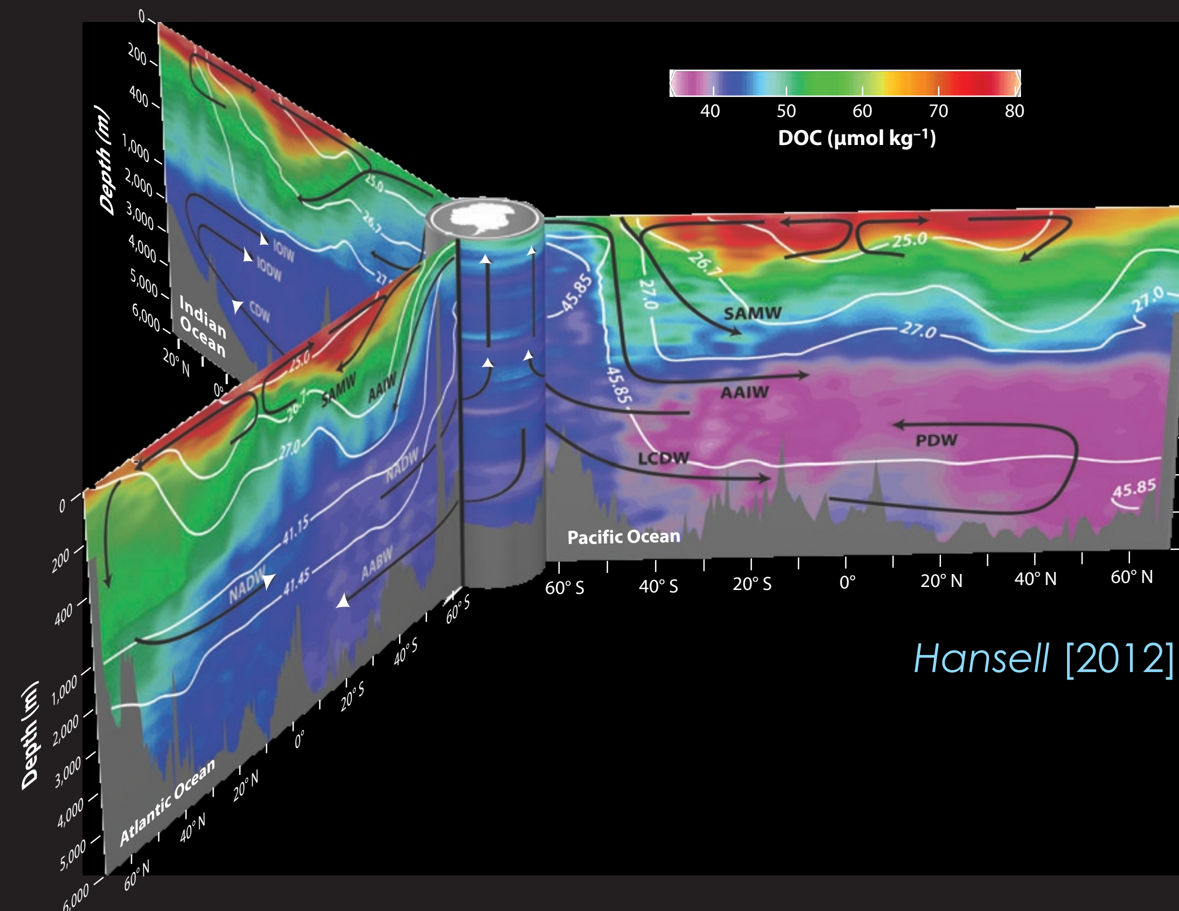


(3) The carbonate pump

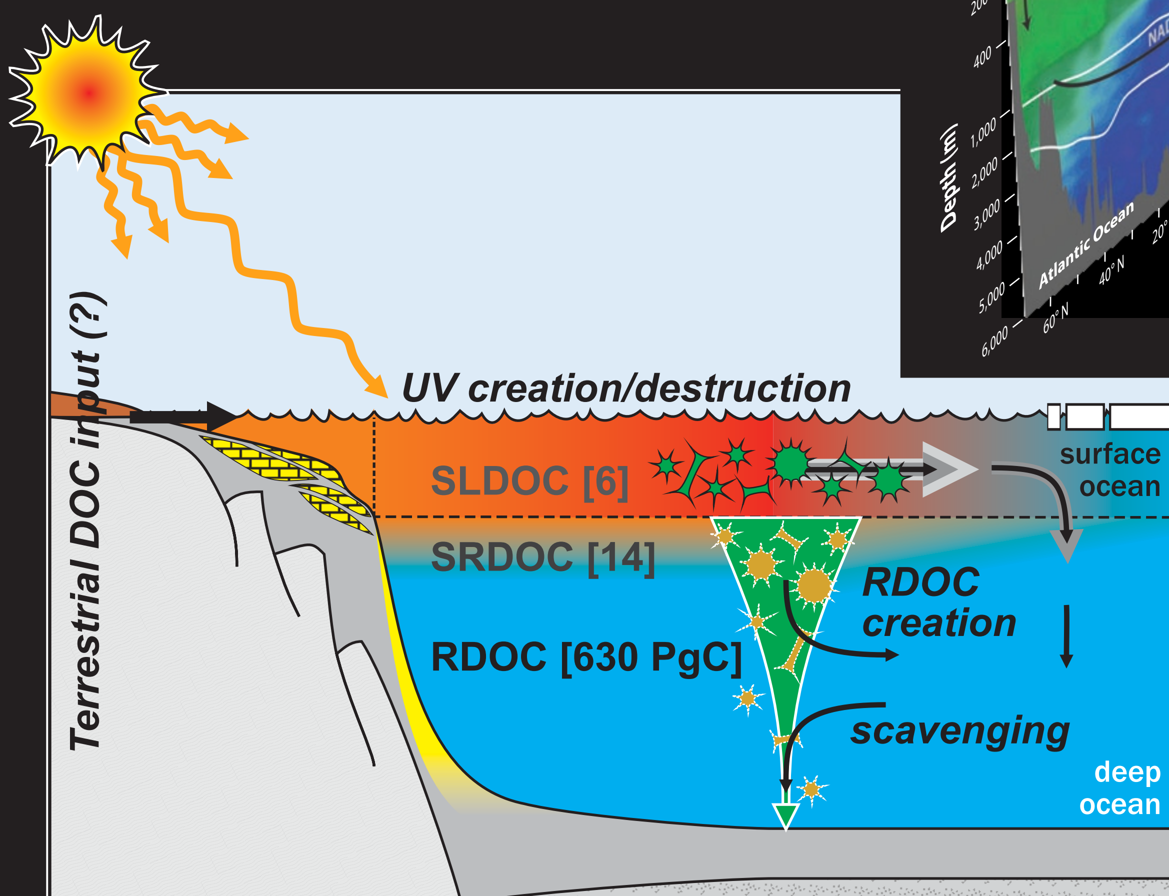




(4) The microbial (dissolved organic) carbon pump

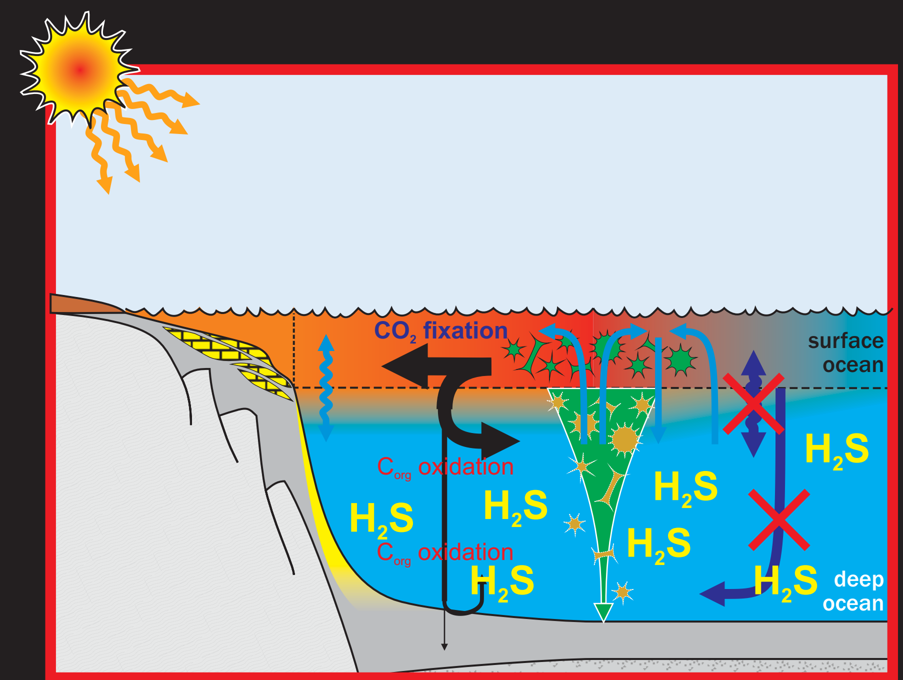


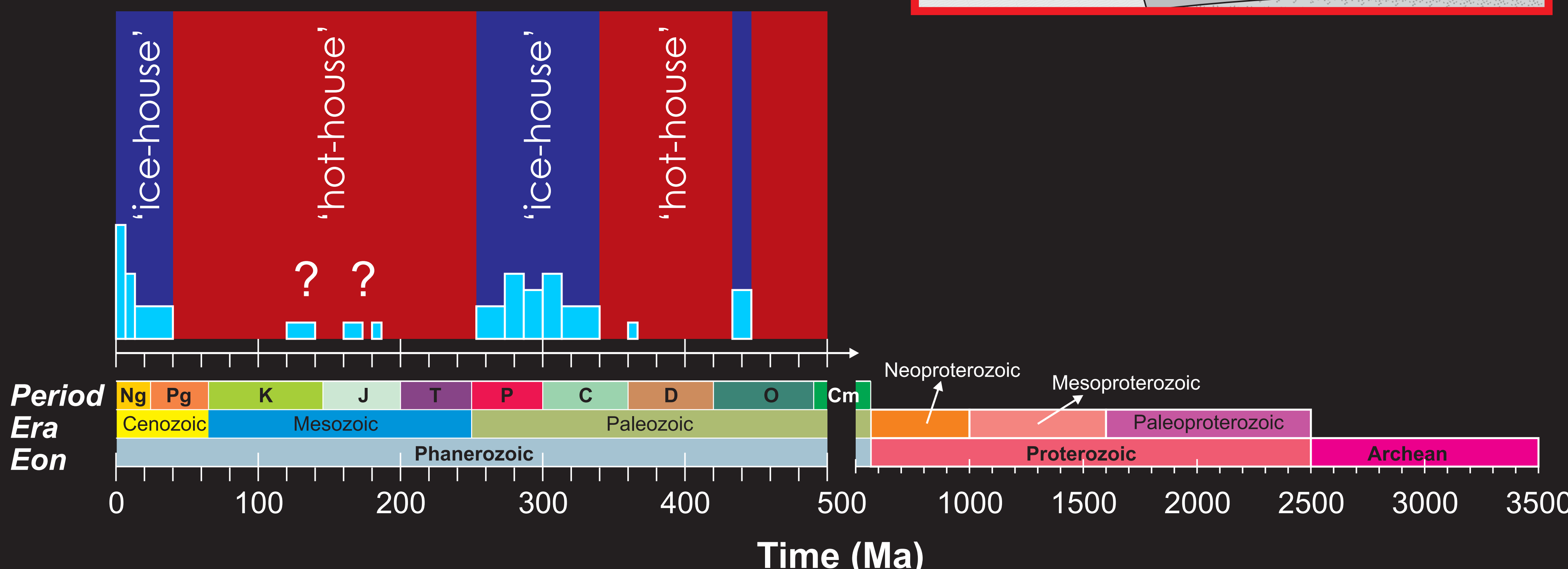
Hansell [2012]



Evolution of the Biological Pump:

The 'stagnant' ocean(?)





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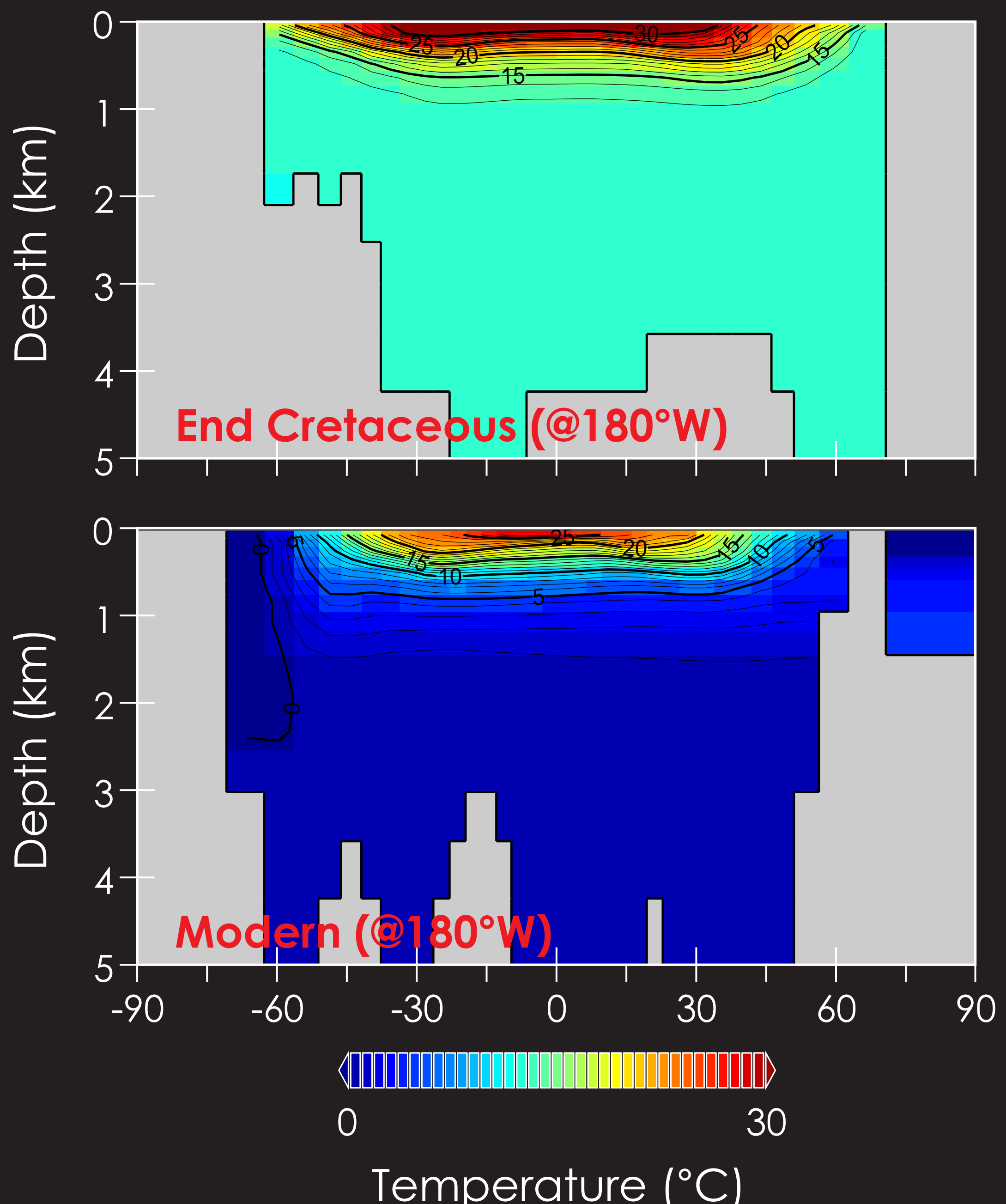

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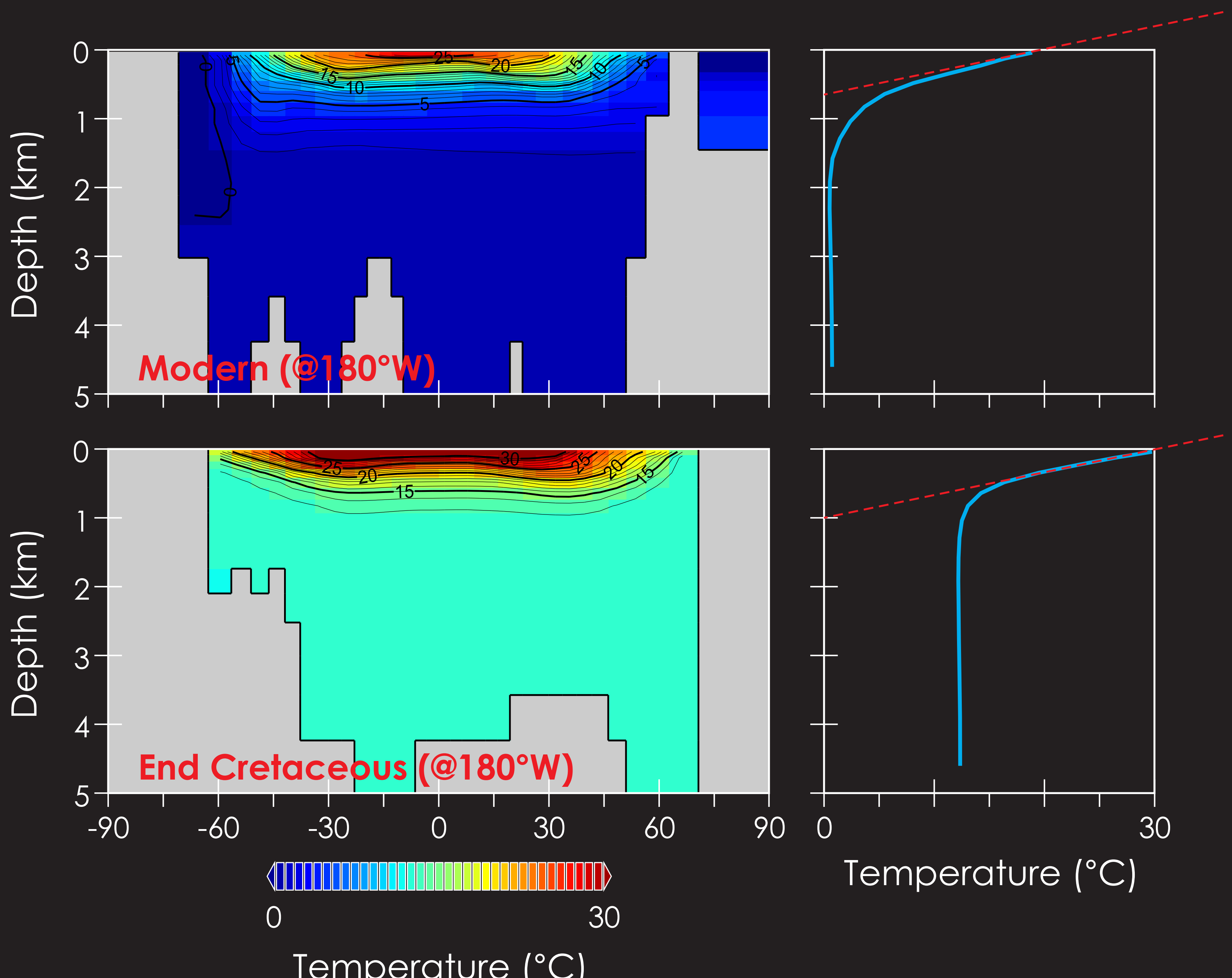
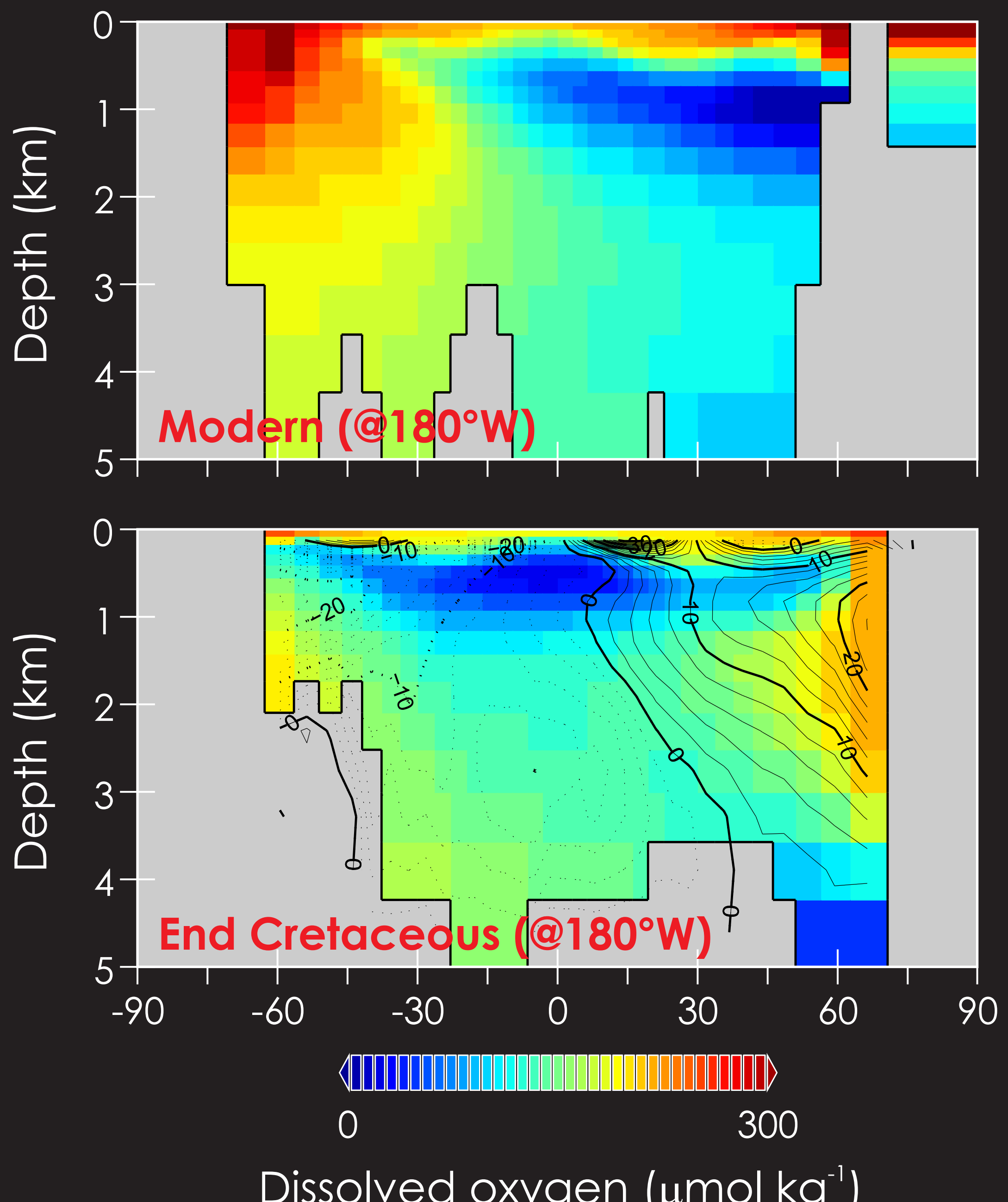
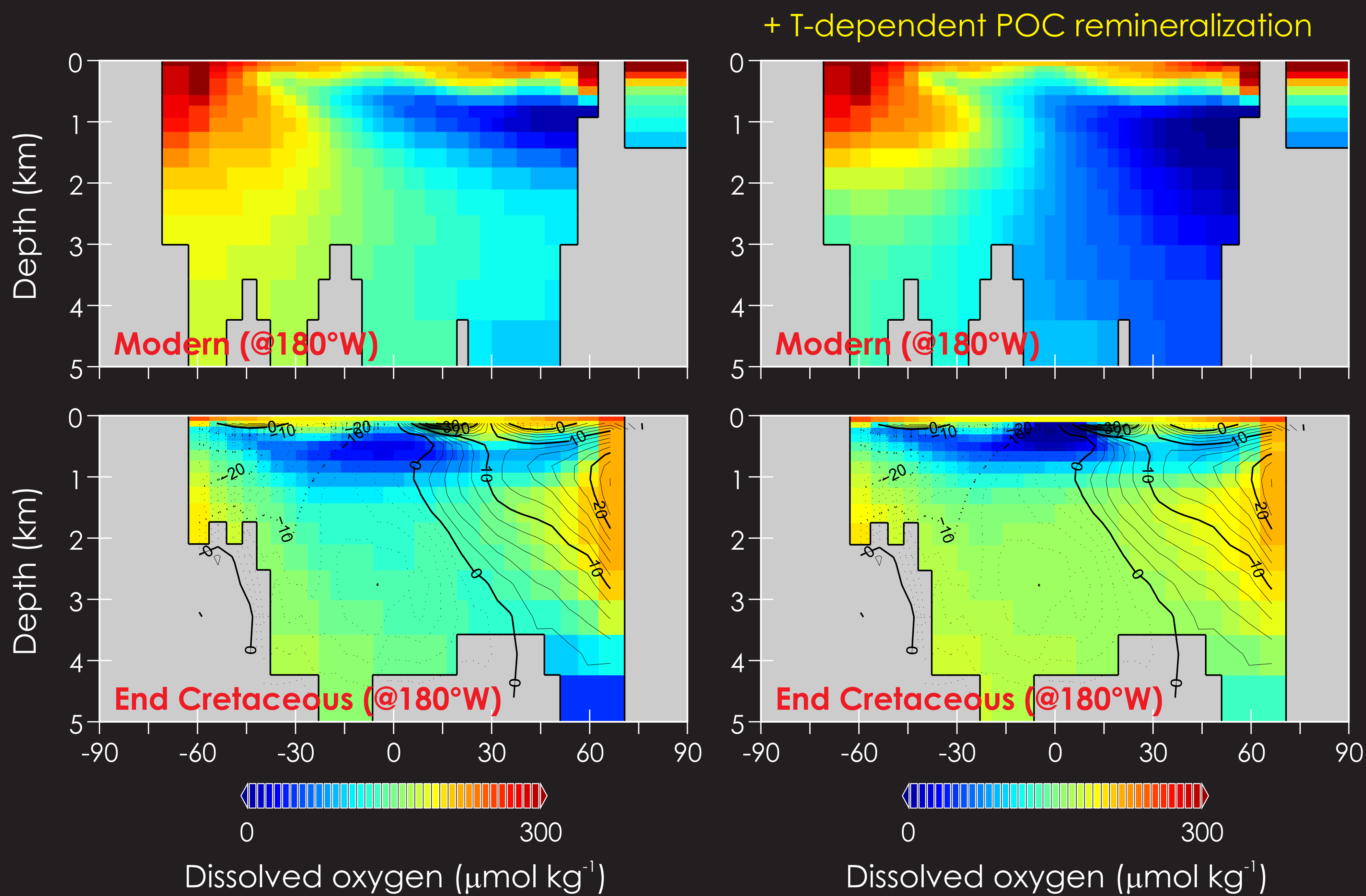


The 'stagnant' ocean(?)



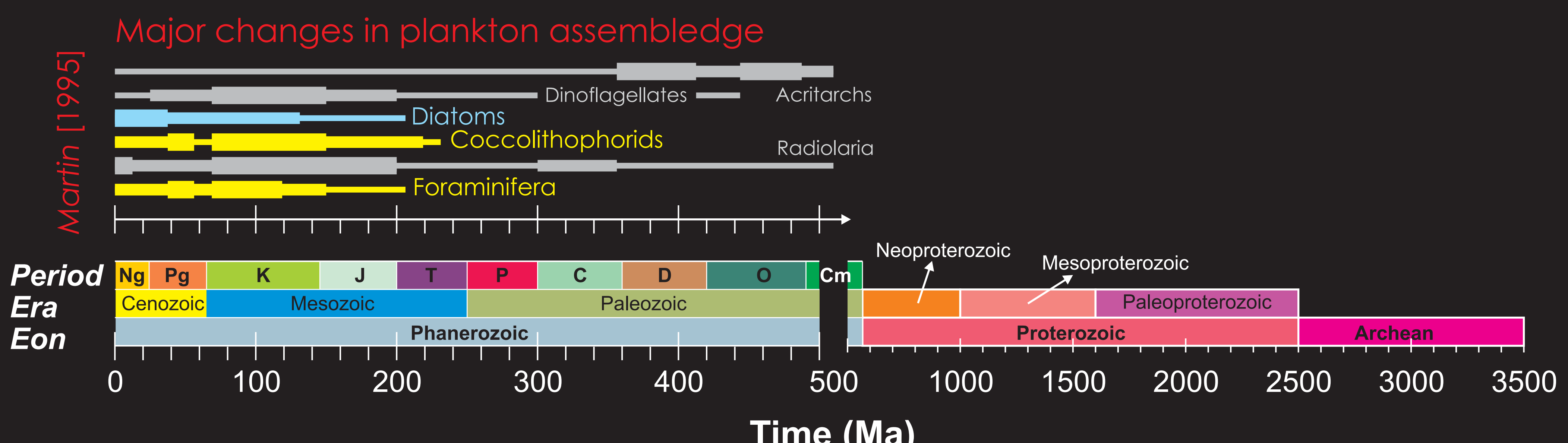
The 'stagnant' ocean(?)

*** see: Eleanor John's talk after lunch ***

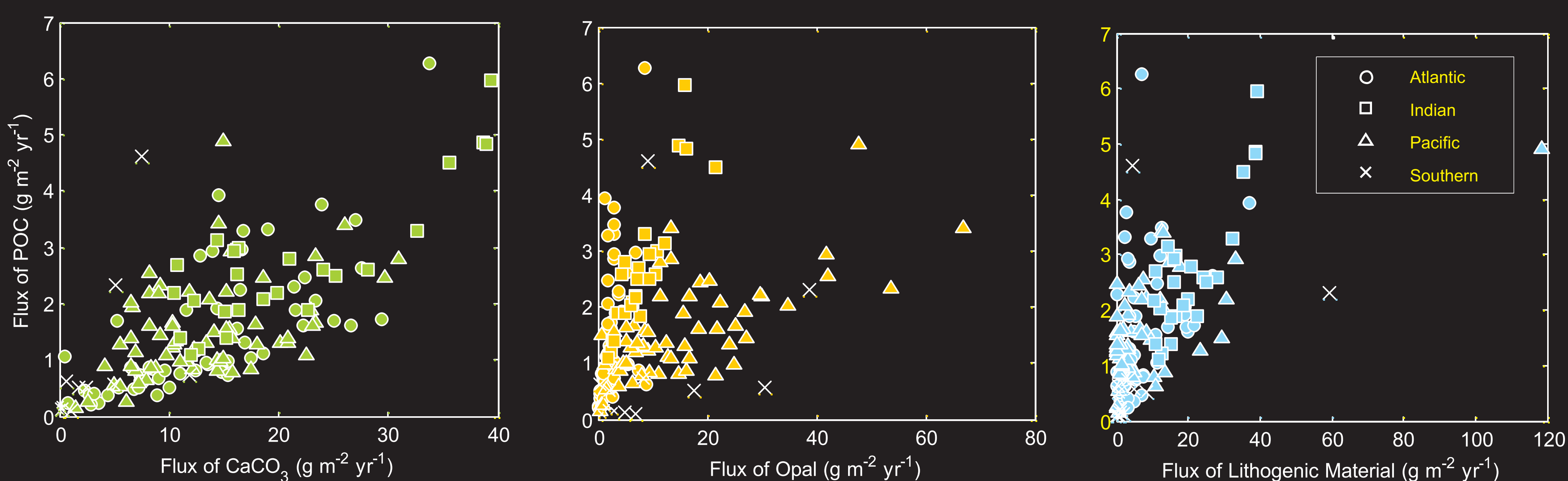


Evolution of the Biological Pump:

Pelagic biomineralizers and the 'ballast hypothesis'

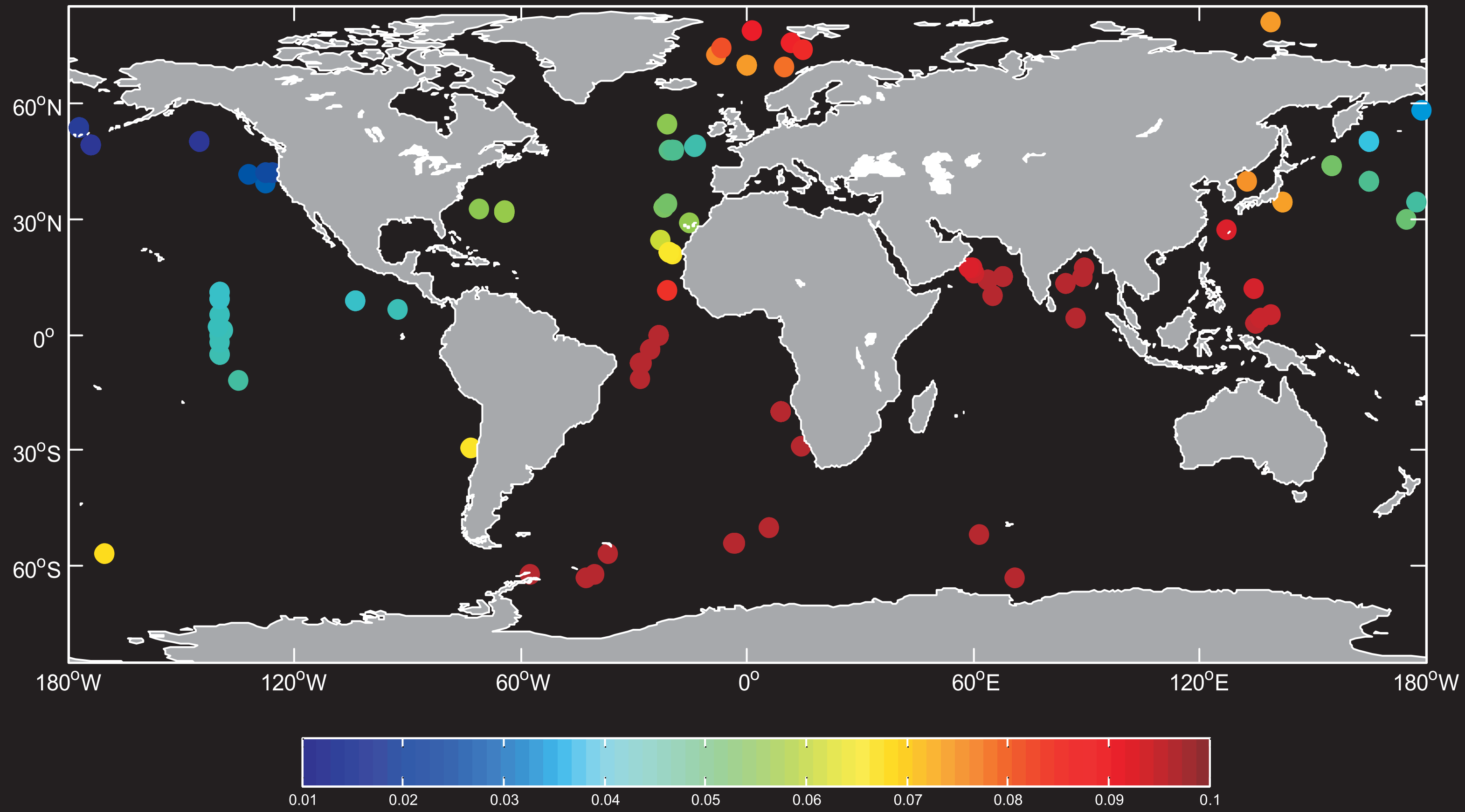


Pelagic biomineralizers and the 'ballast hypothesis'



Wilson et al. [2012]

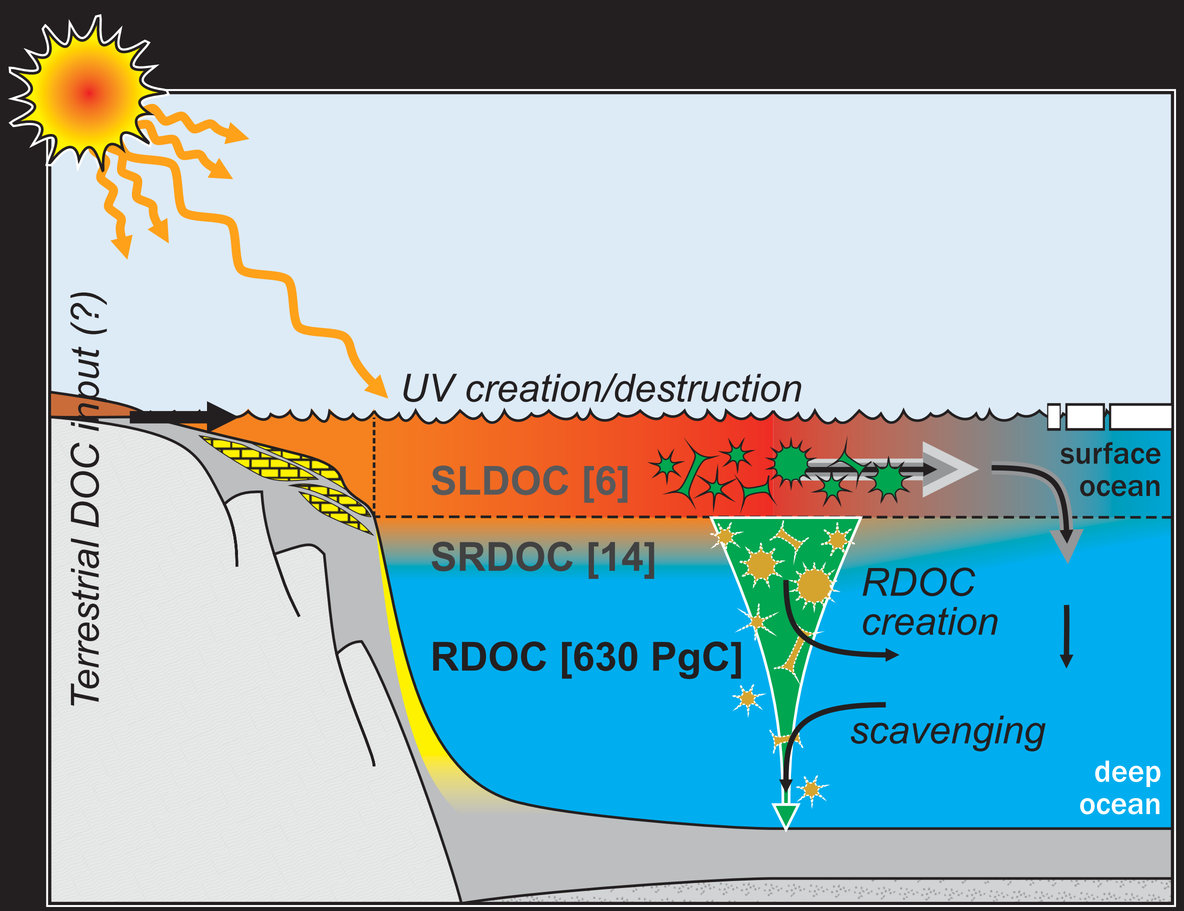
Pelagic biomineralizers and the 'ballast hypothesis'

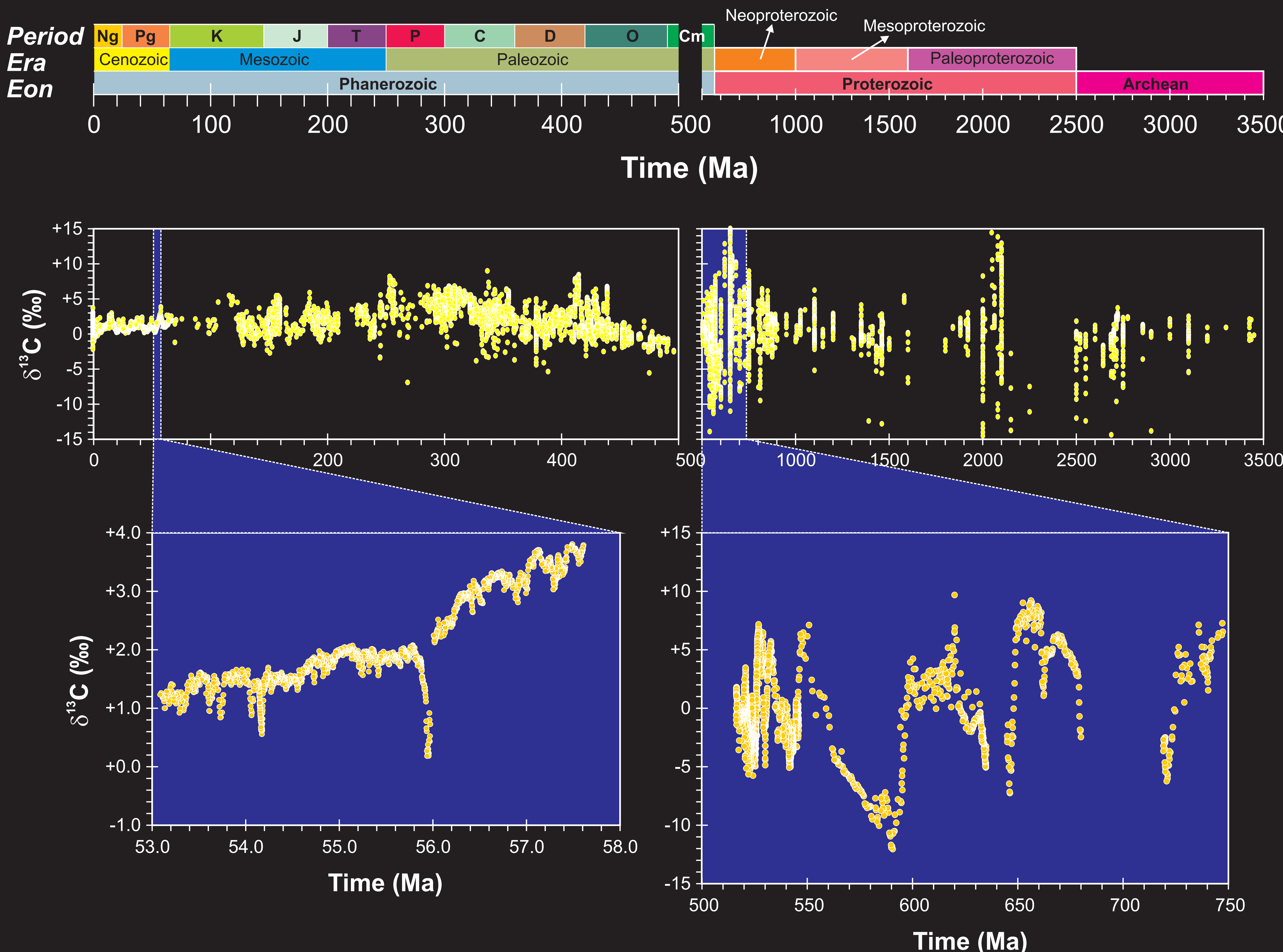


Spatial distribution of carrying capacity (ballasting) coefficients calculated using geographically weighted regression analysis for $CaCO_3$.

Wilson et al. [2012]

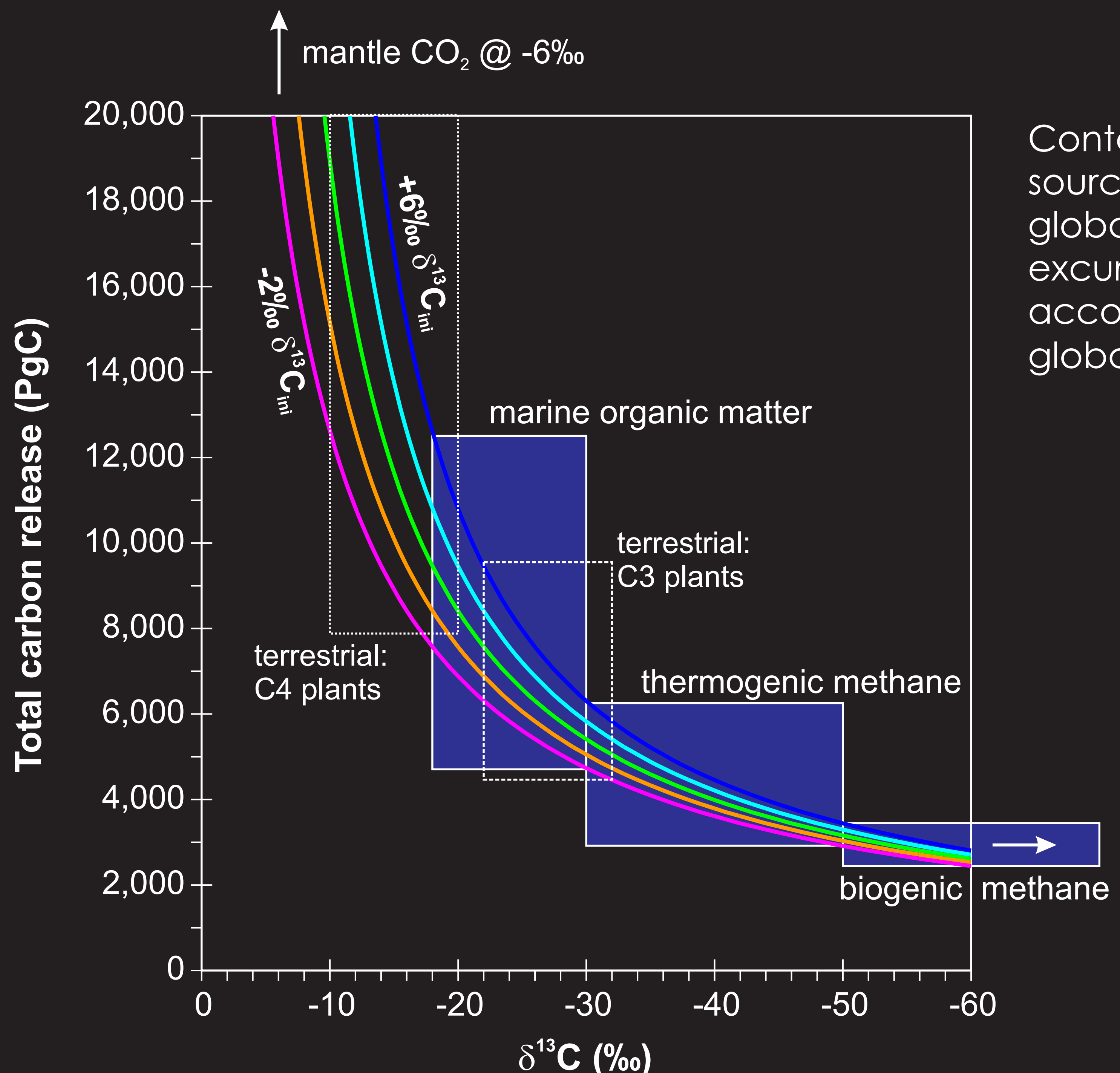
Evolution of the Biological Pump:
A DOC-dominated carbon cycle?





Ridgwell and Arndt [submitted]

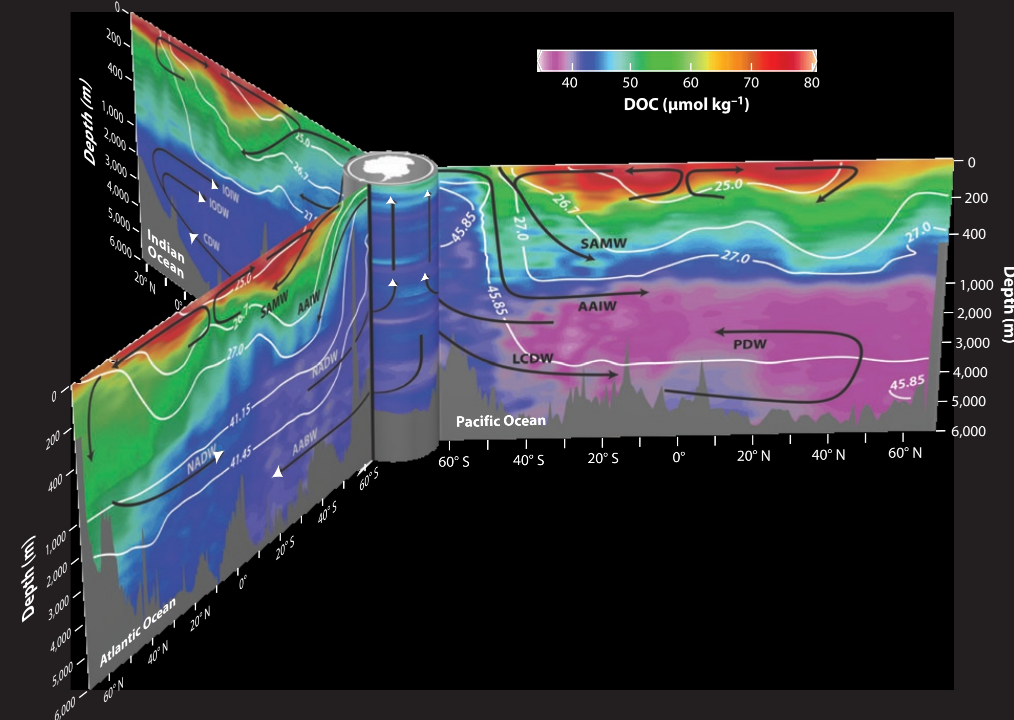
A DOC-dominated carbon cycle?

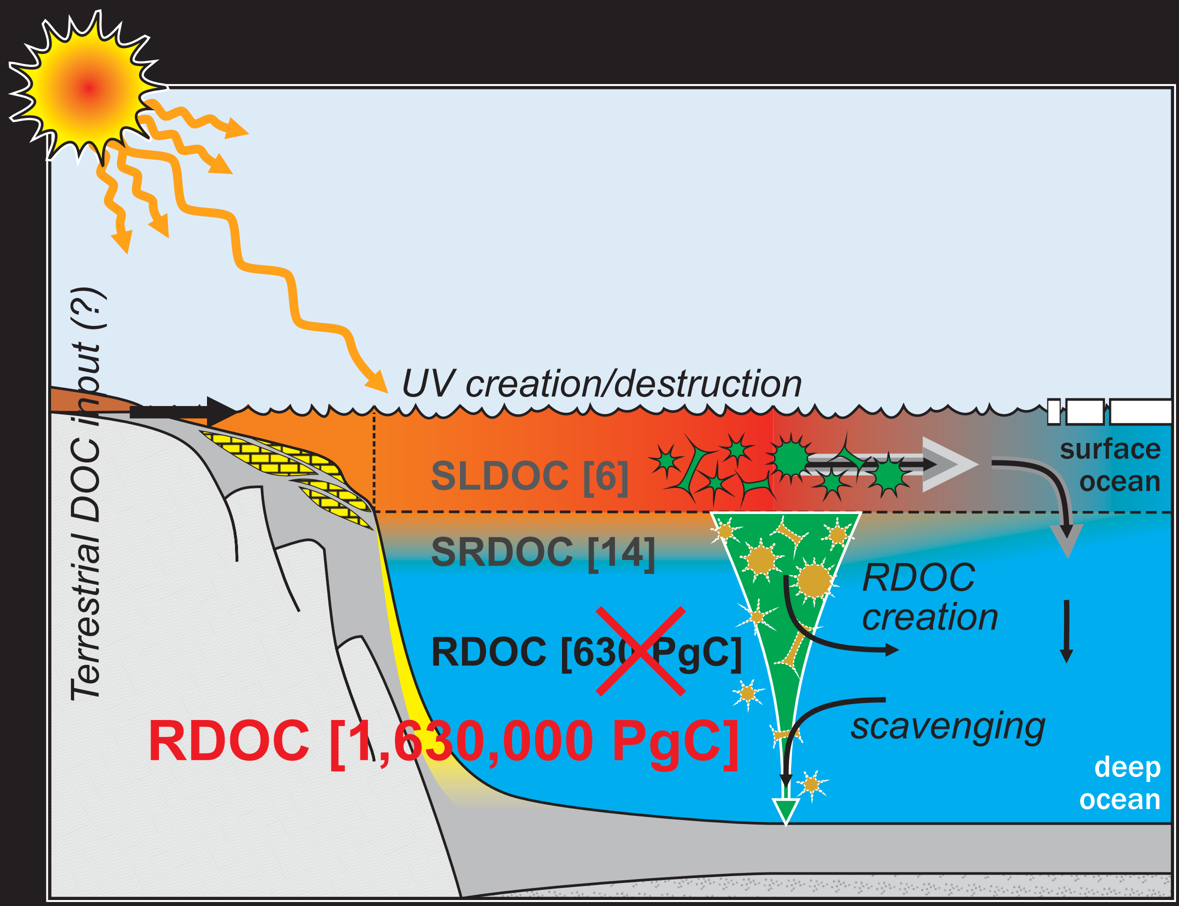


Contours of carbon release vs. source isotopic signature for a global -4‰ carbon isotopic excursion. Contours differ according to the initial mean global δ^{13}C.

Ridgwell and Arndt [submitted]

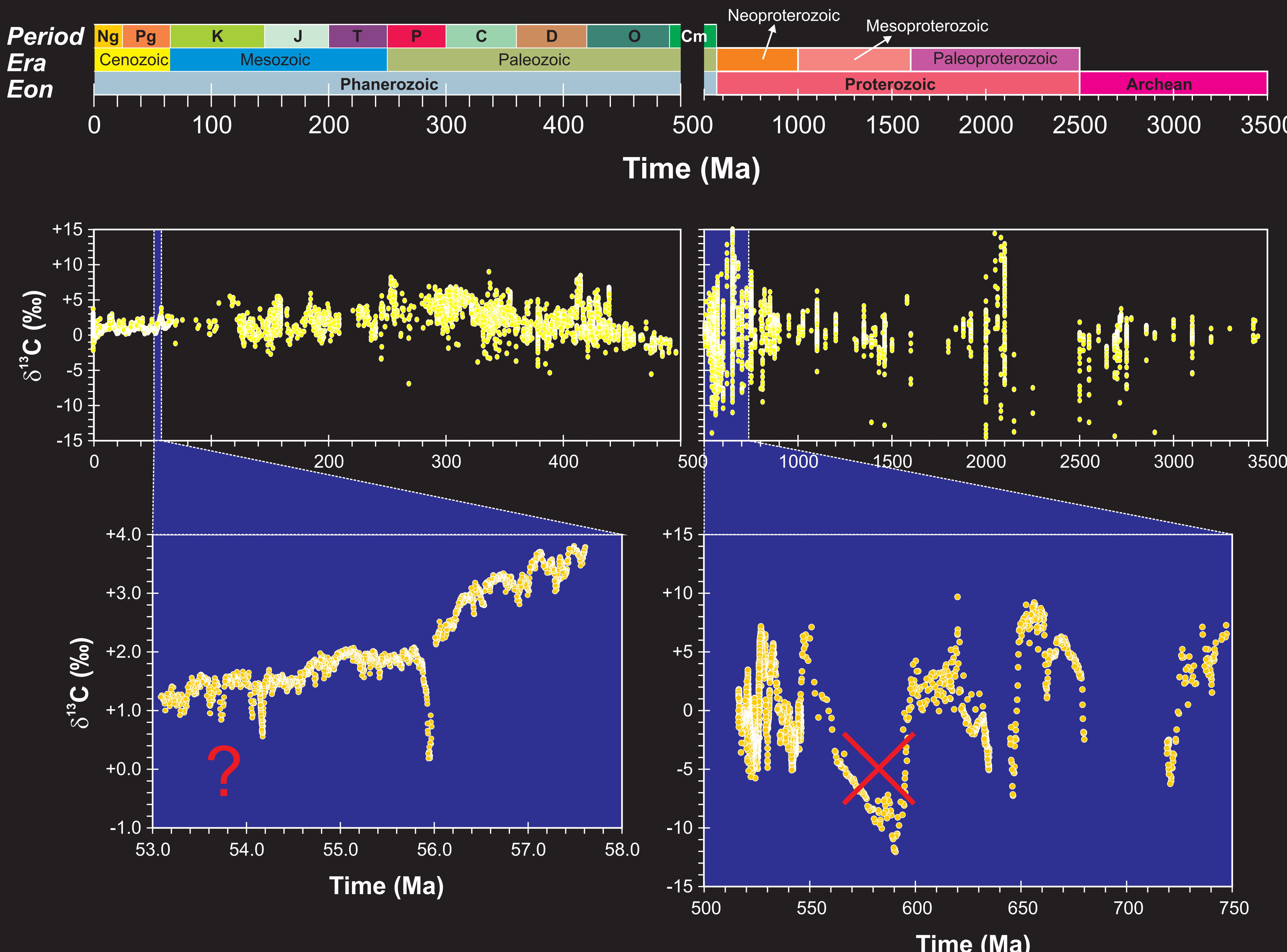
A DOC-dominated carbon cycle?





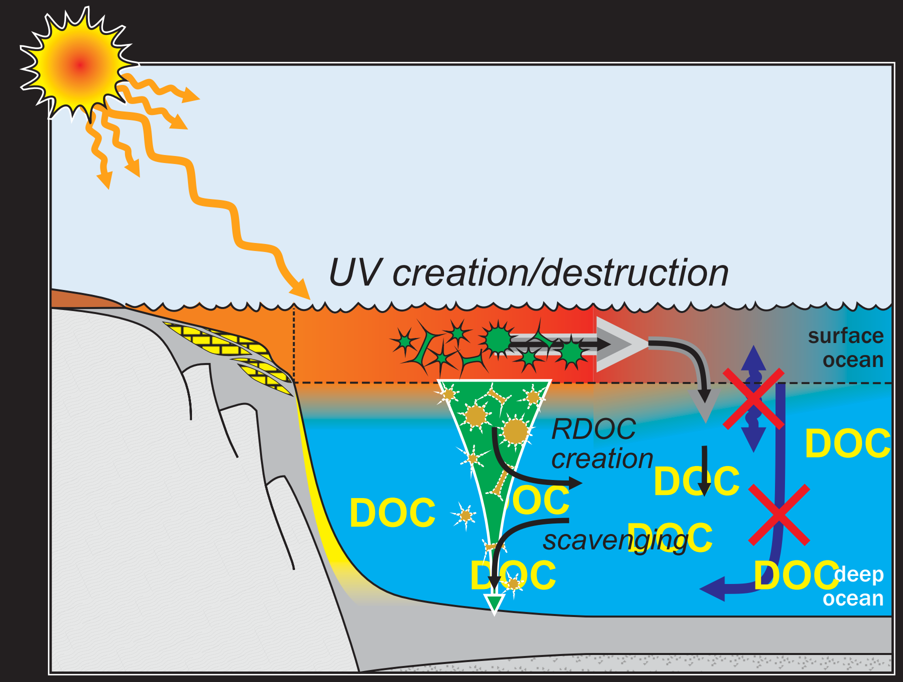
In the *Rothman et al.* [2003] model, the RDOC reservoir is assumed to have been at least 10 times the size of the inorganic (ocean DIC + atmospheric pCO_2) reservoir. For a modern DIC + pCO2 reservoir of 39,000 PgC, this mean 390,000 PgC of DOC – more than 500 times larger than modern). For a higher 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^-.

Ridgwell and Arndt [submitted]

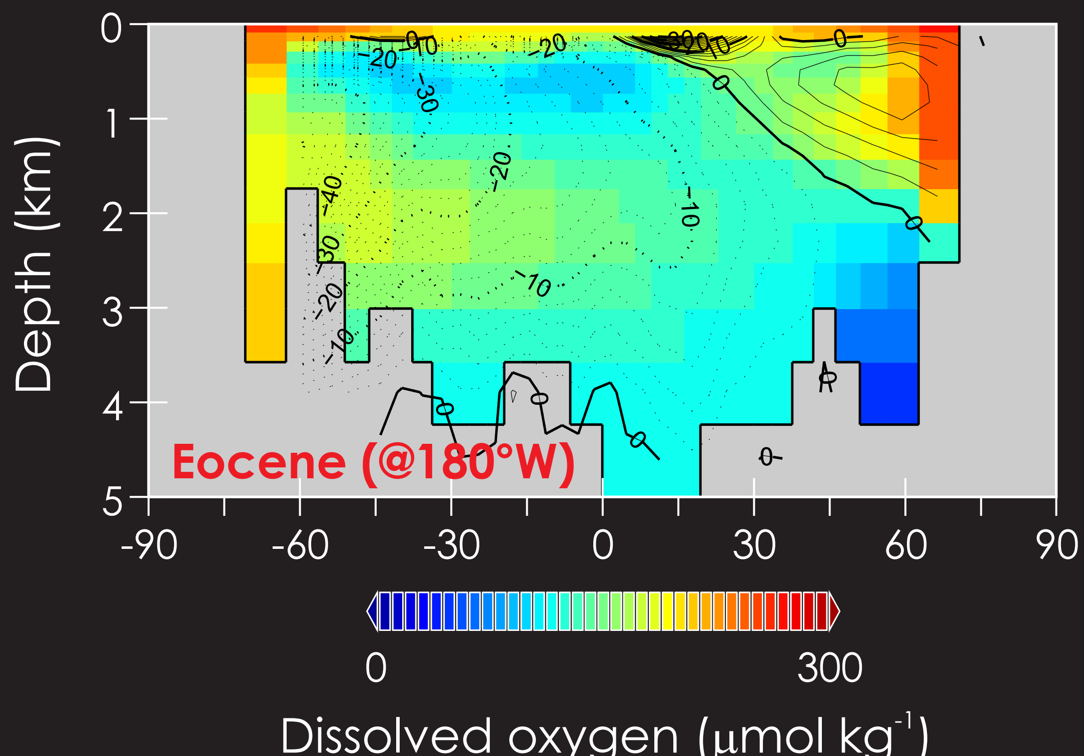


Ridgwell and Arndt [submitted]

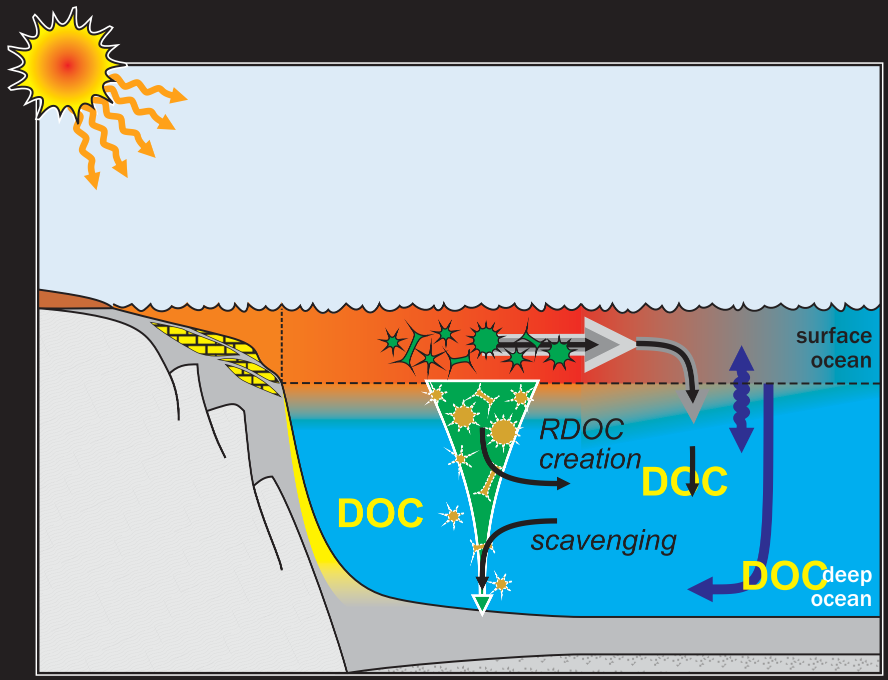
A DOC-dominated carbon cycle?

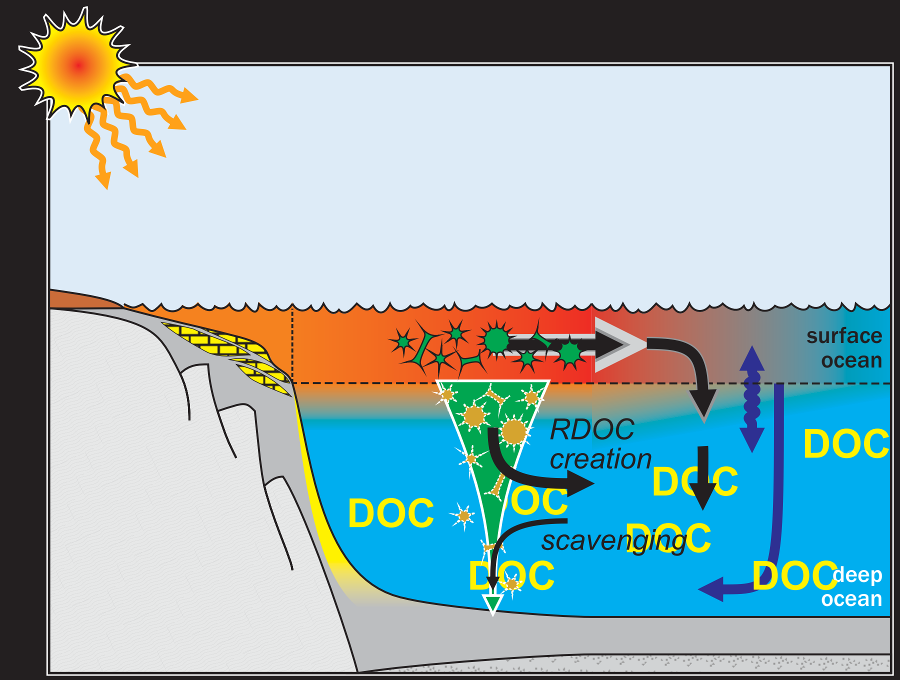


Sexton et al. [2011]

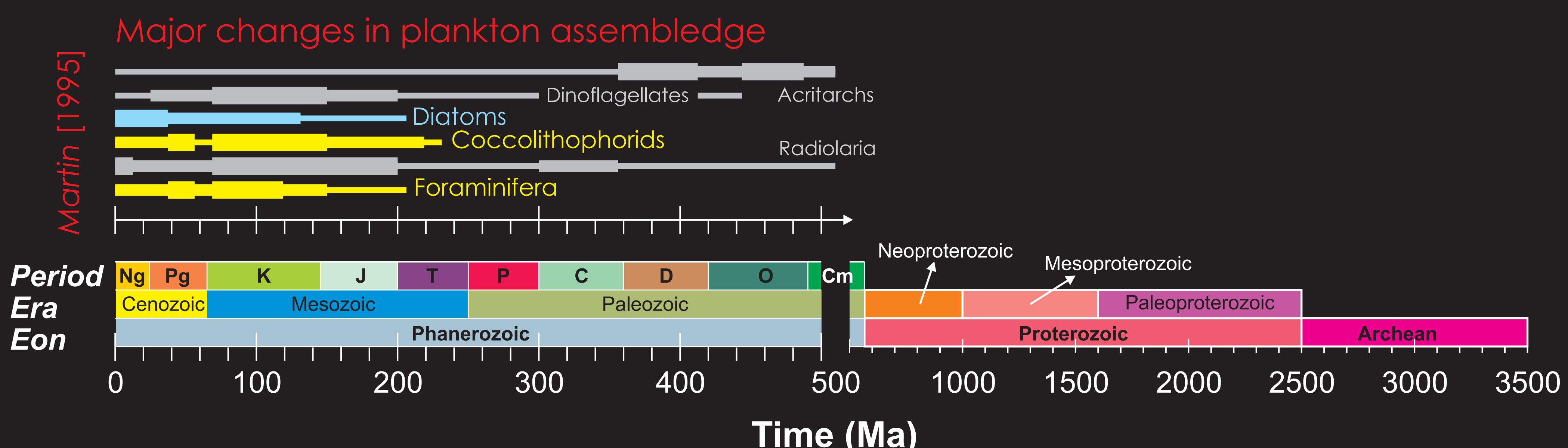


In the Eocene hyperthermal RDOC hypothesis, difficulties include envisioning a sufficiently stratified deep ocean (even when ignoring the lack of any evidence for widespread anoxia) that could partition RDOC away from the upper ocean and destruction by oxidation/photo-dedregation.



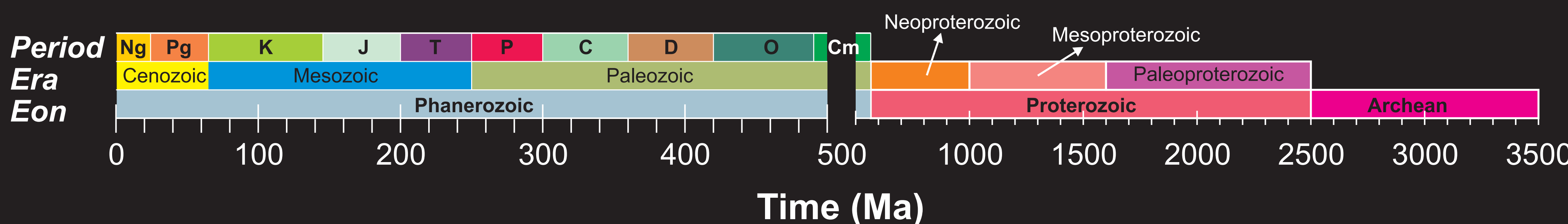


One possibility might be a biotic change that resulted in a drastic reduction in RDOC production. Notably: the (modern) decay time of RDOC – ca. 10 kyr – is consistent with the time-scale of PETM onset.

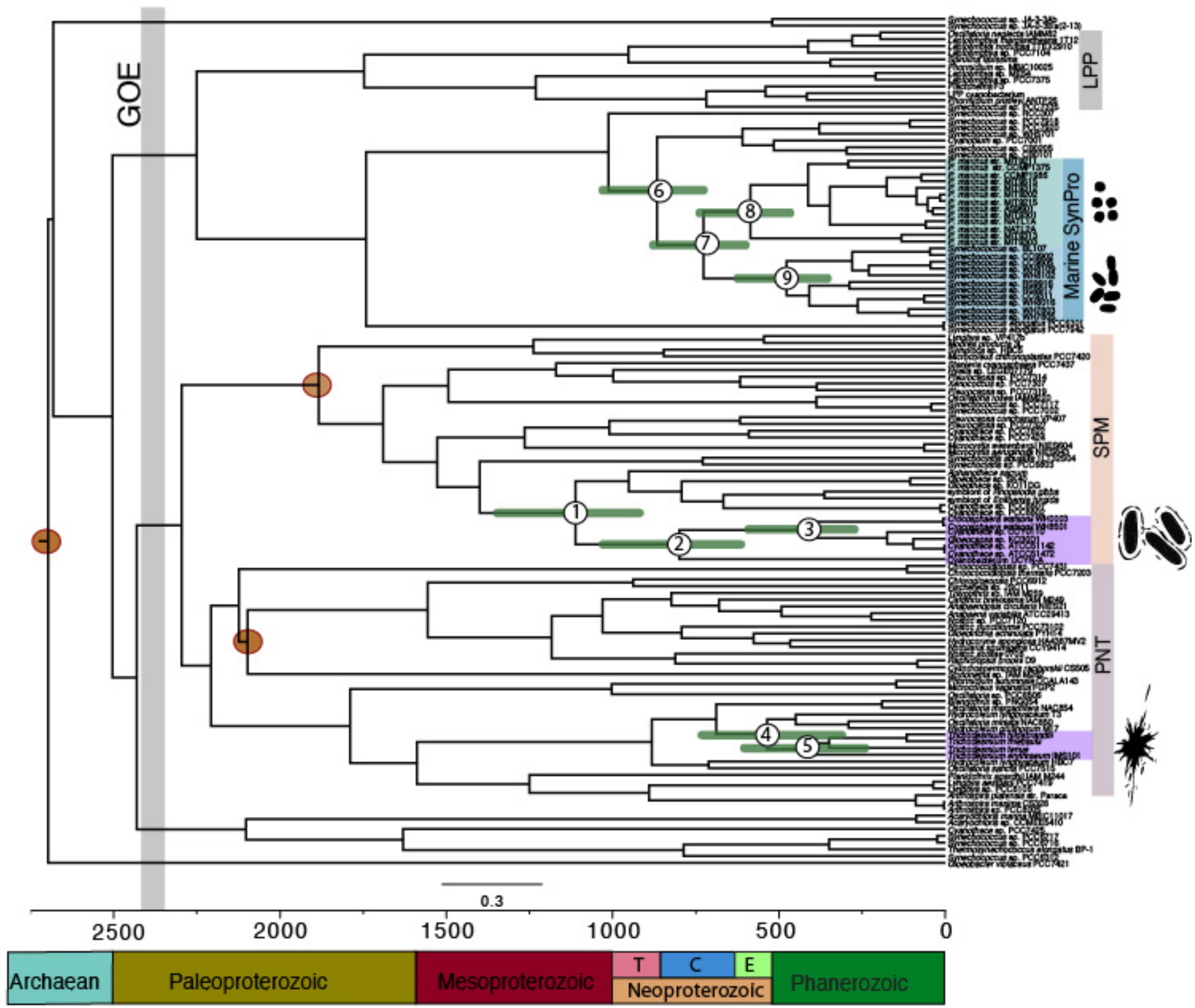


Evolution of the Biological Pump:

Beginnings

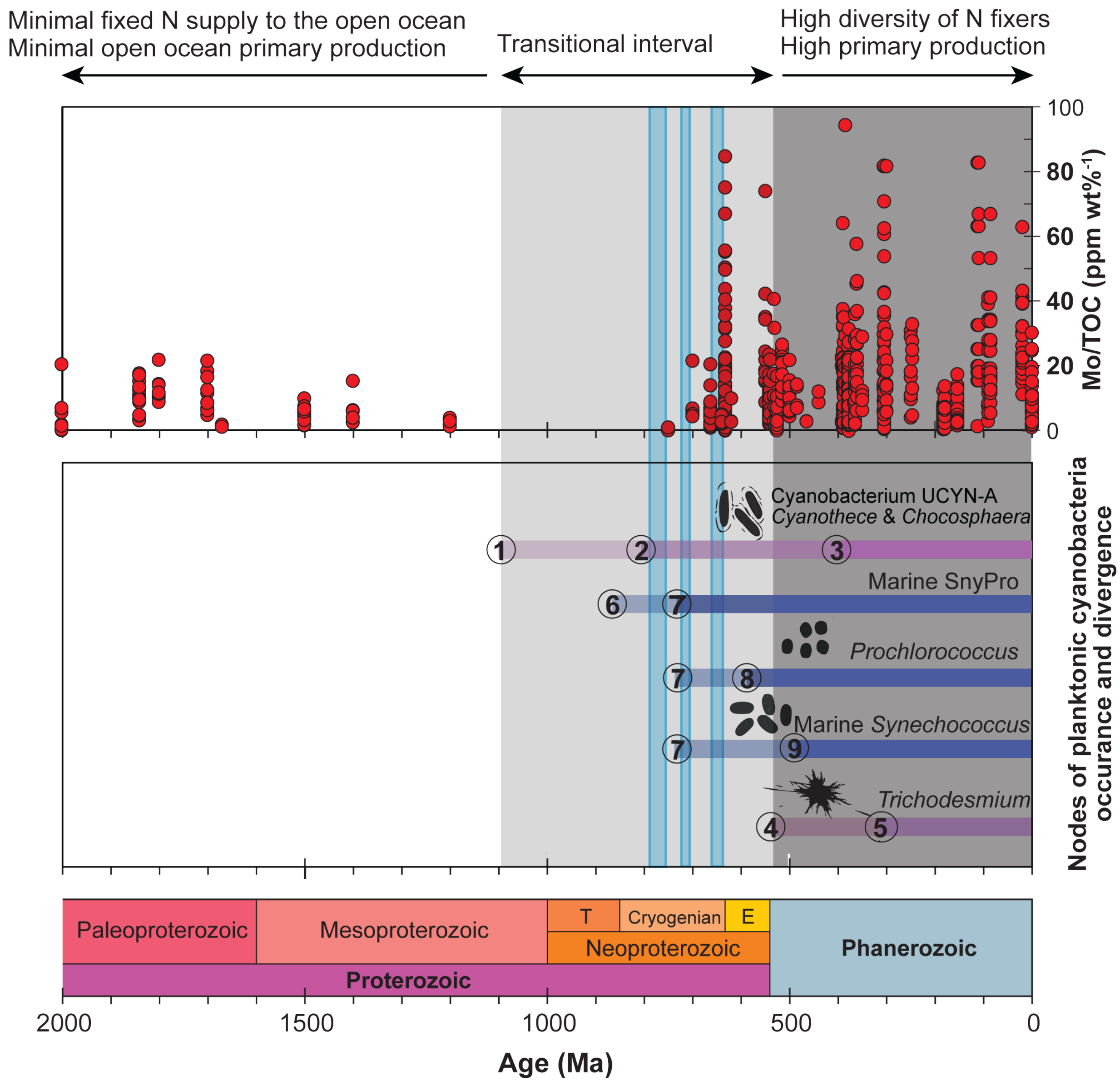


Phylogeny of cyanobacteria - marine planktonic



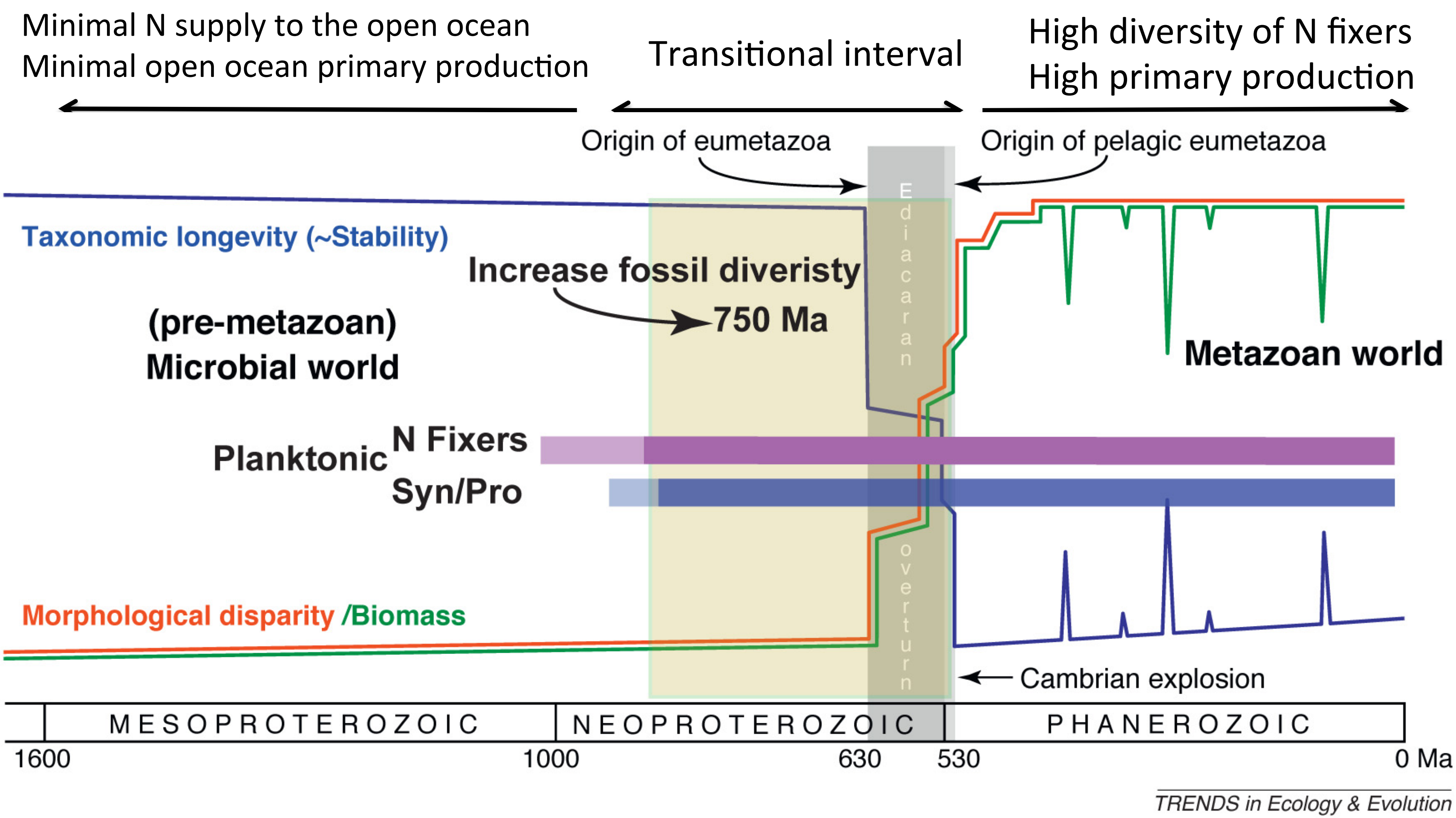
Sanchez-Baracaldo et al. *Submitted*

Marine planktonic cyanobacteria and Molybdenum record



Sahoo et al (2012); Sanchez-Baracaldo et al *submitted*

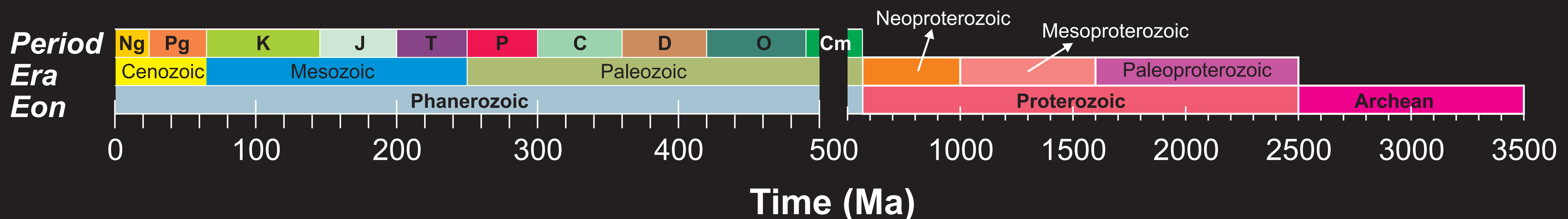
Biological pump during the boring billion?



Butterfield (2011)

Evolution of the Biological Pump:

Summary (of sorts)

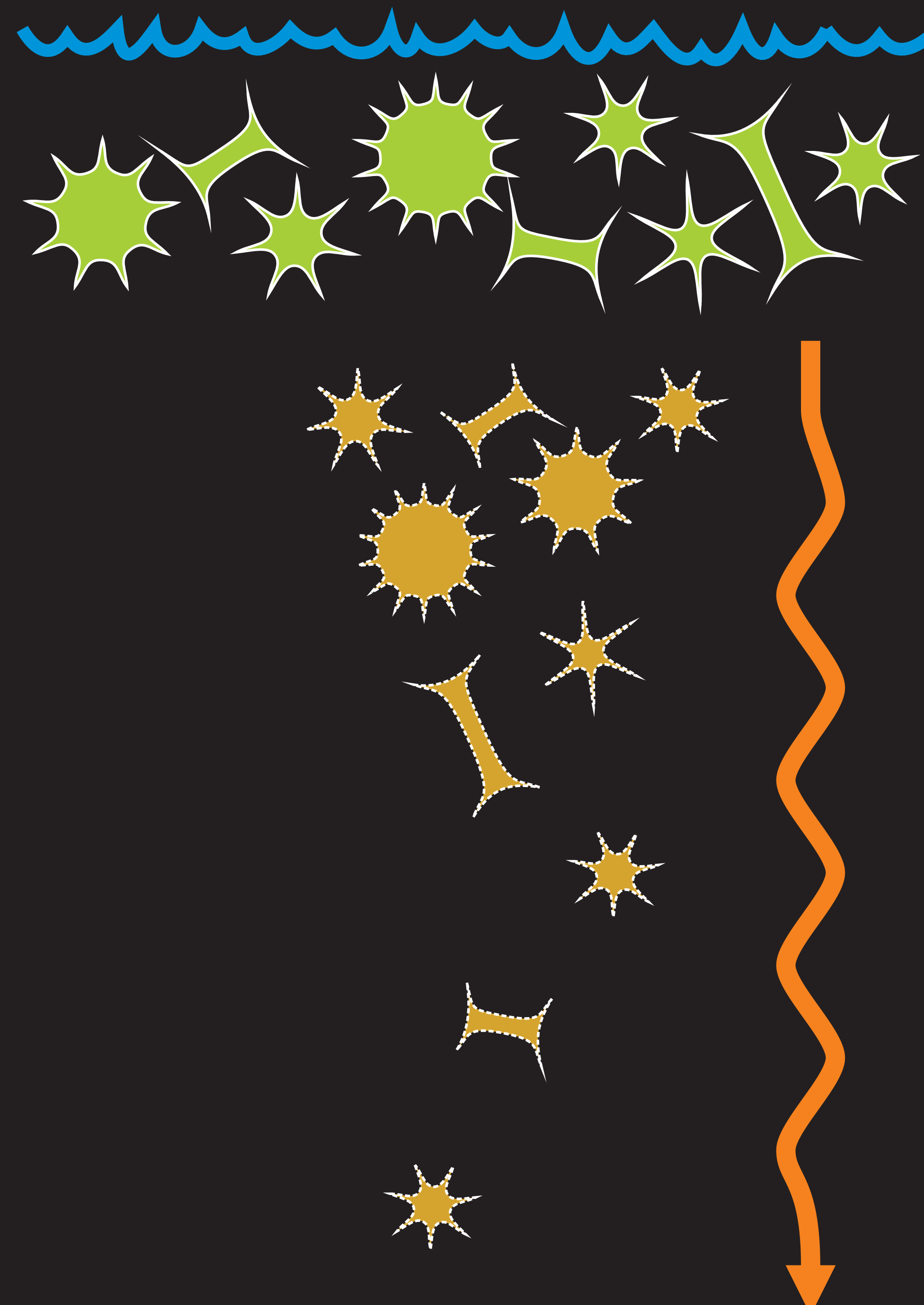


Thanks to:

Jamie Wilson & Steve Barker [Cardiff]

Patricia Sanchez-Baracaldo [Bristol]

Eleanor John, Paul Pearson [Cardiff]



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