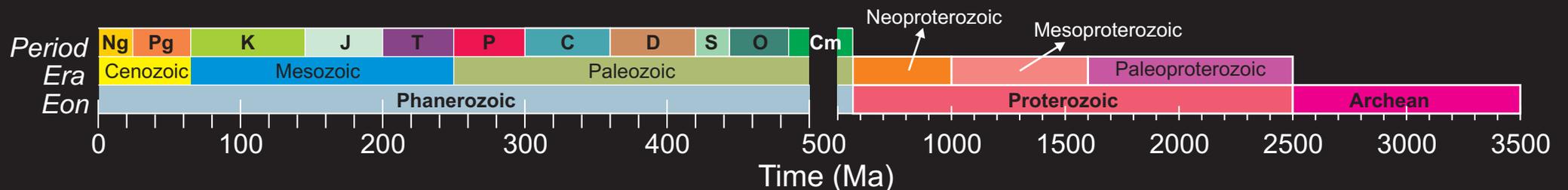


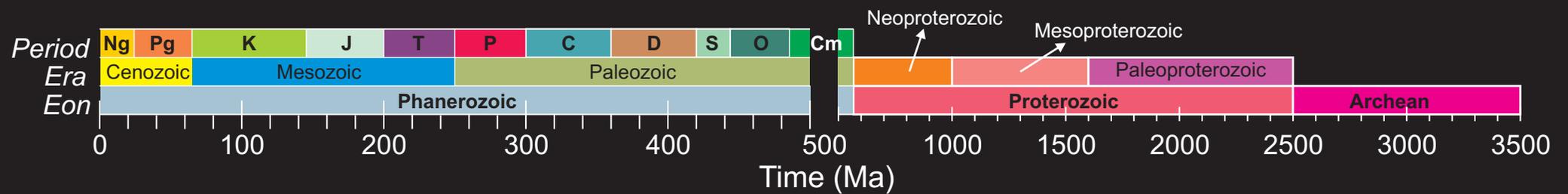
Past transitions and perturbations in global carbon cycling

(what can we learn about Earth system function and the interpretation of paleoenvironmental proxies?)

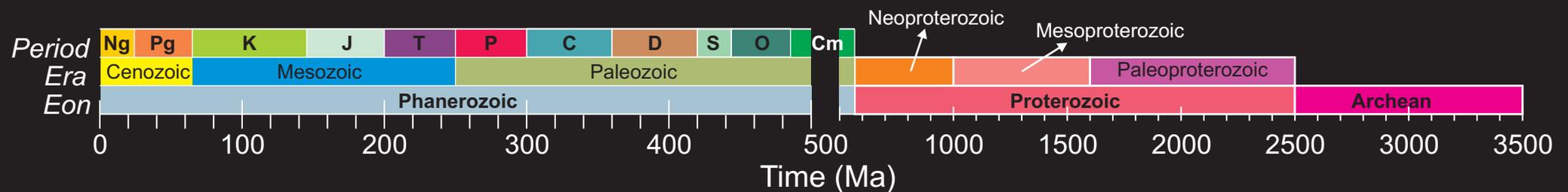
Andy Ridgwell



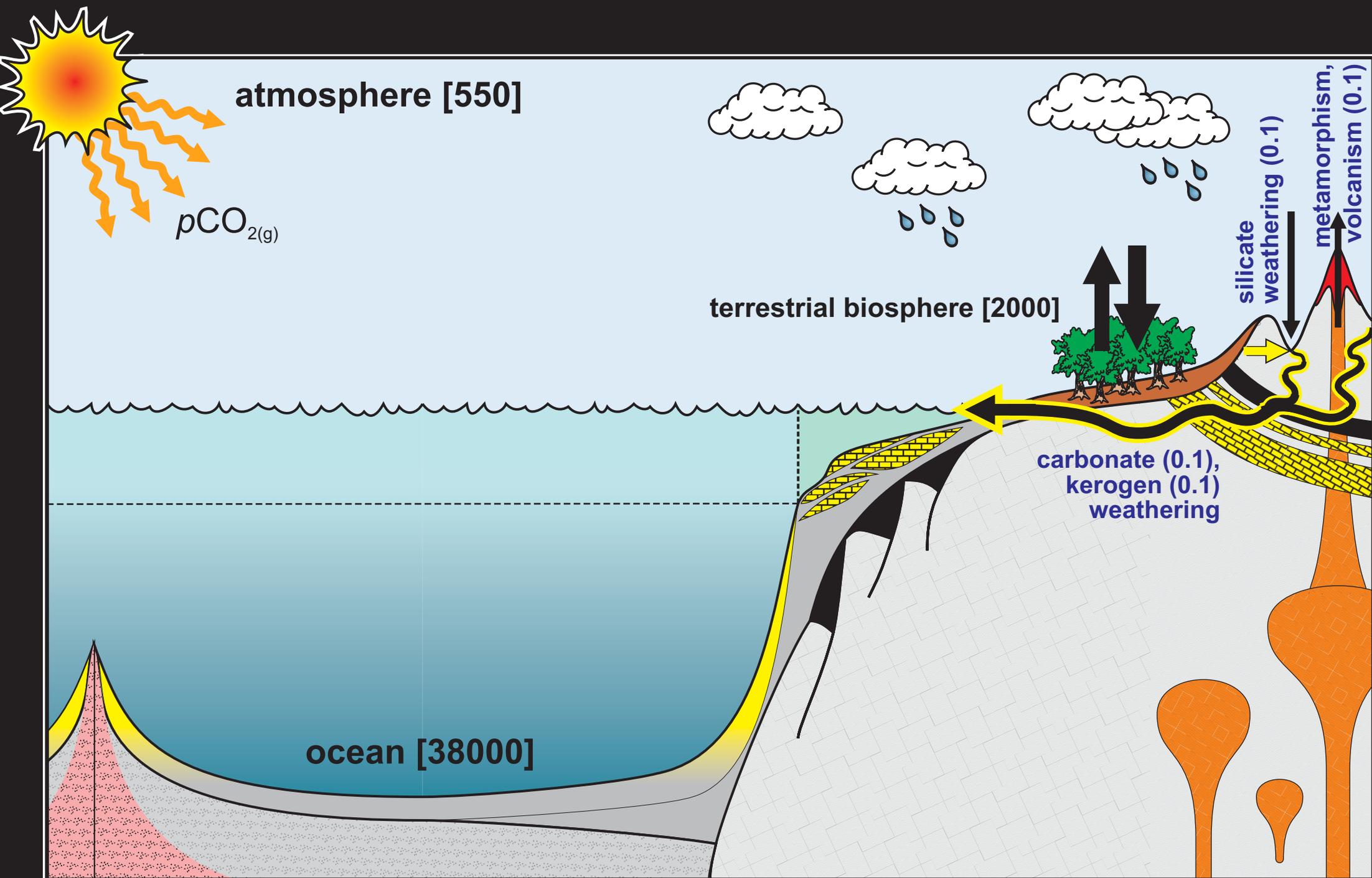
OR: Not the PETM (almost)



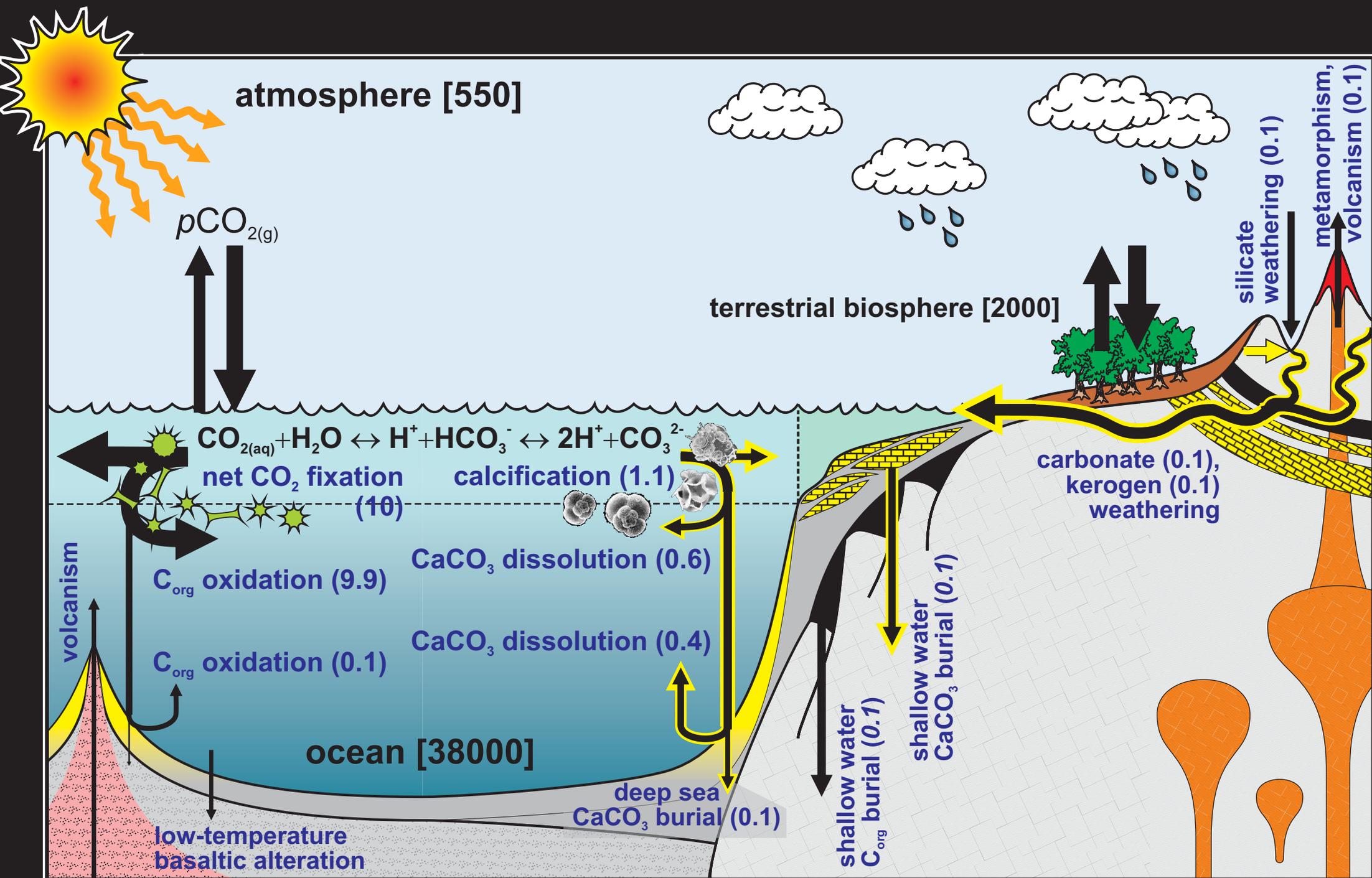
There will be a 1 EUR fine for saying 'PETM' out loud



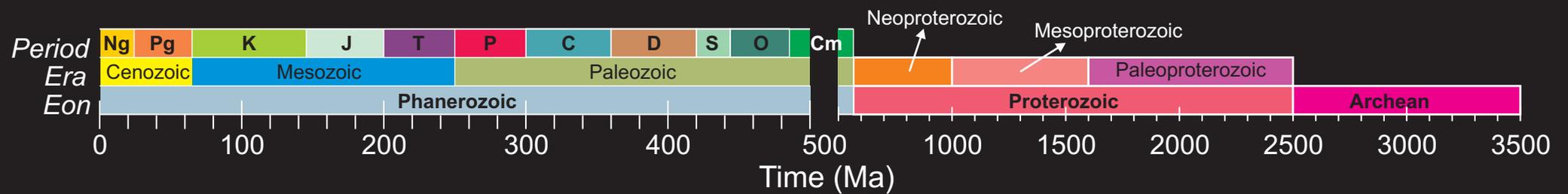
Ocean carbon cycling

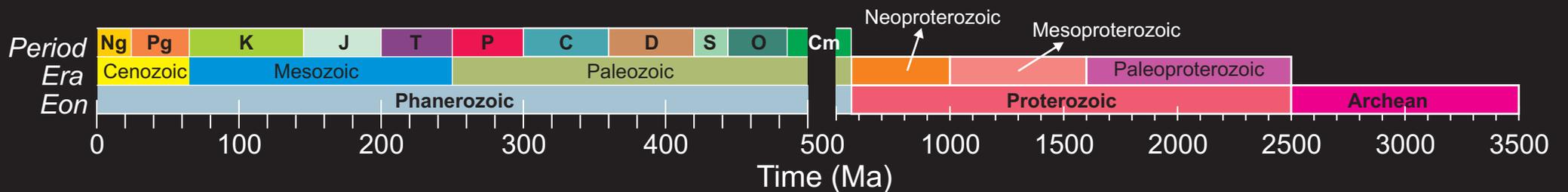
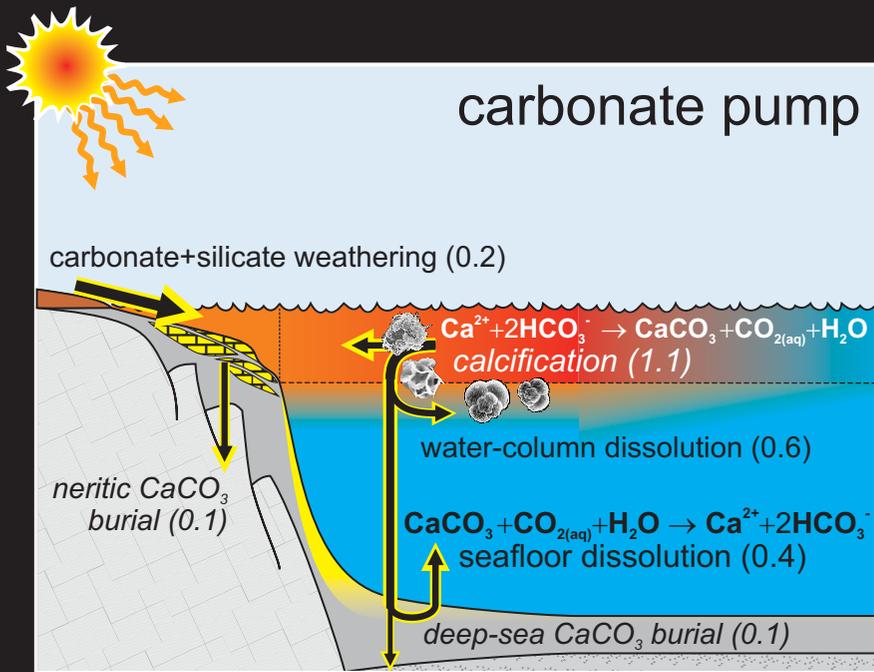
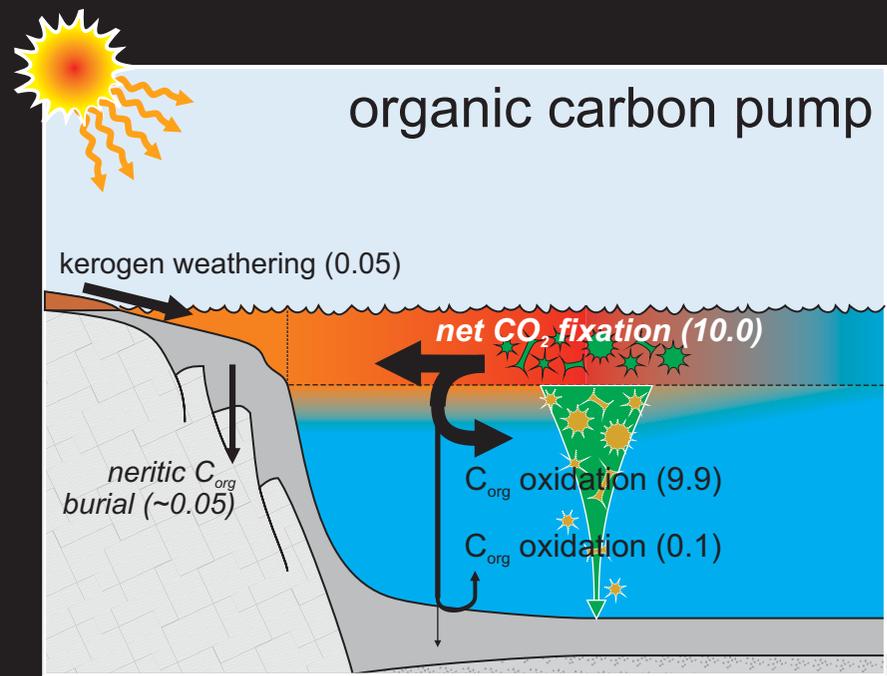
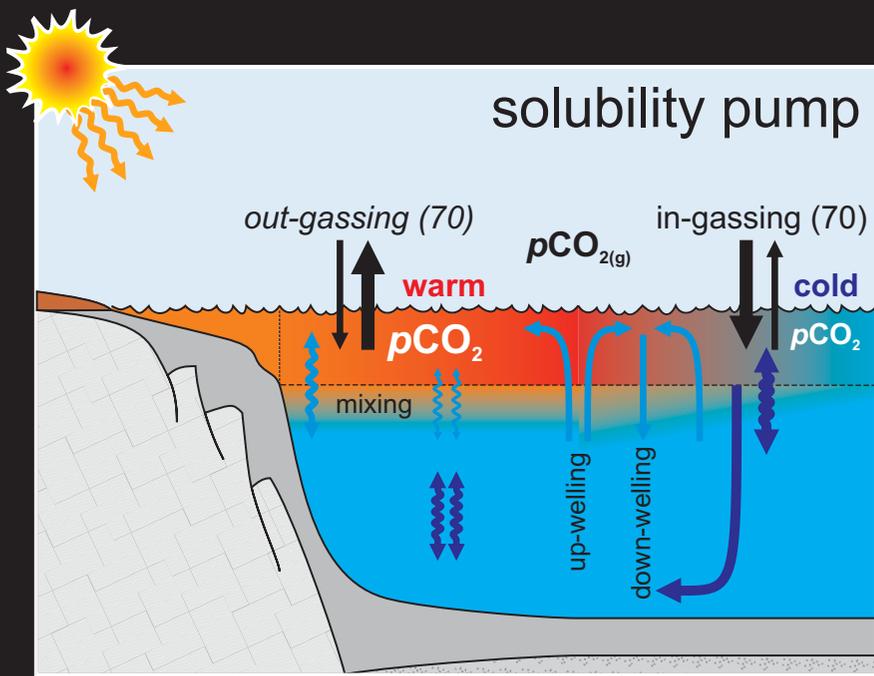


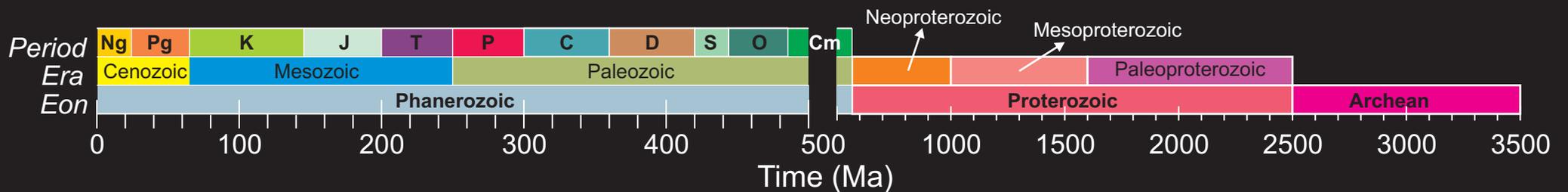
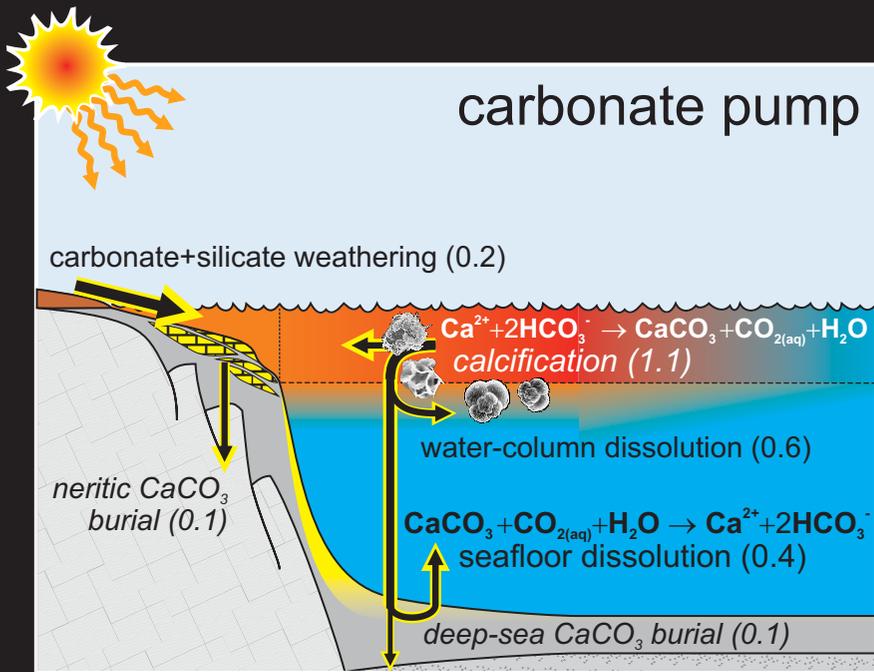
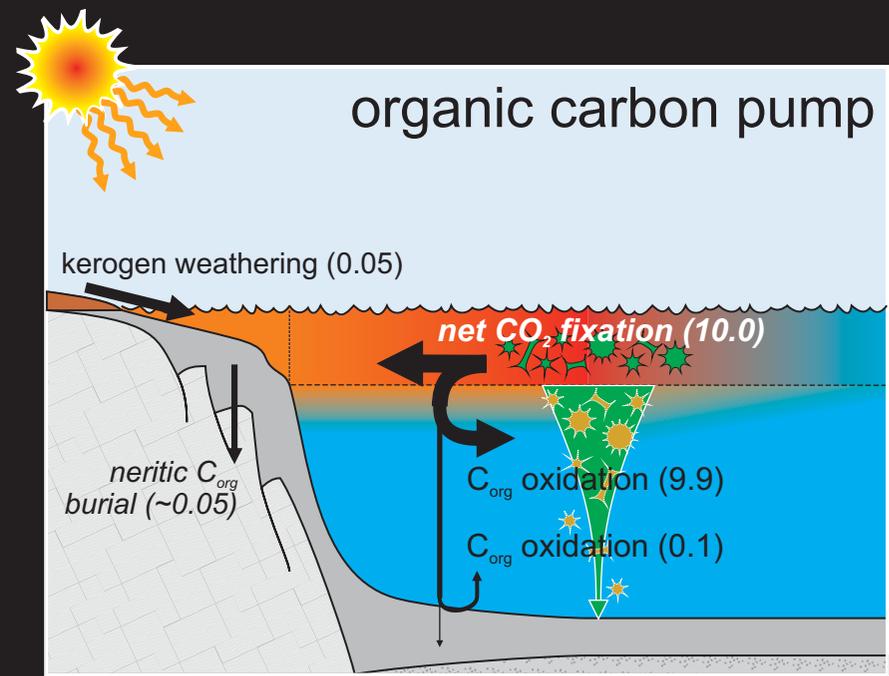
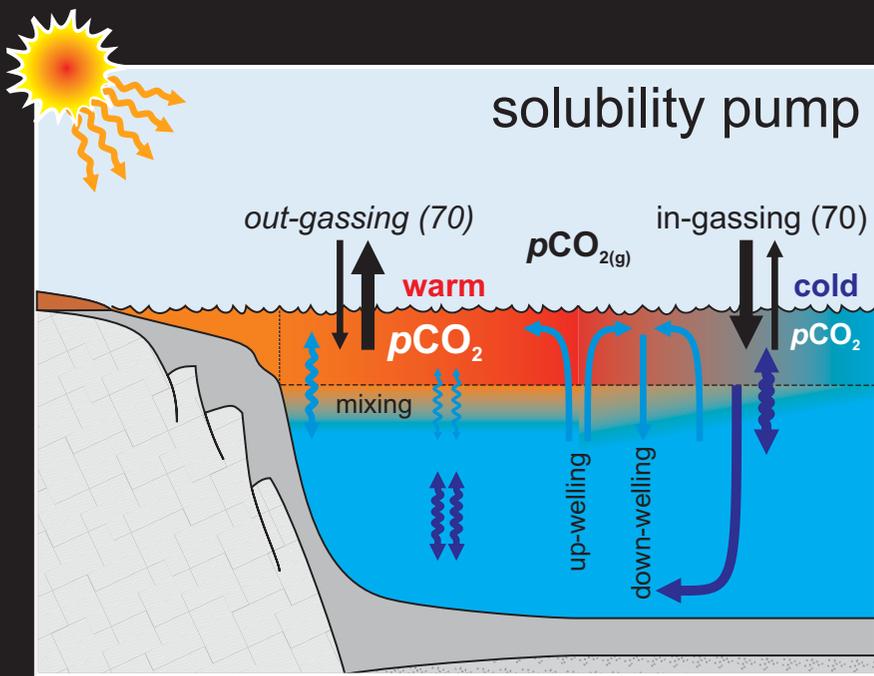
Ocean carbon cycling

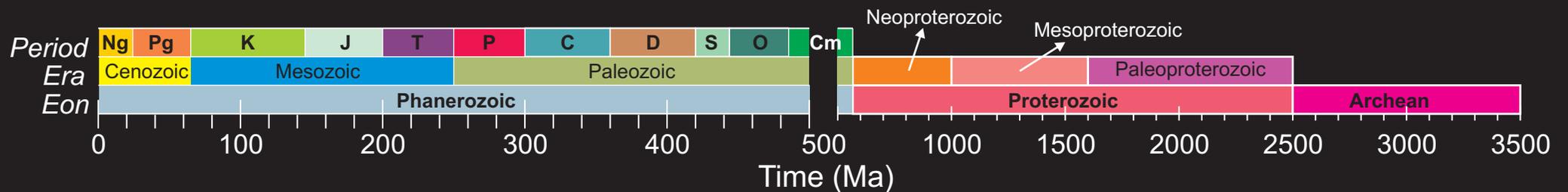
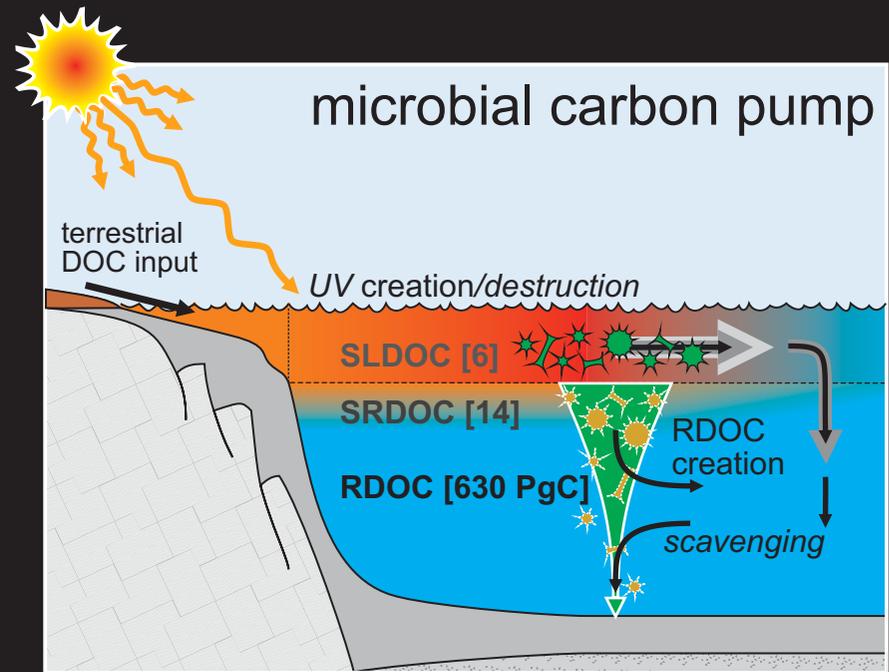
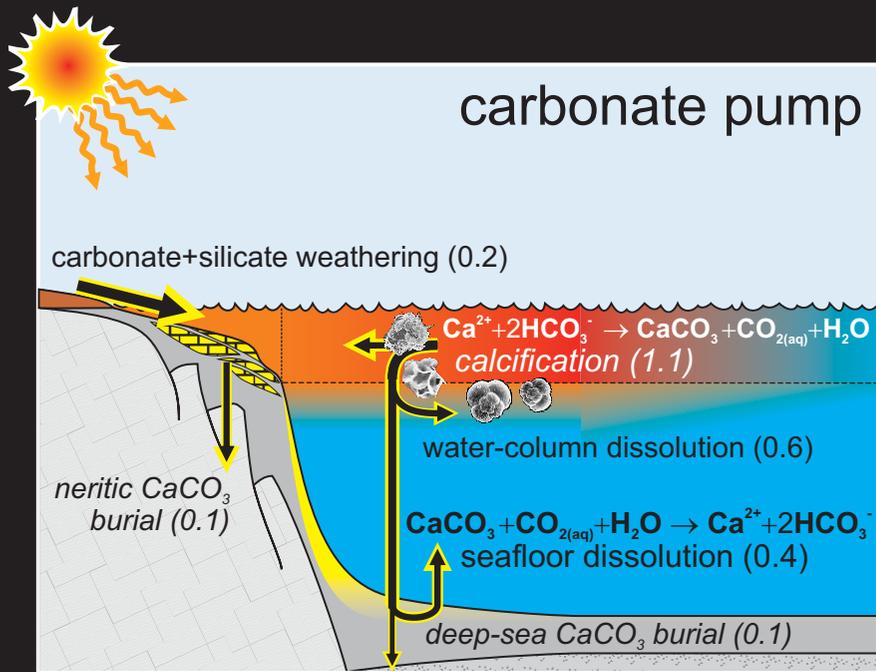
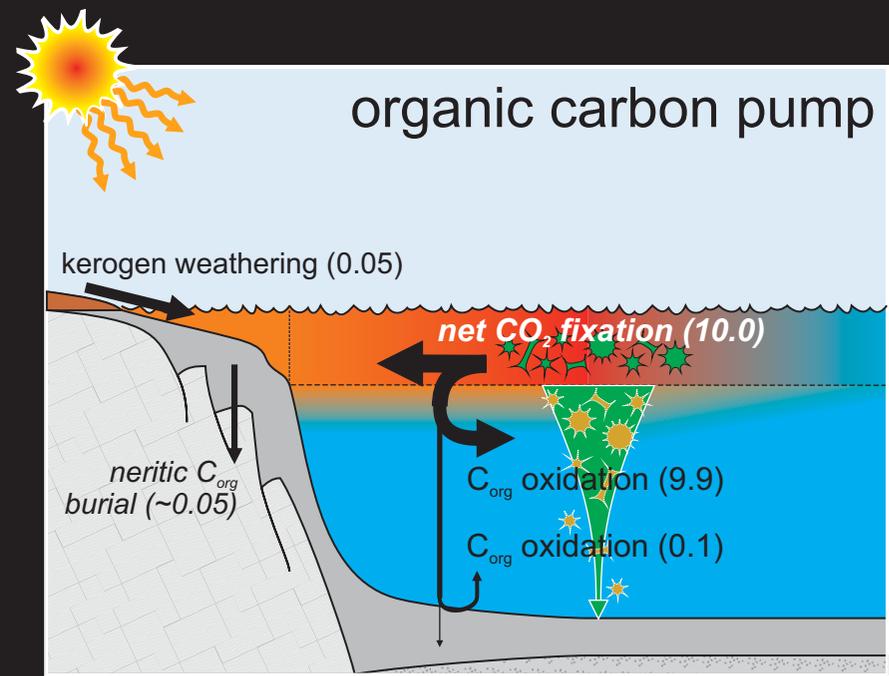
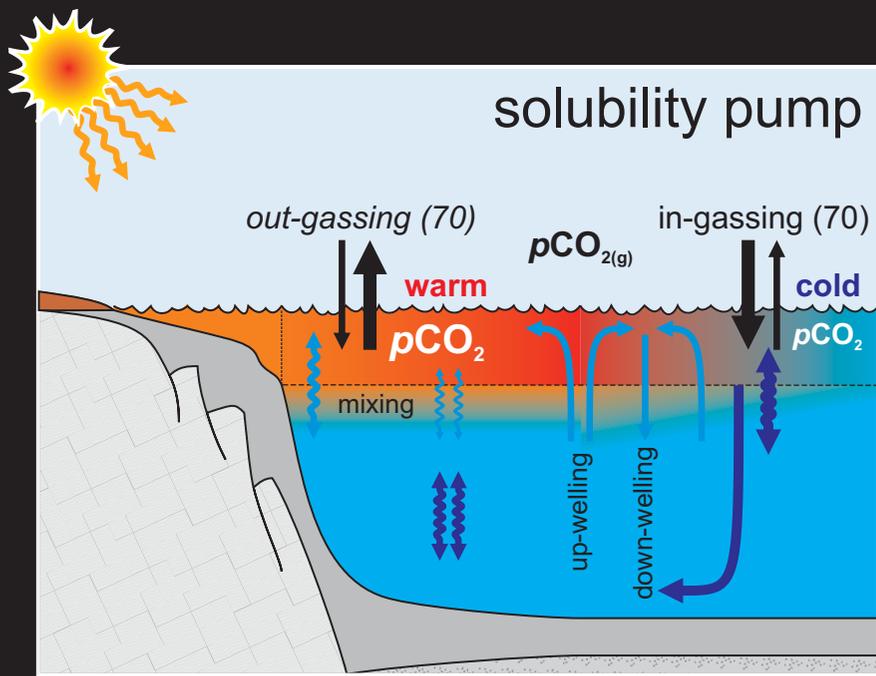


What are the ocean carbon 'pumps'?

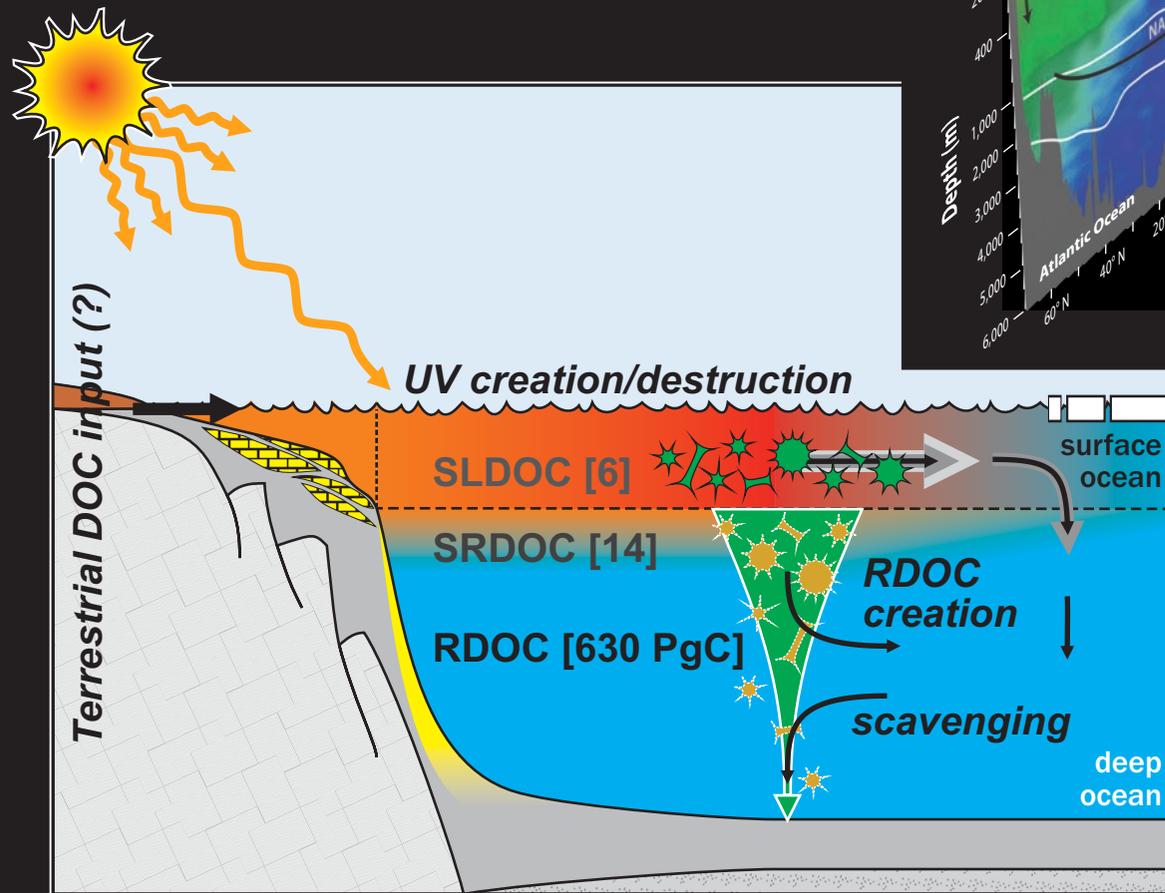
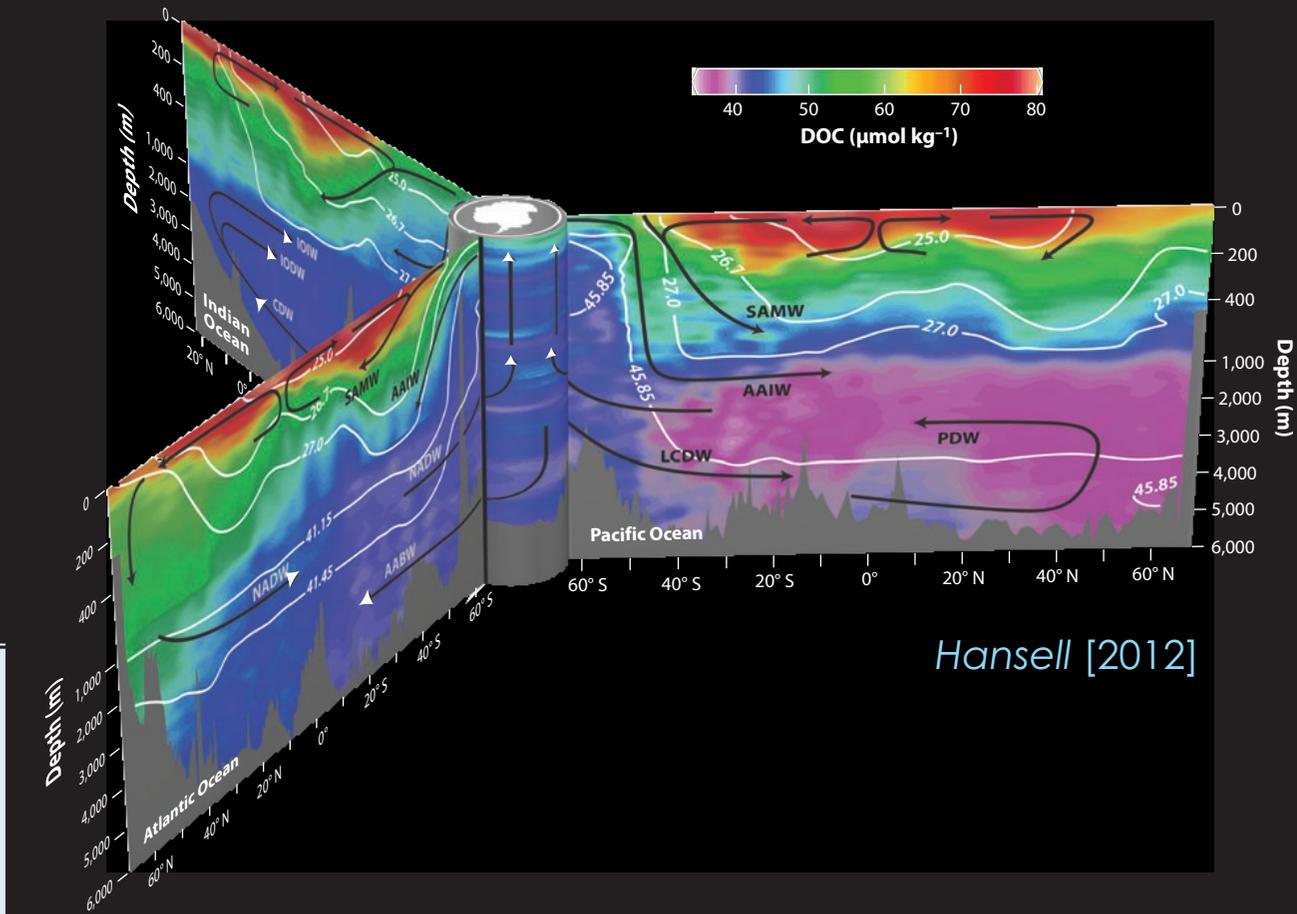


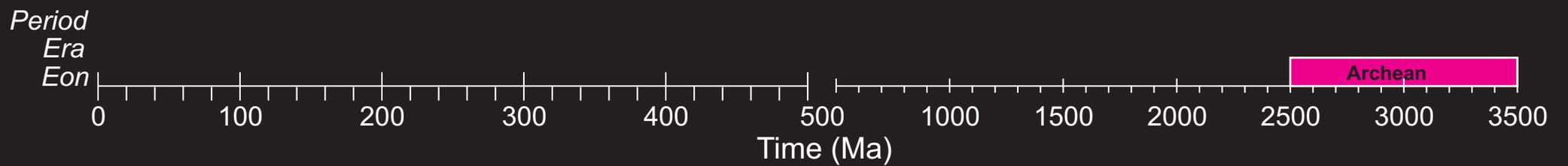
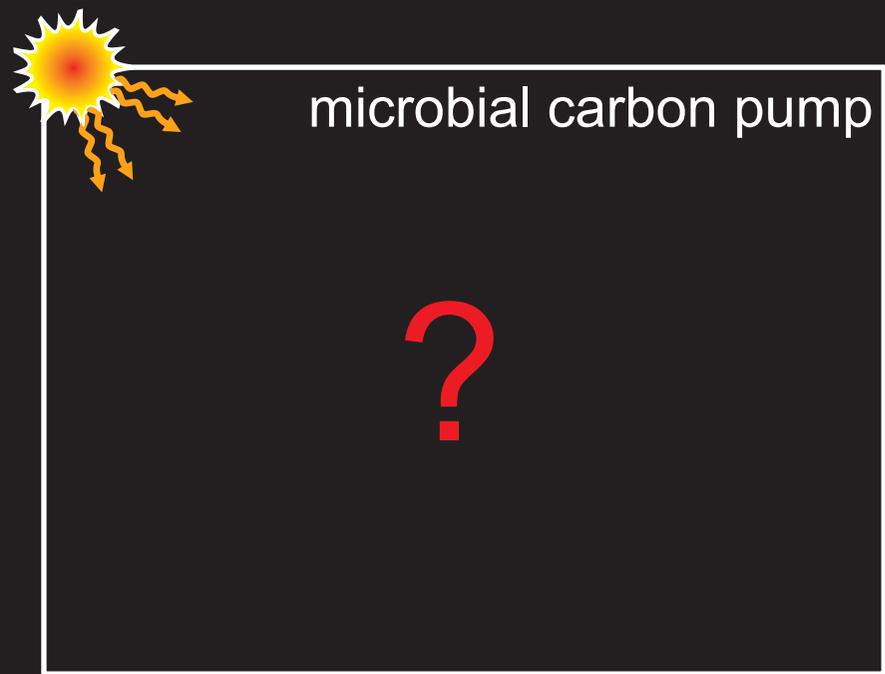
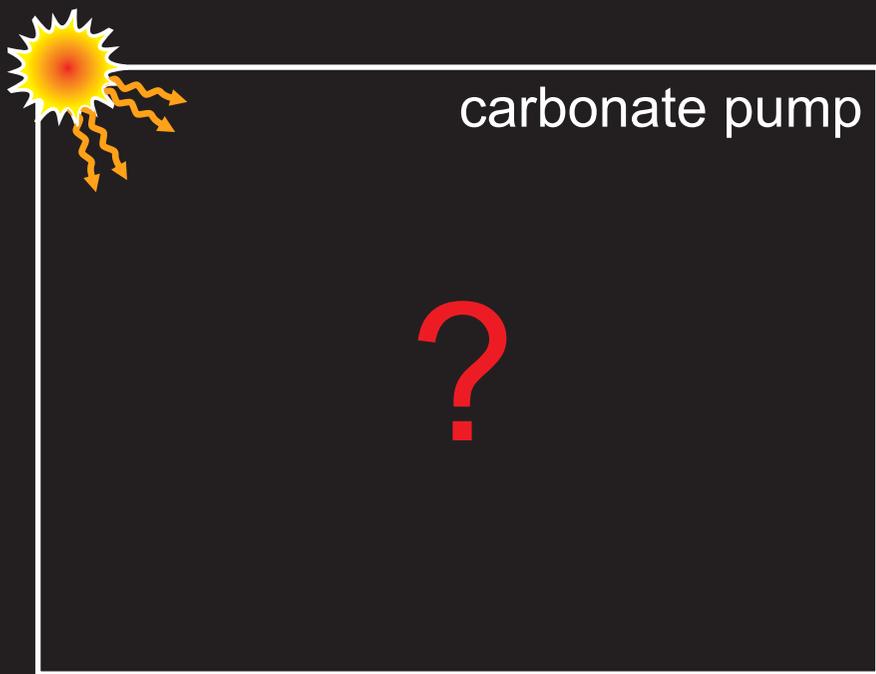
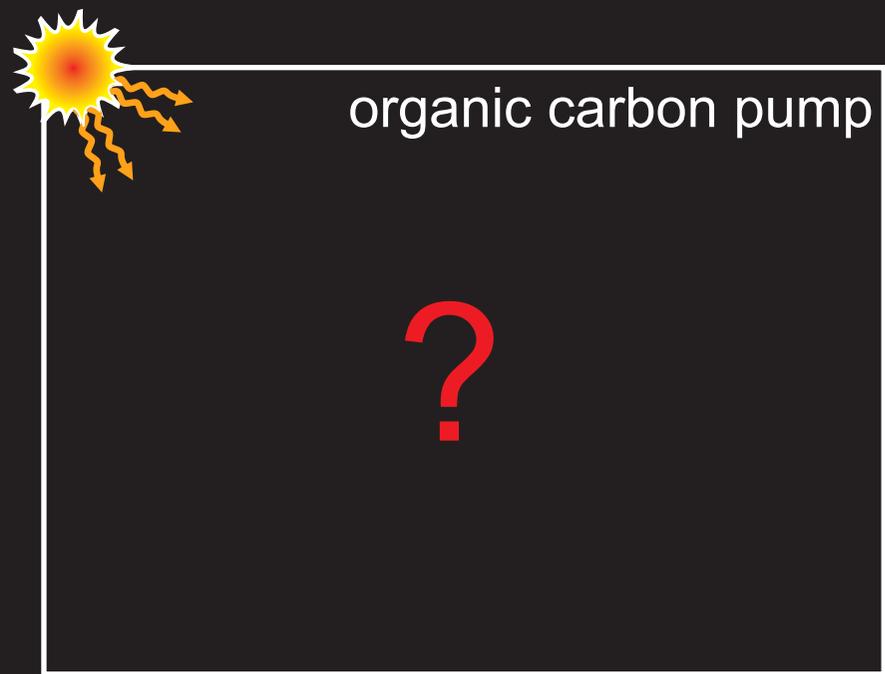
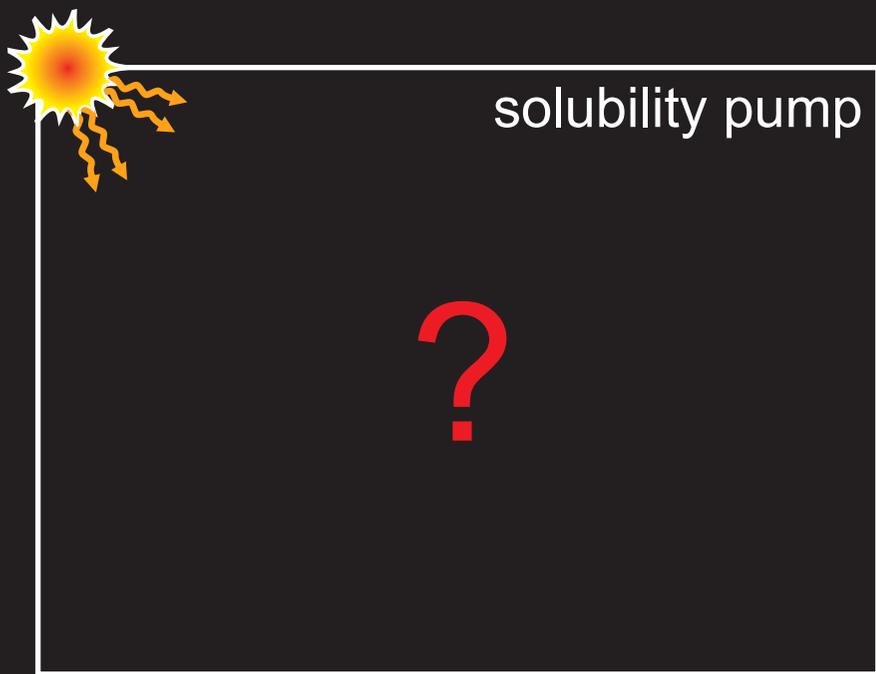


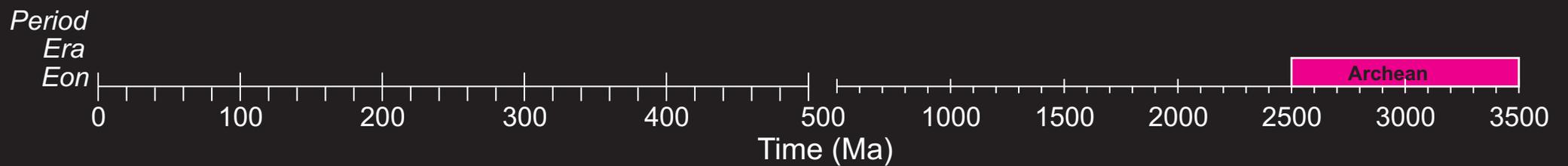
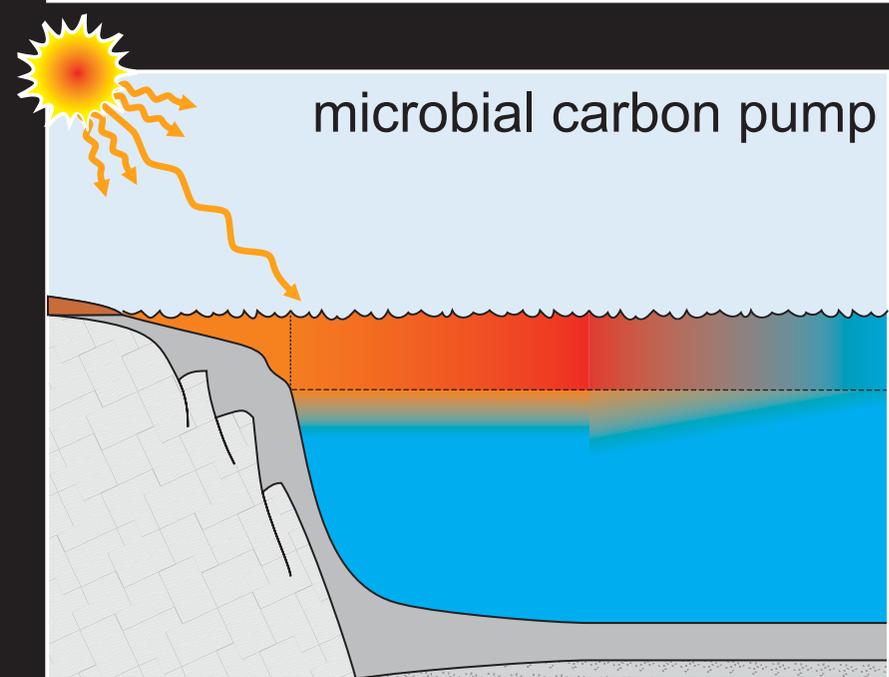
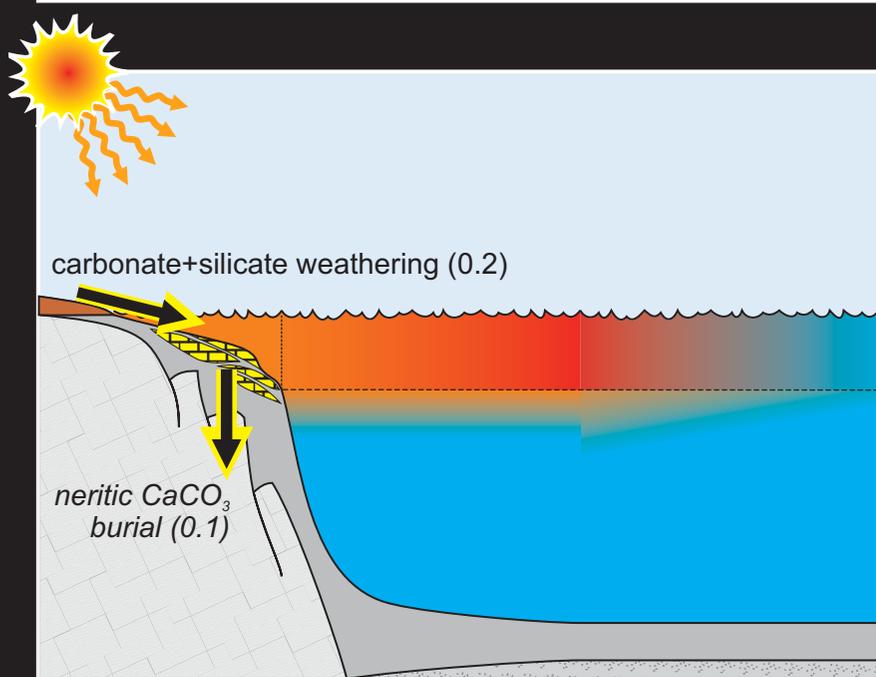
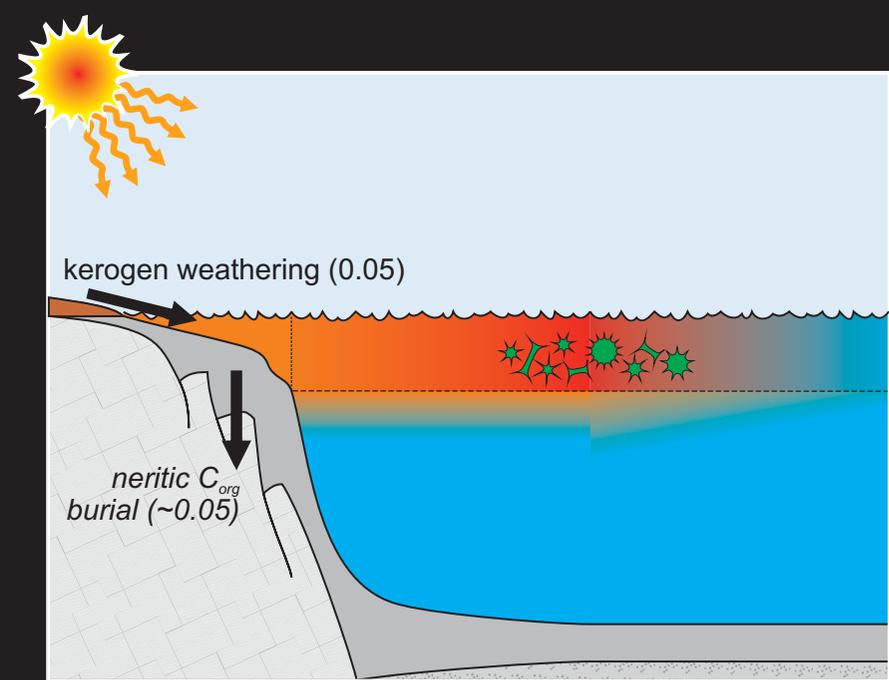
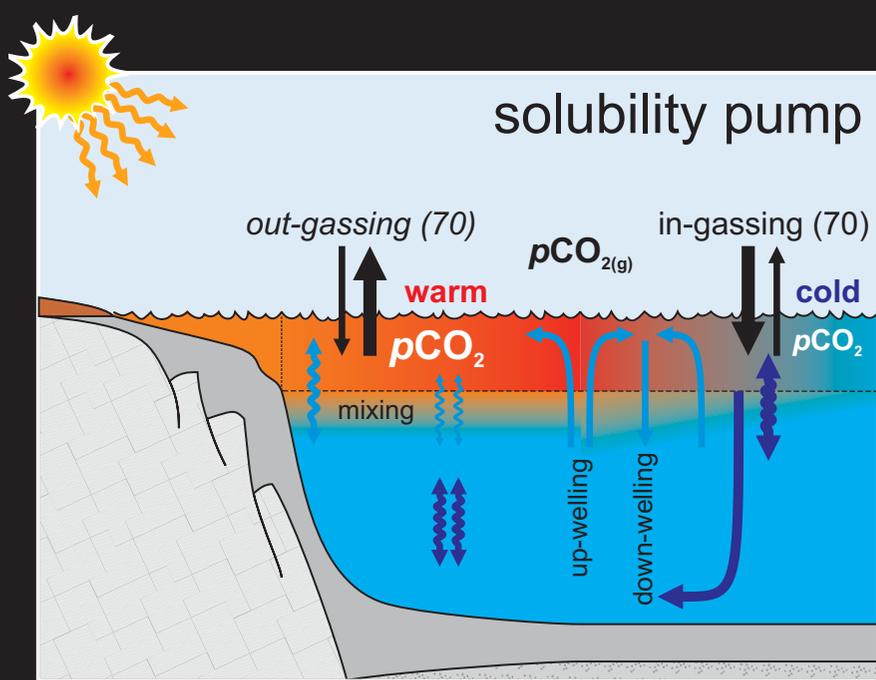


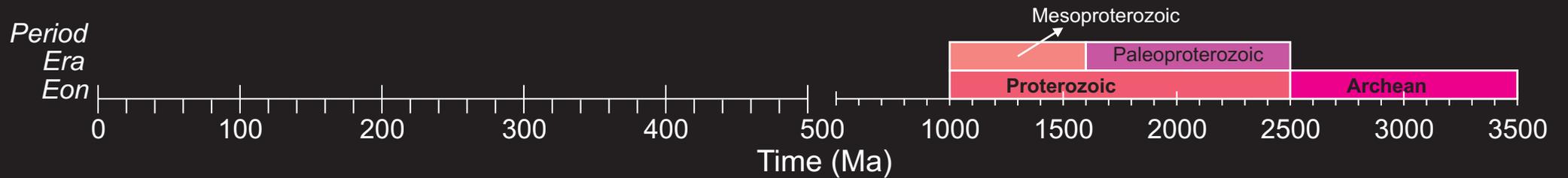
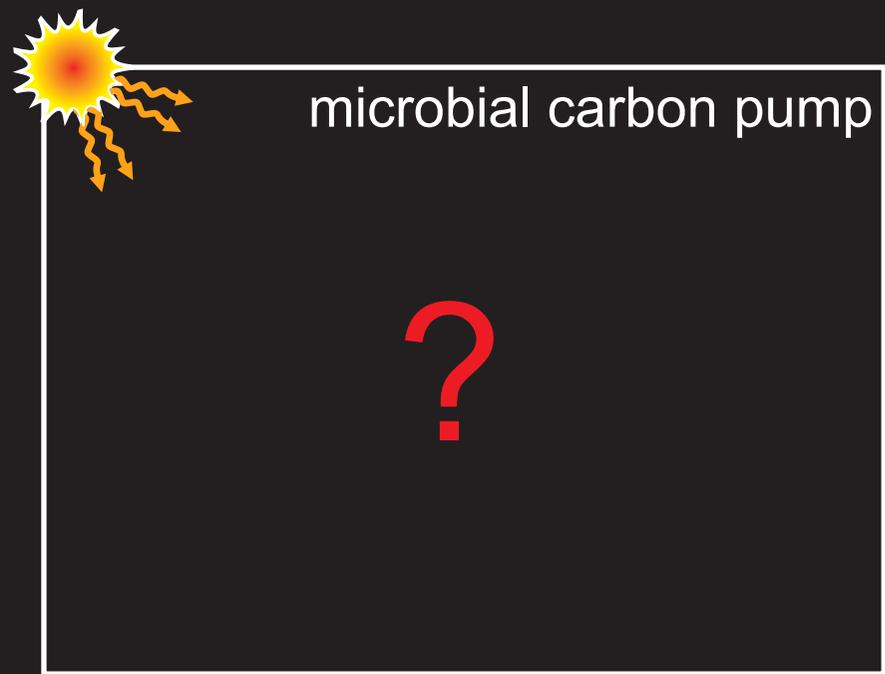
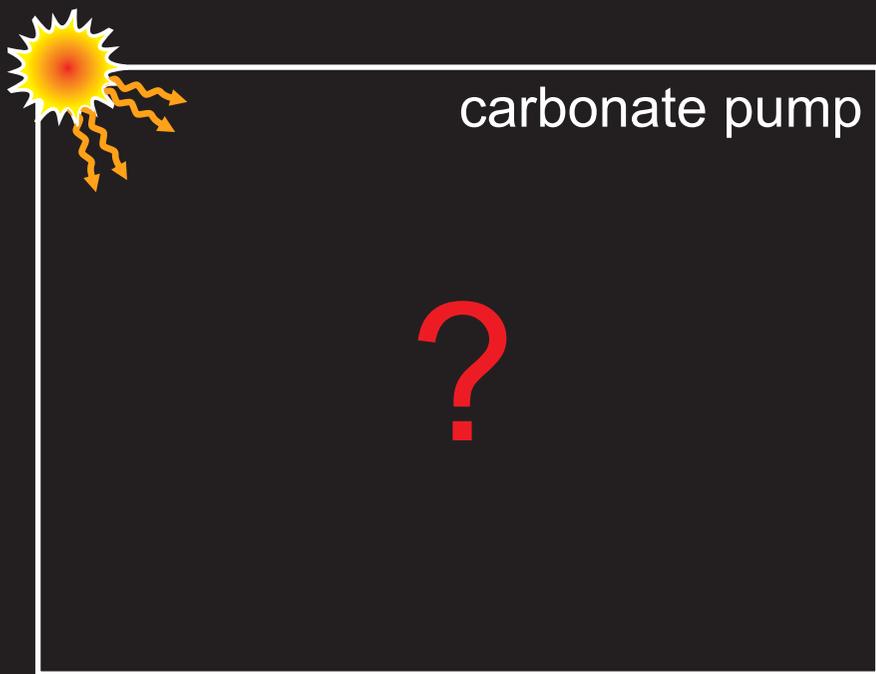
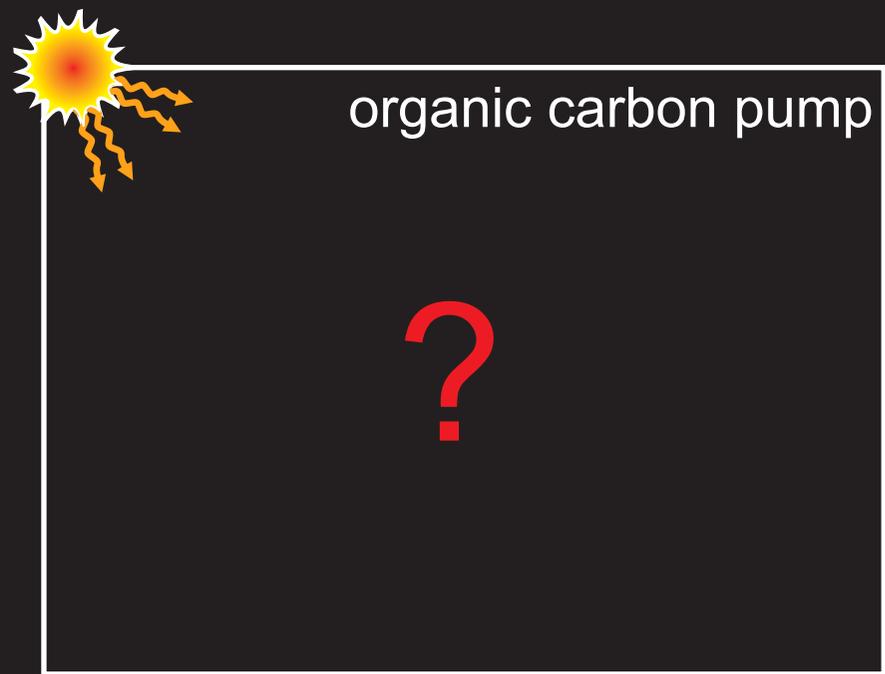
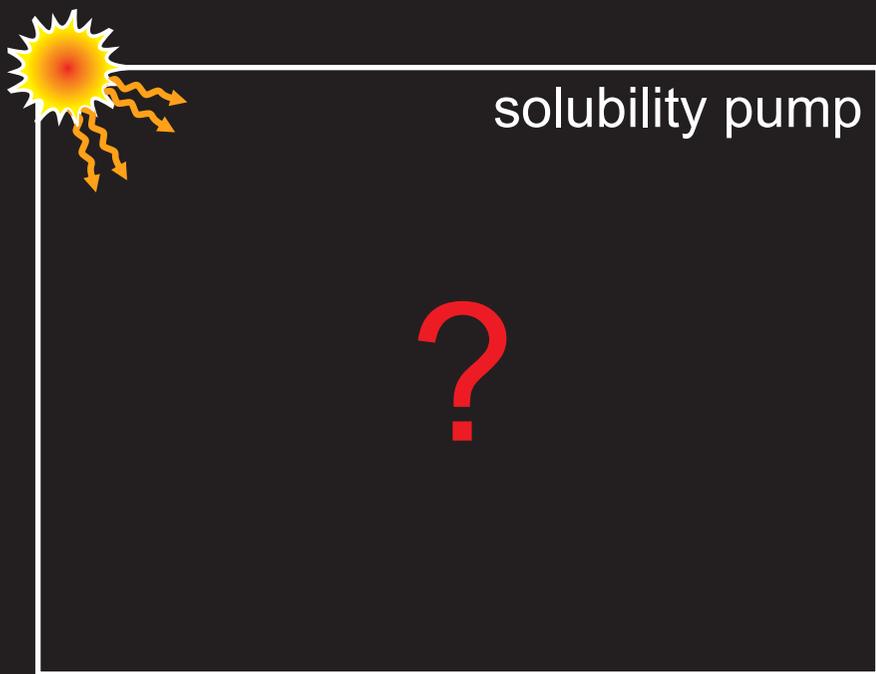


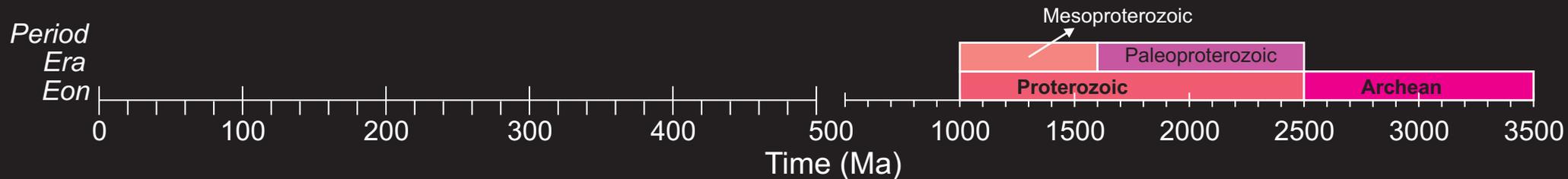
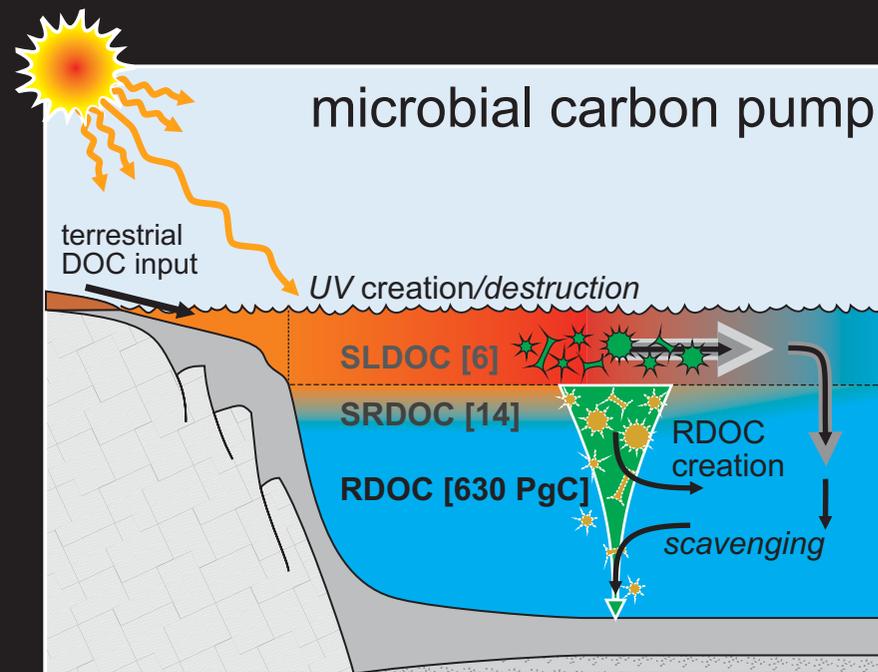
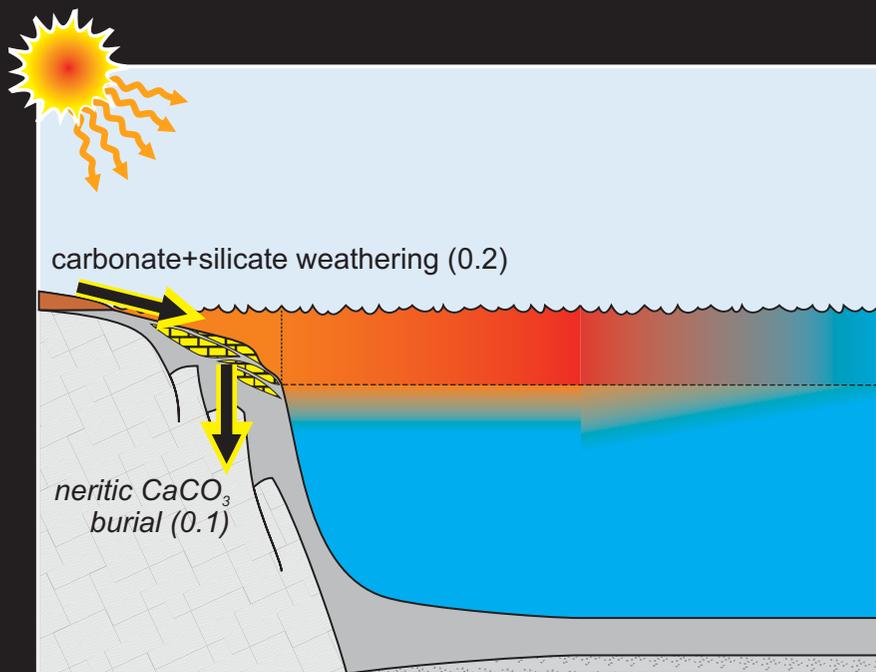
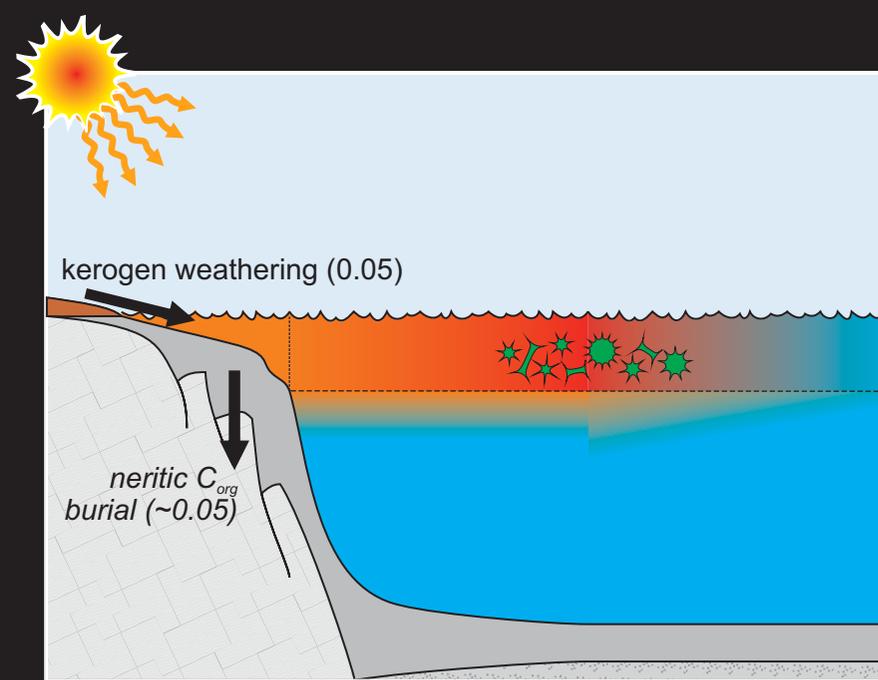
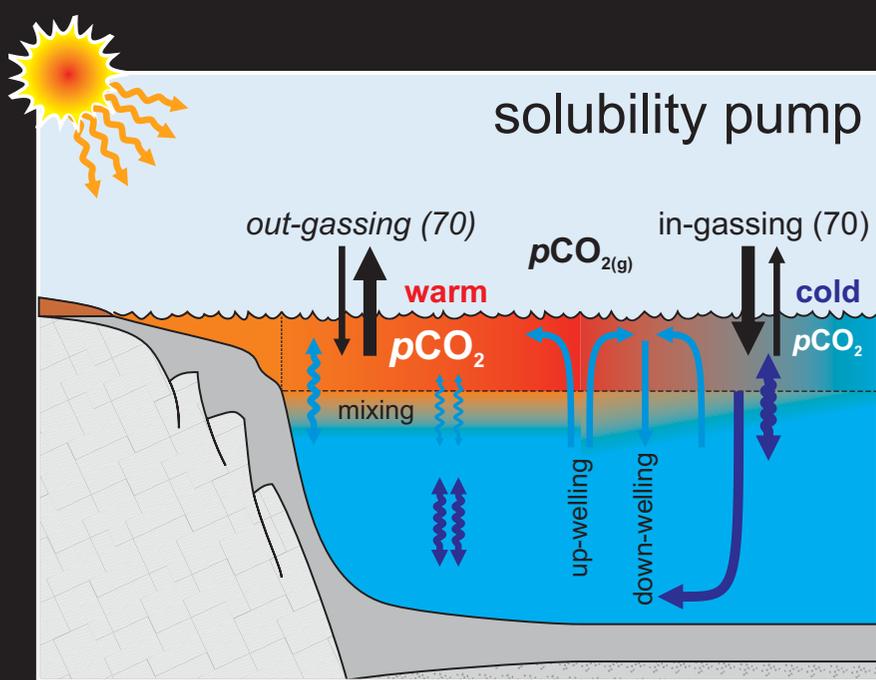
Ocean carbon cycling

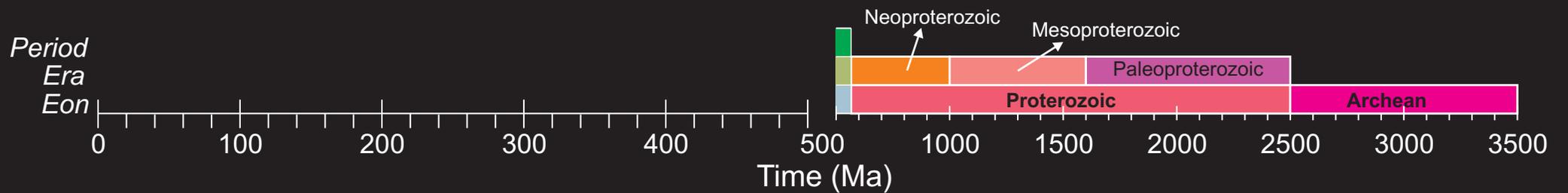
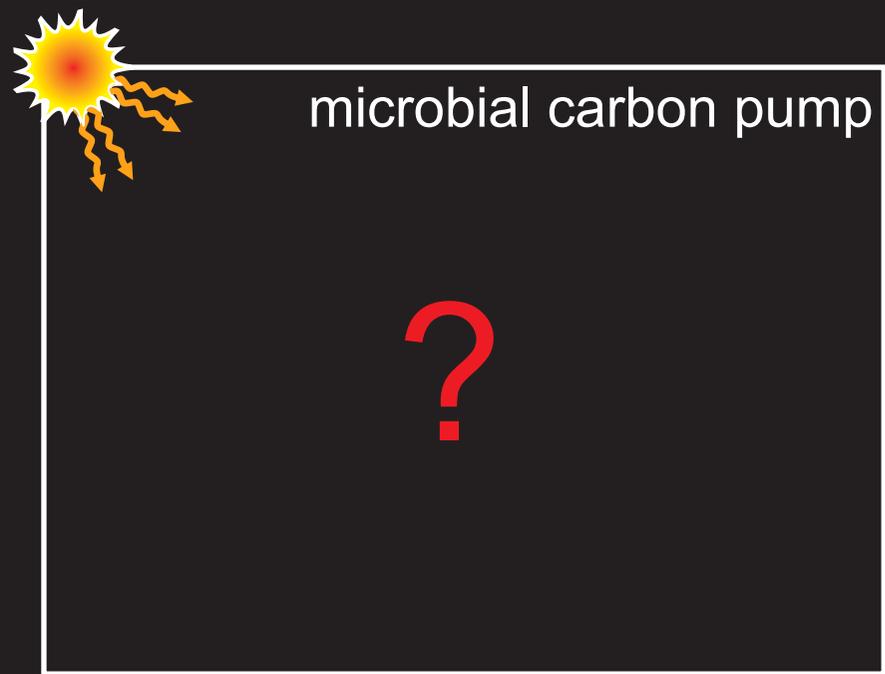
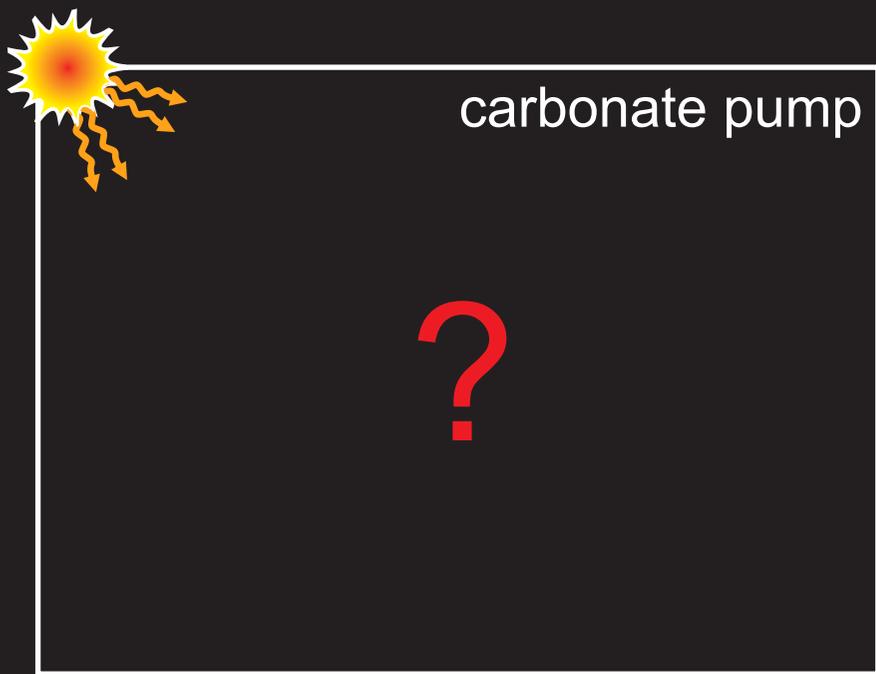
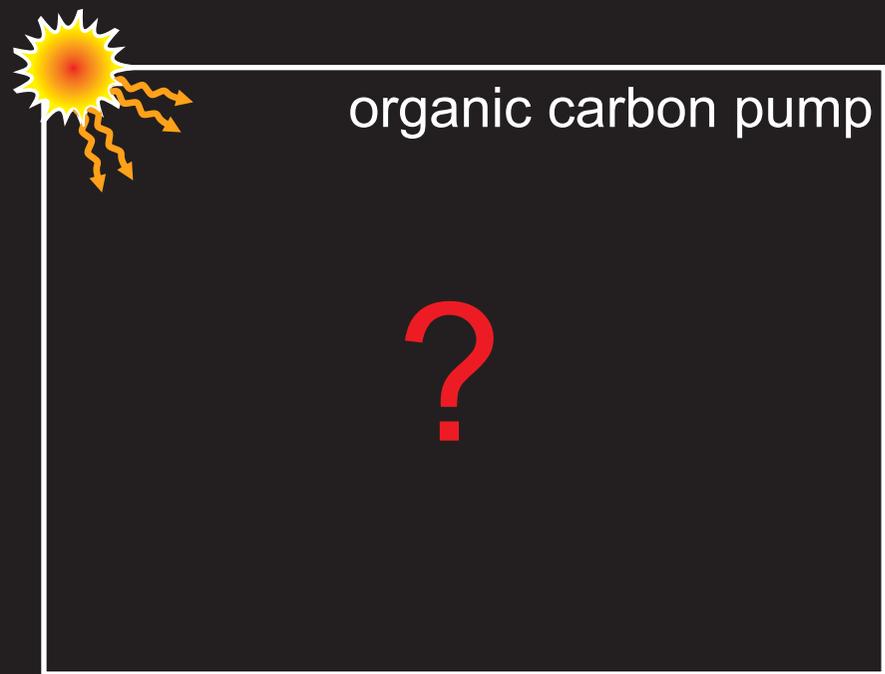
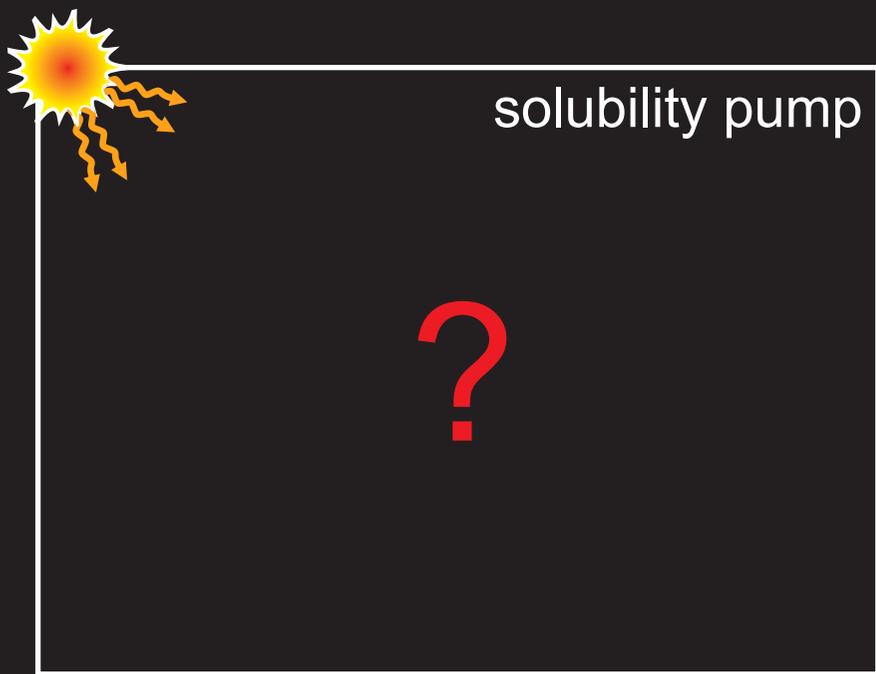


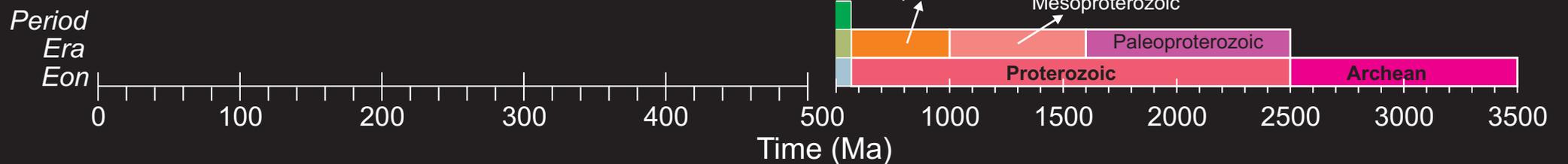
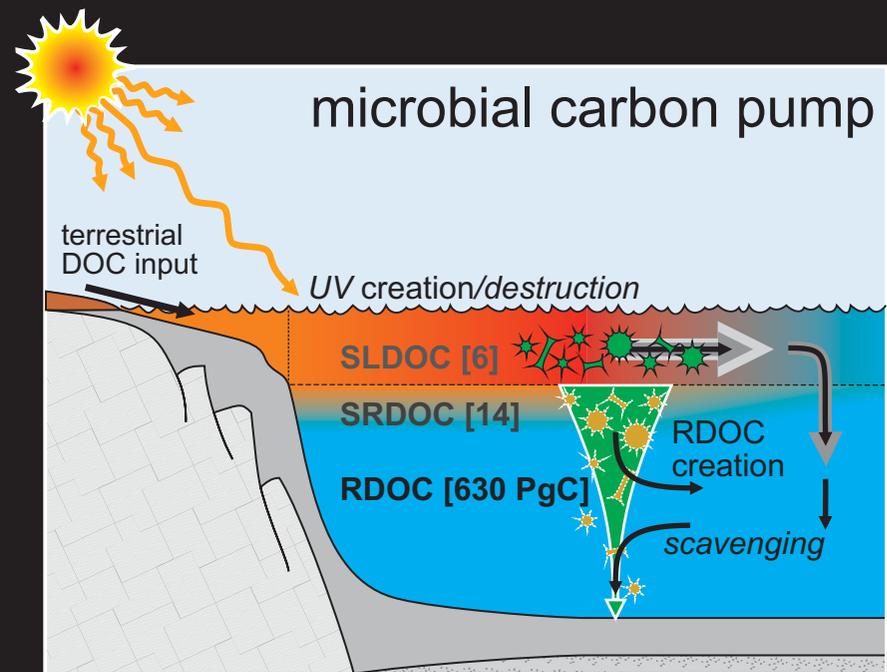
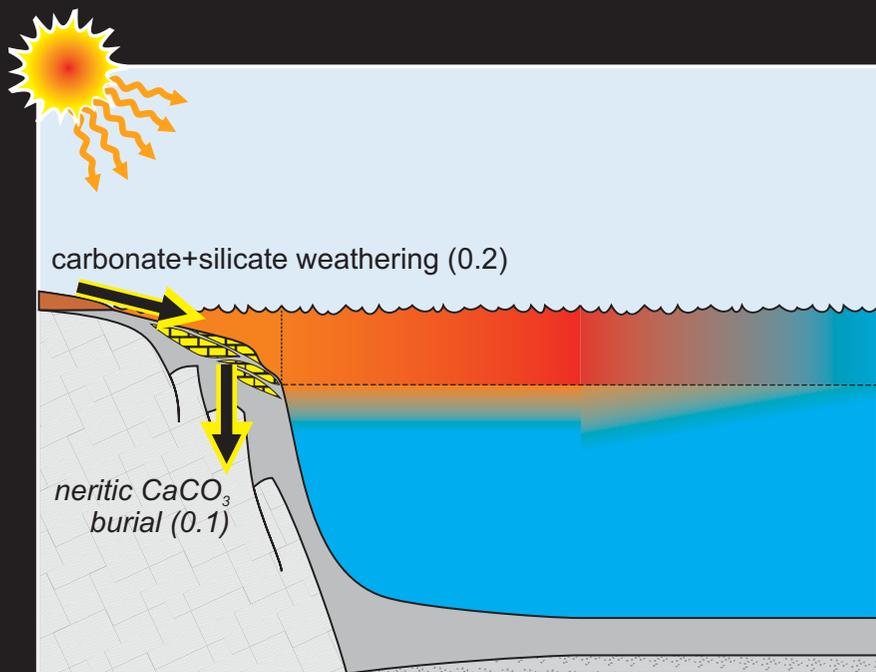
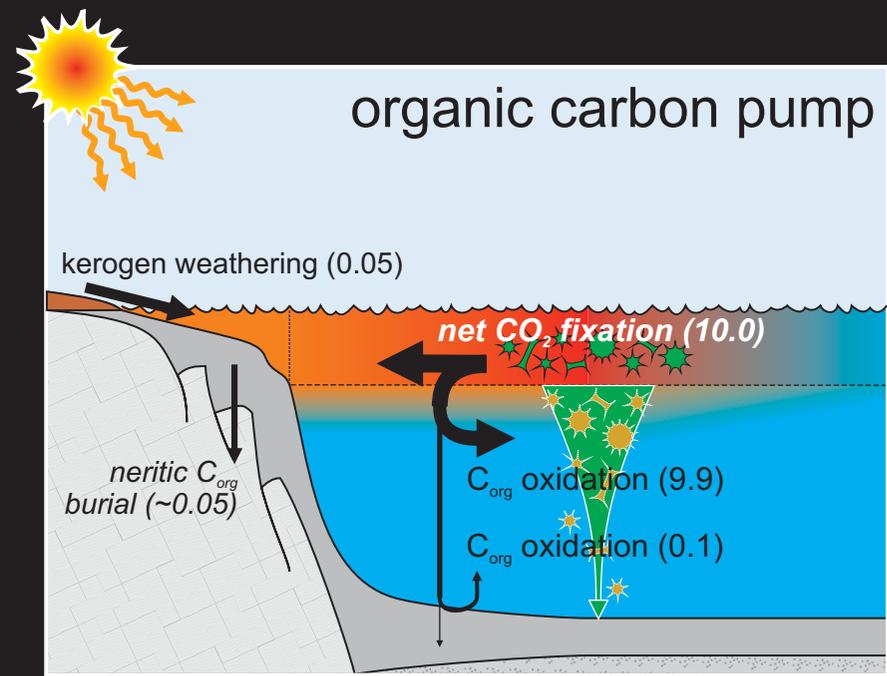
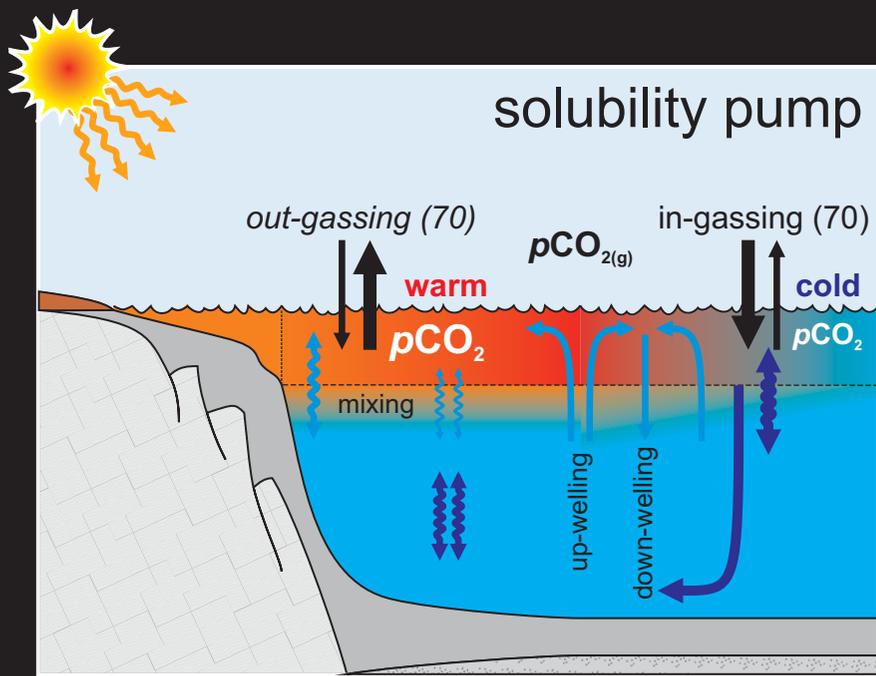


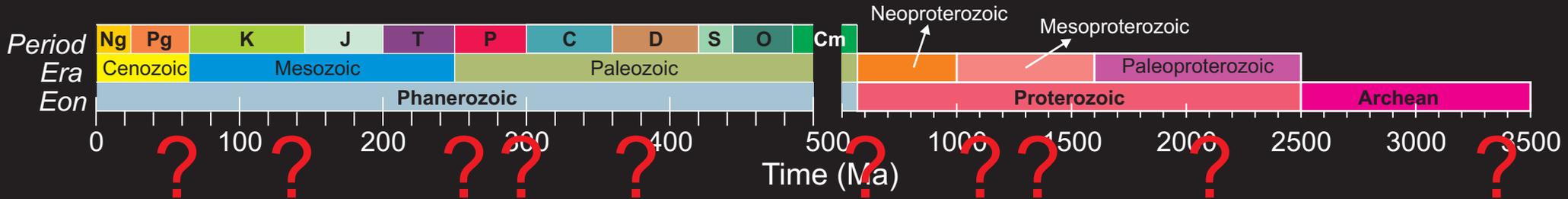
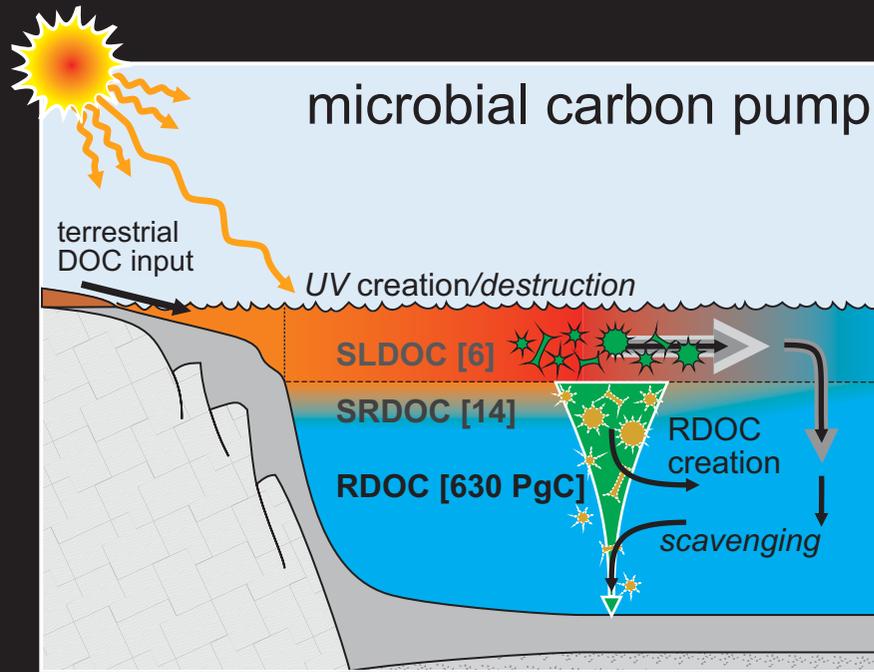
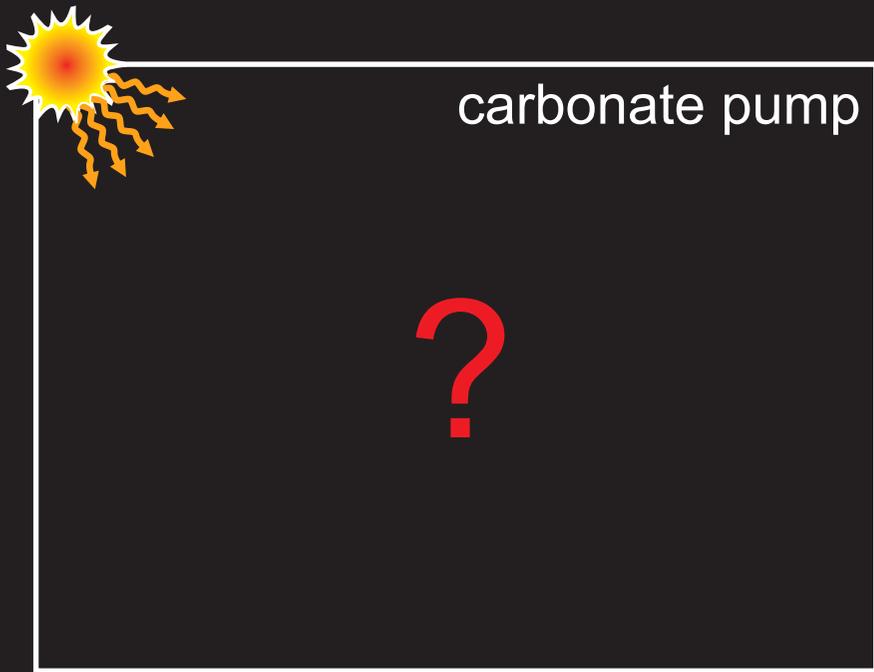
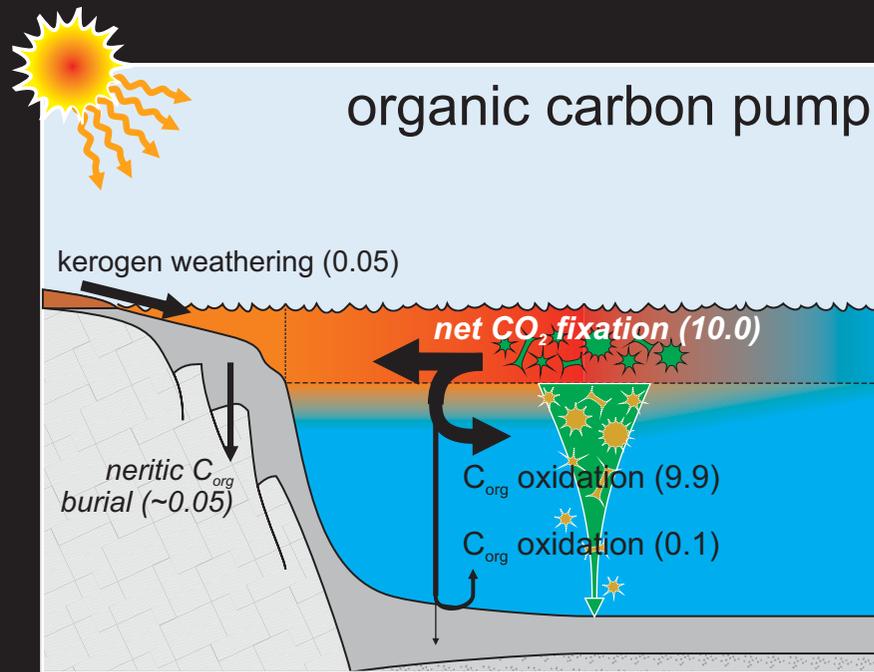
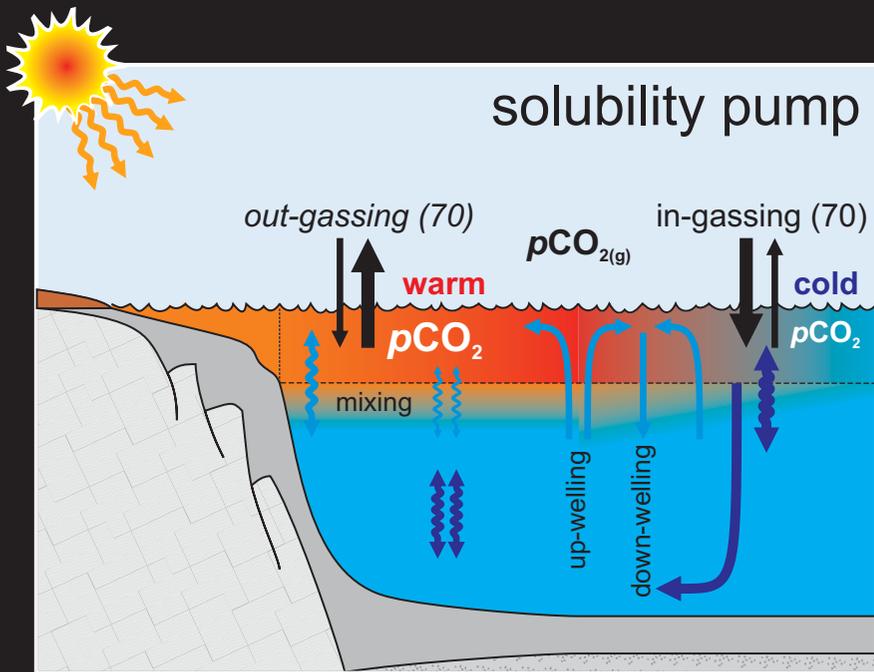


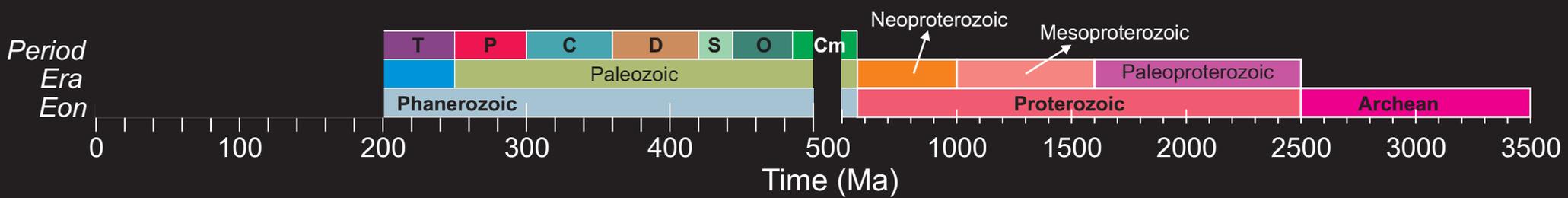
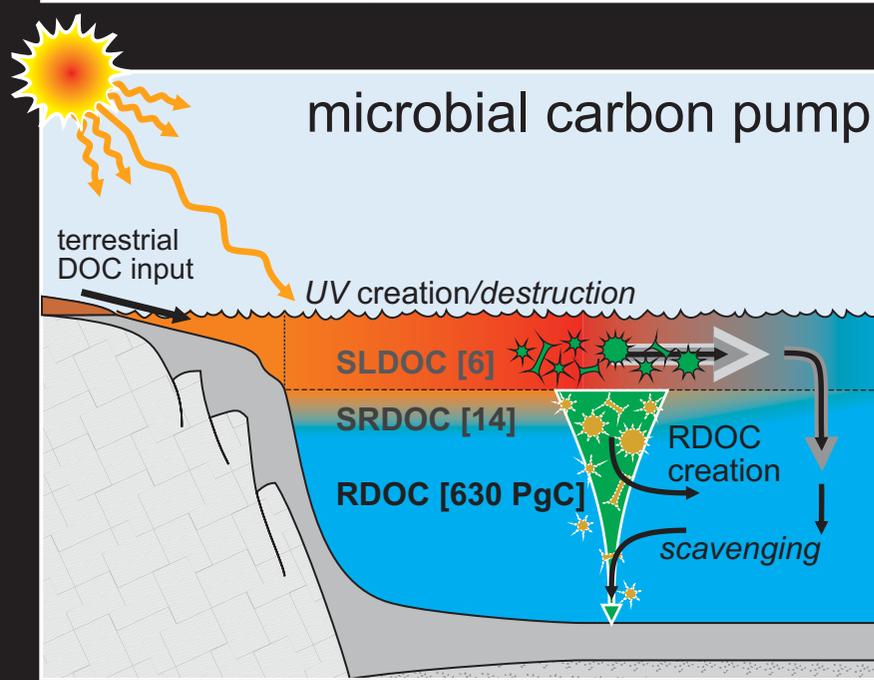
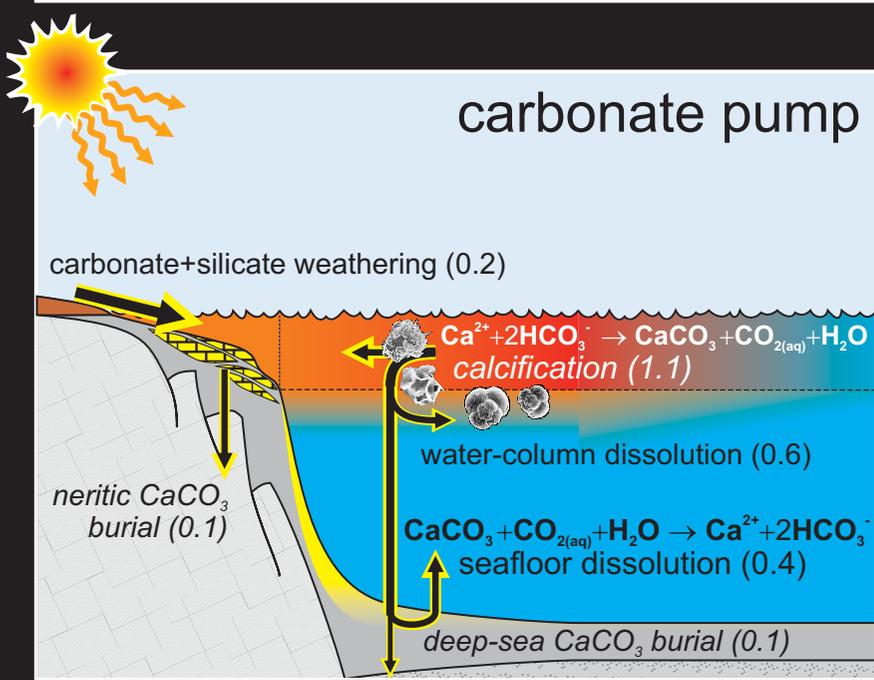
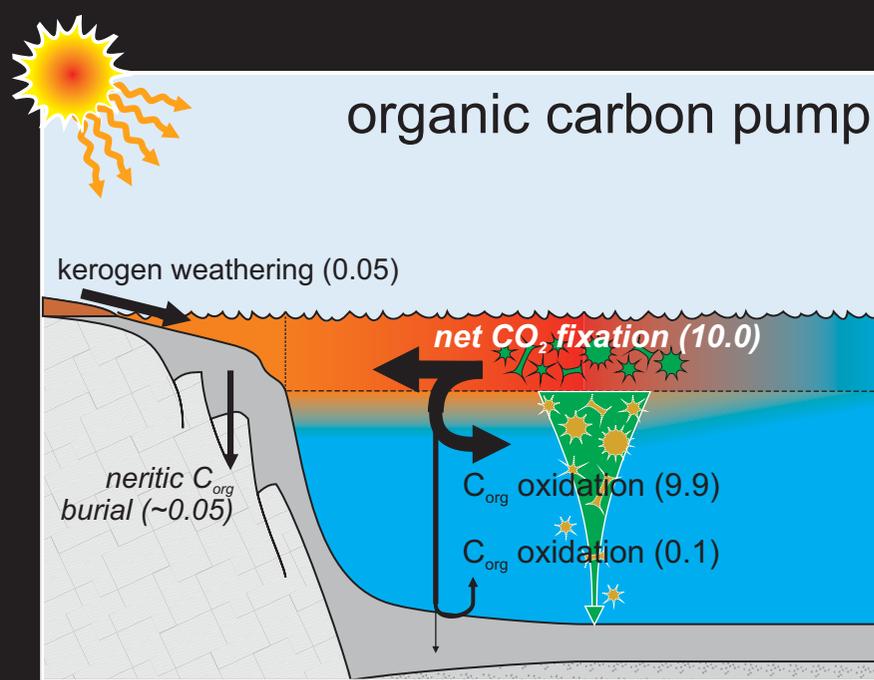
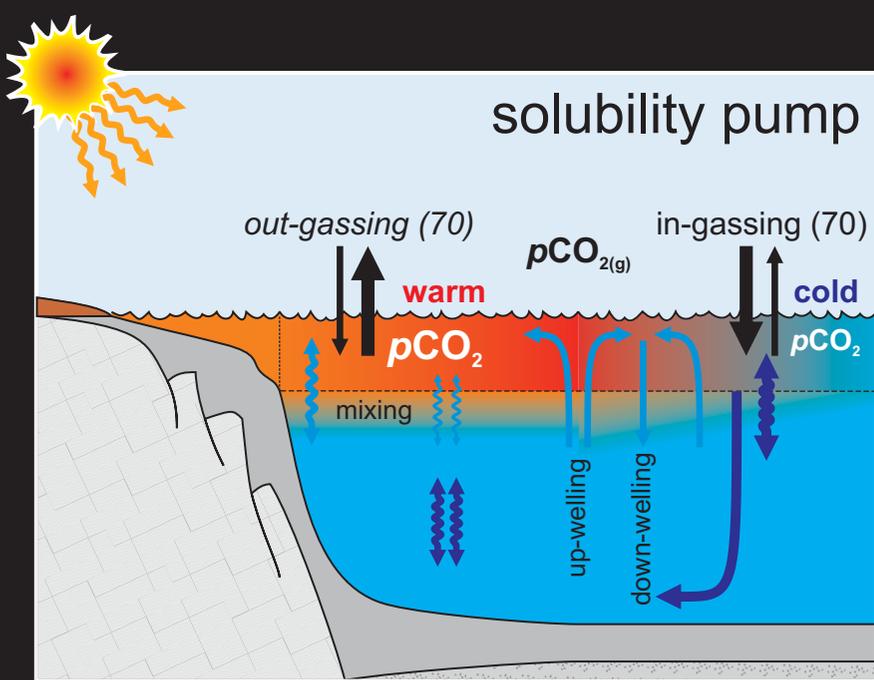


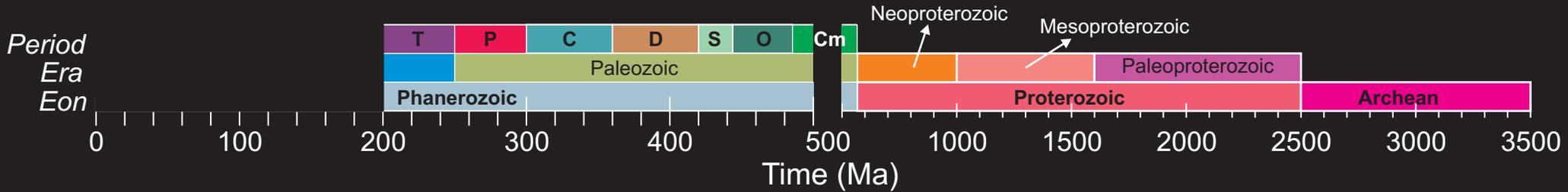
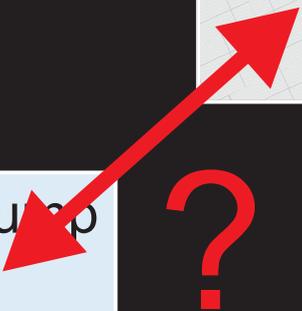
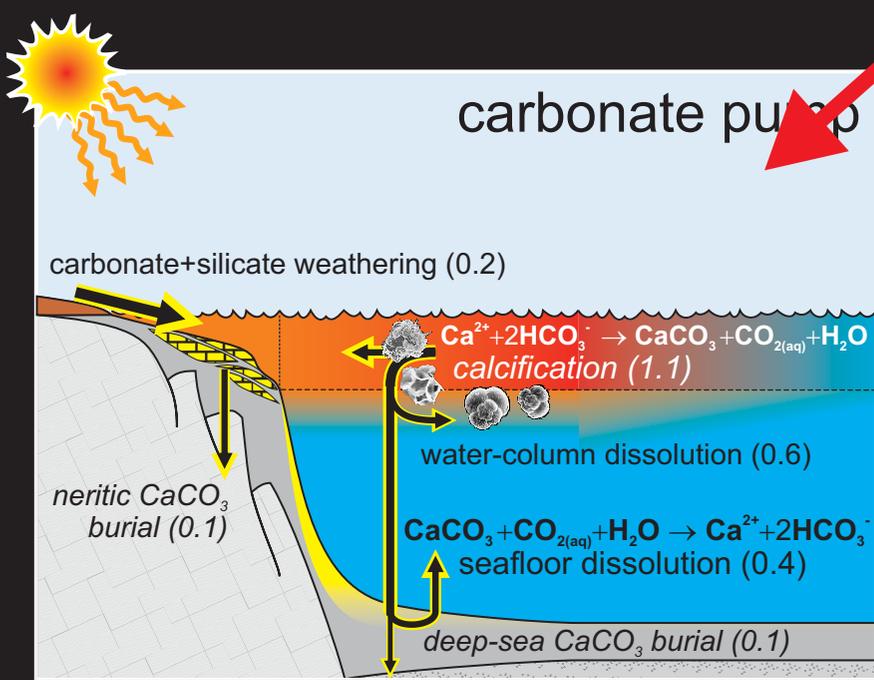
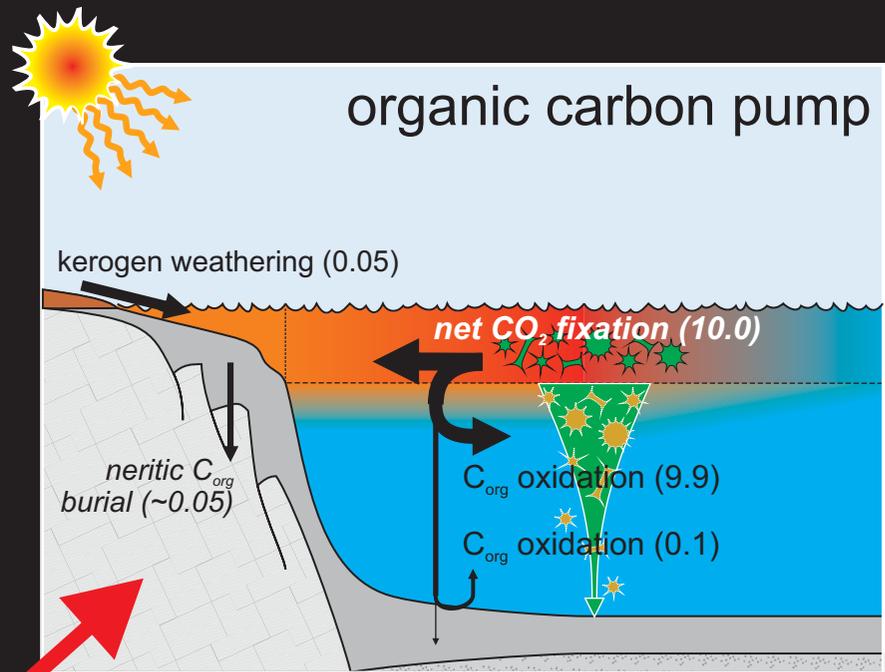


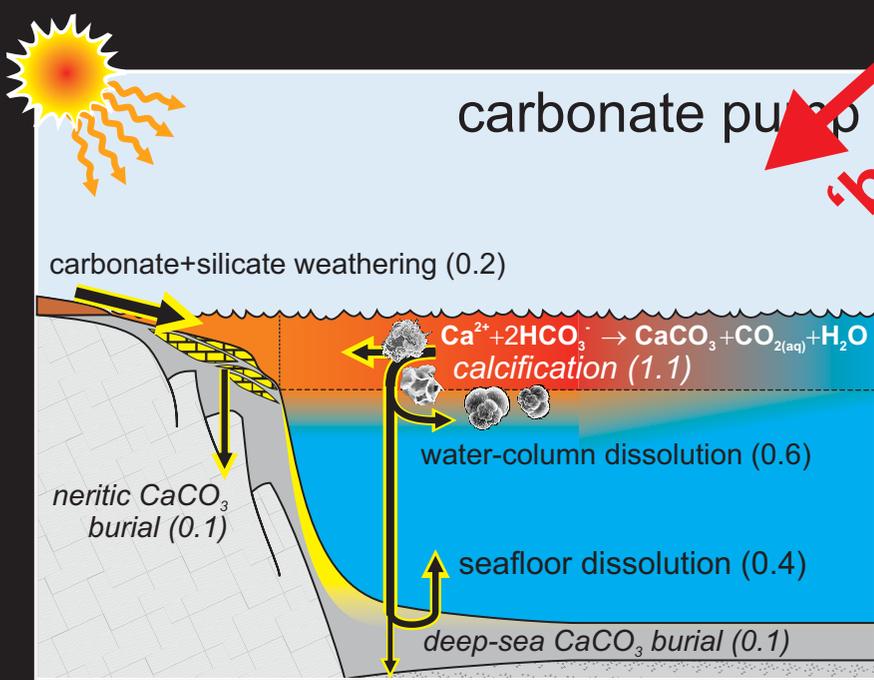
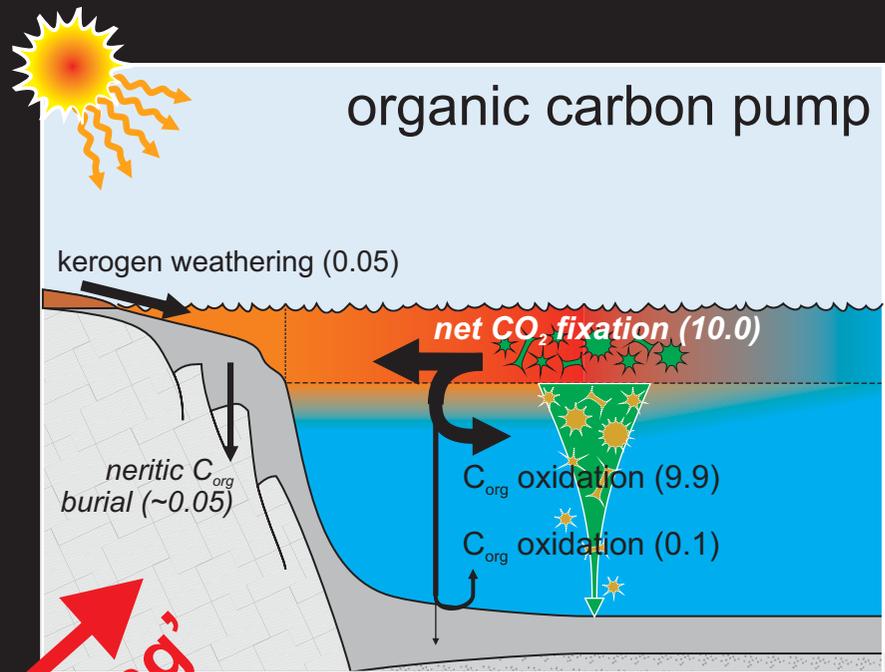




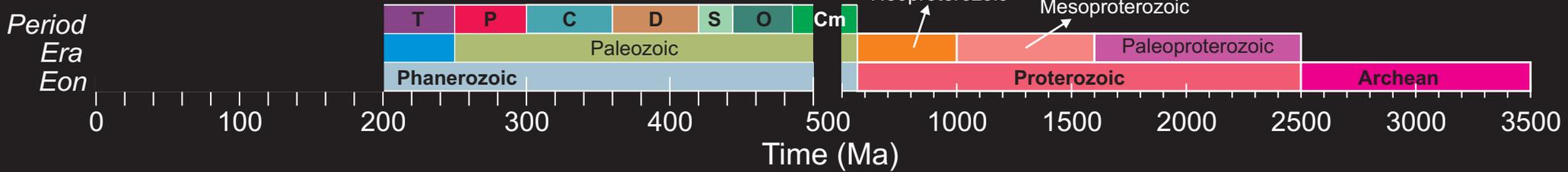
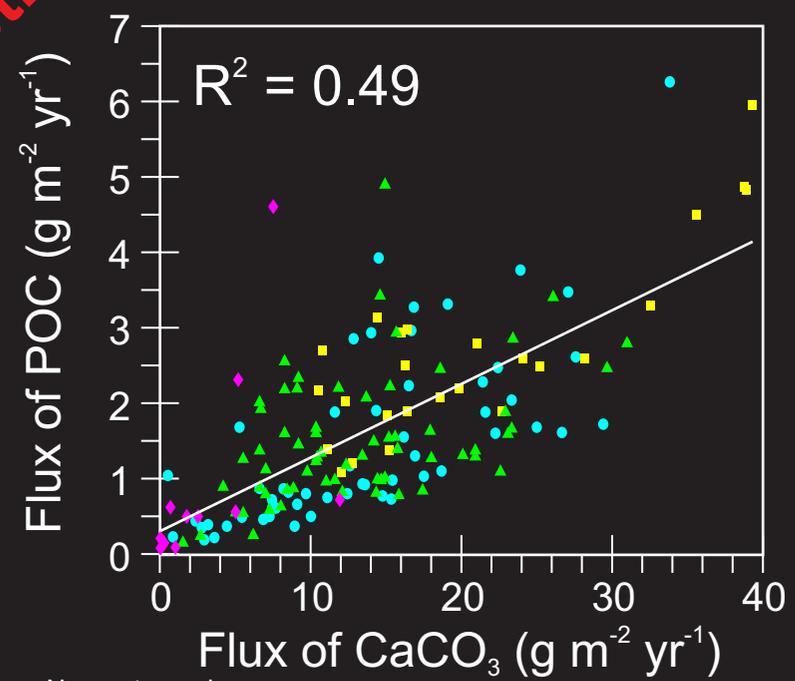


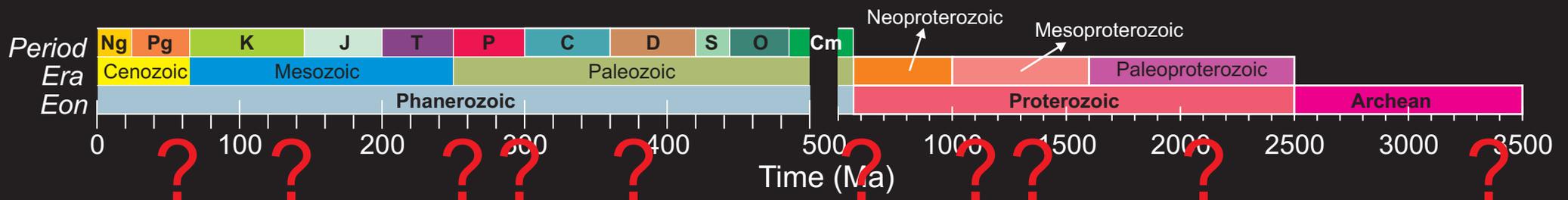
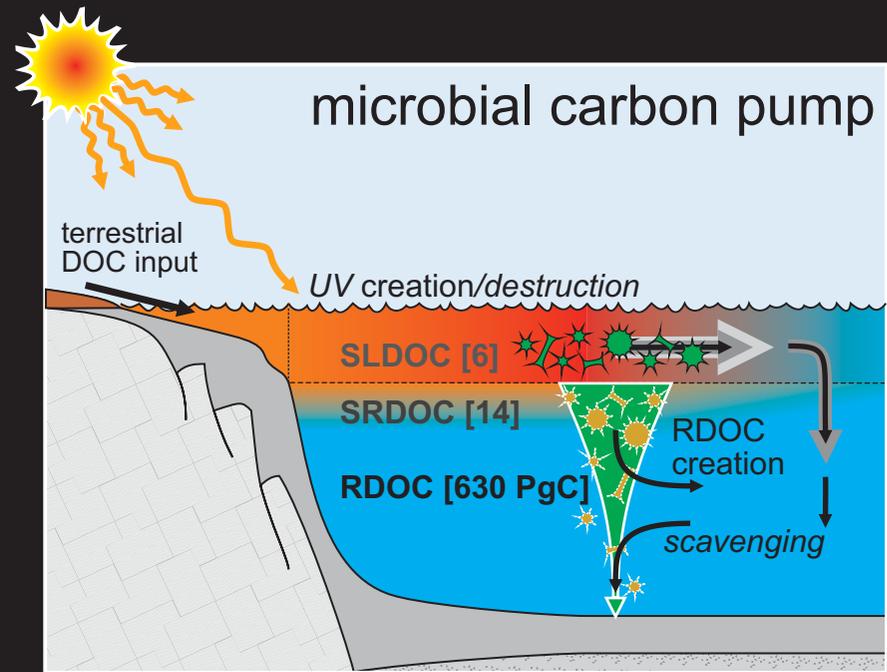
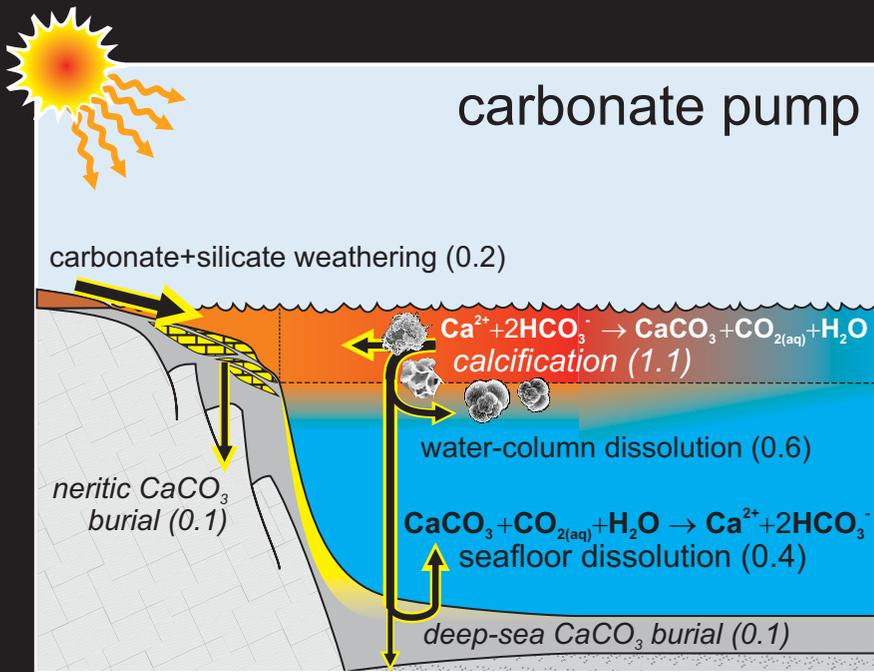
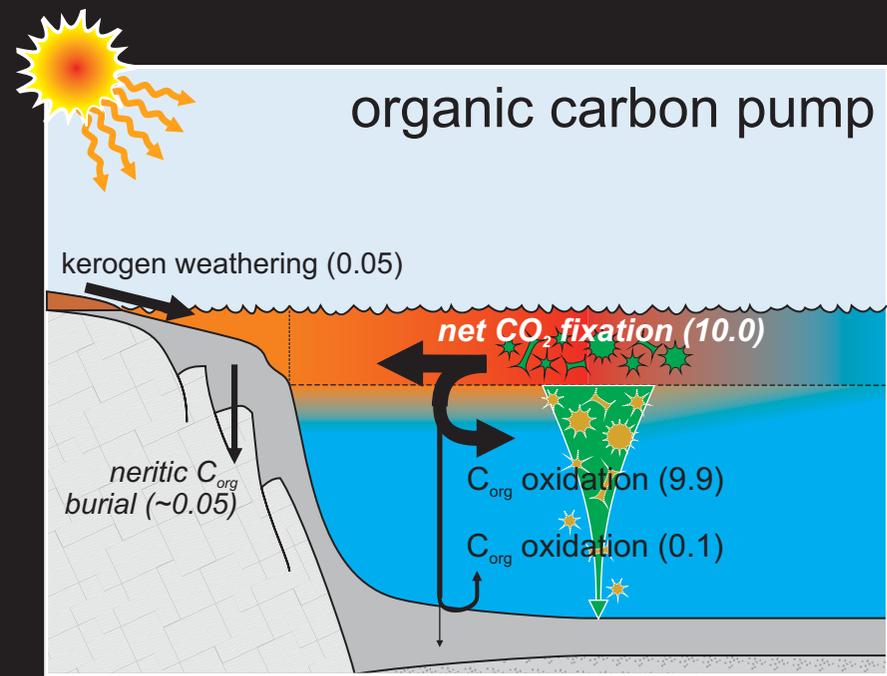
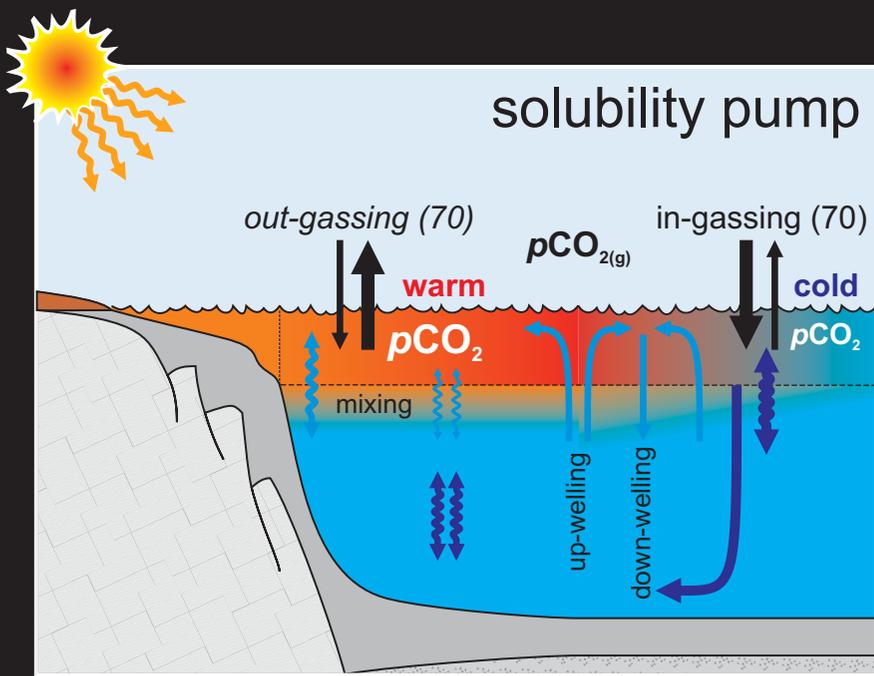






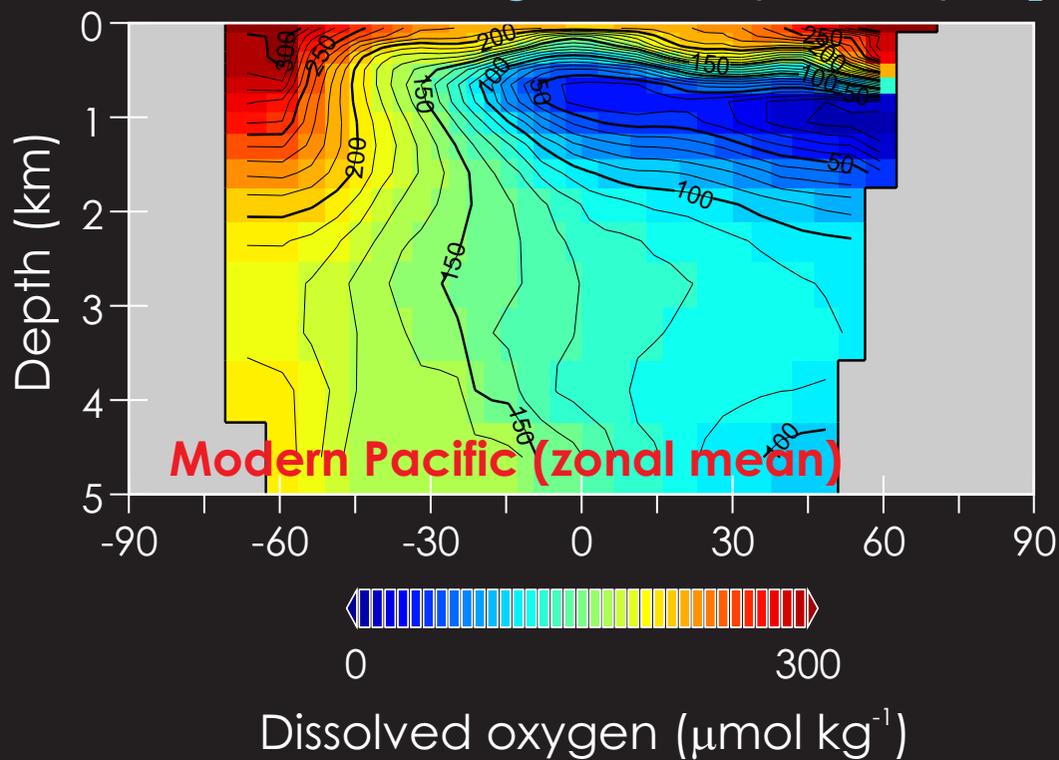
'ballasting'





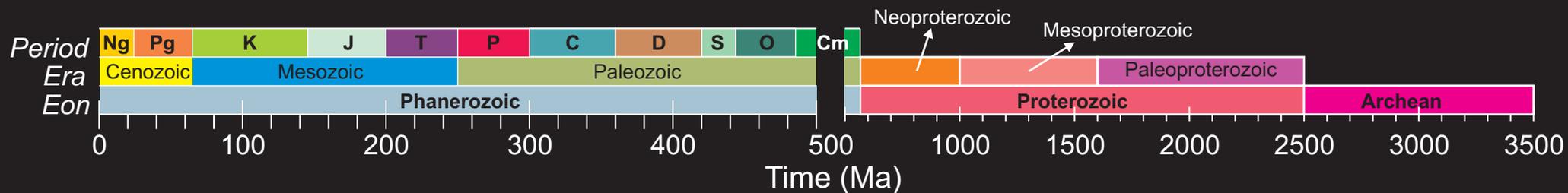
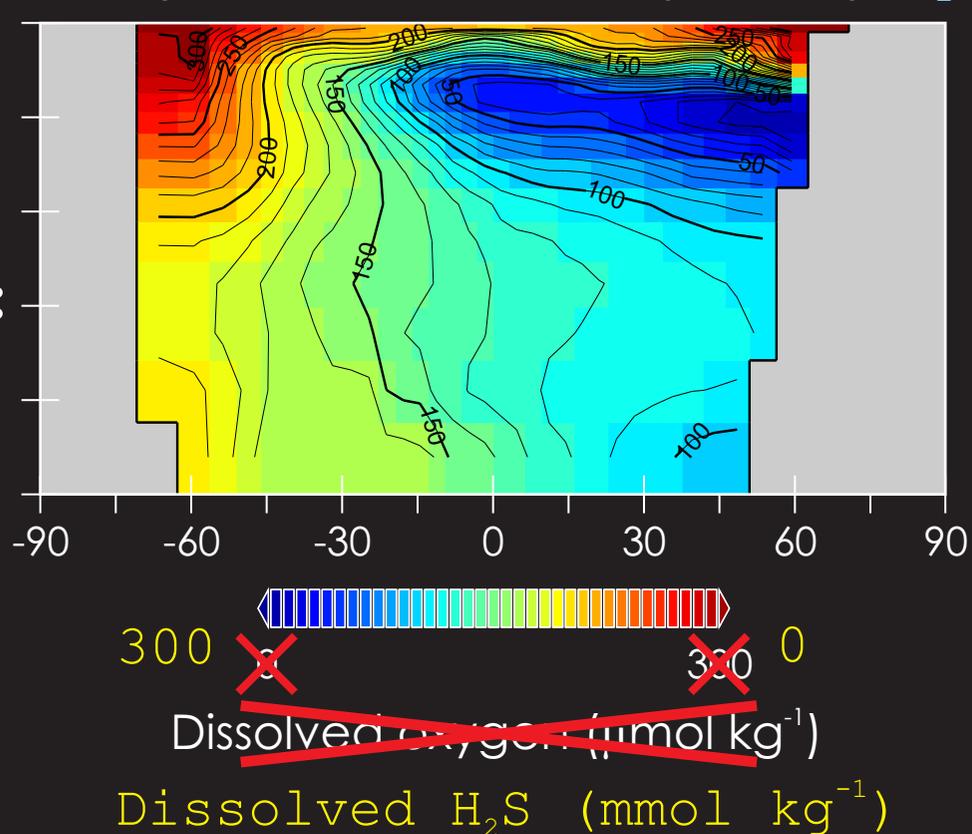
Modern vs. ancient carbon cycling

Modern: High atmospheric pO_2



Early Earth: Low atmospheric pO_2

?

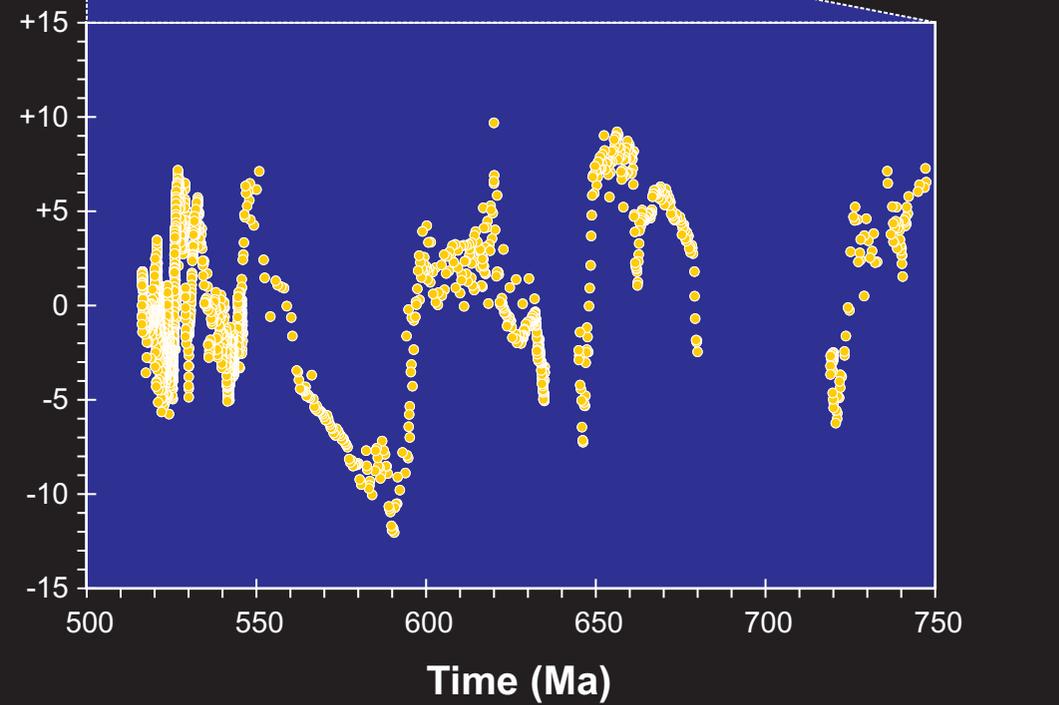
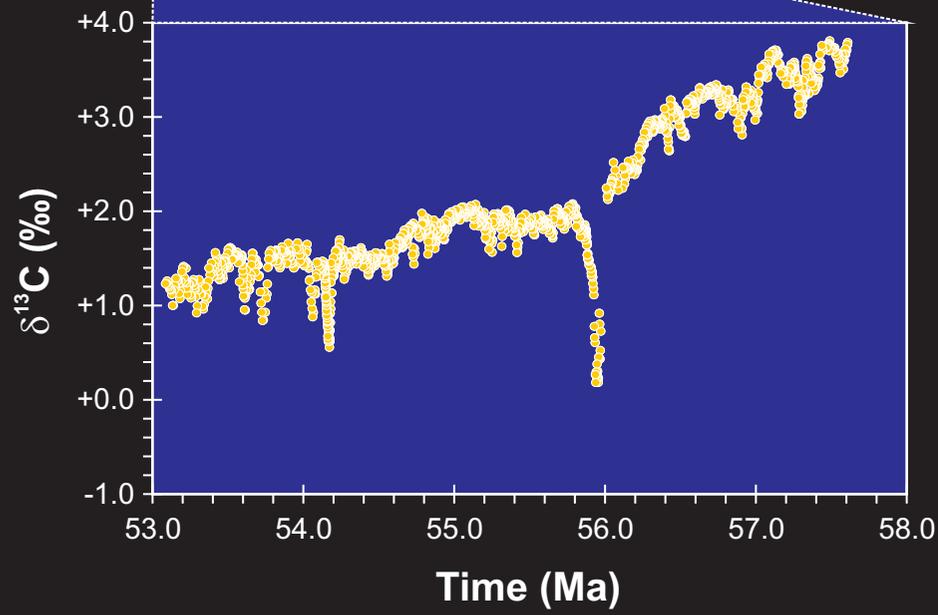
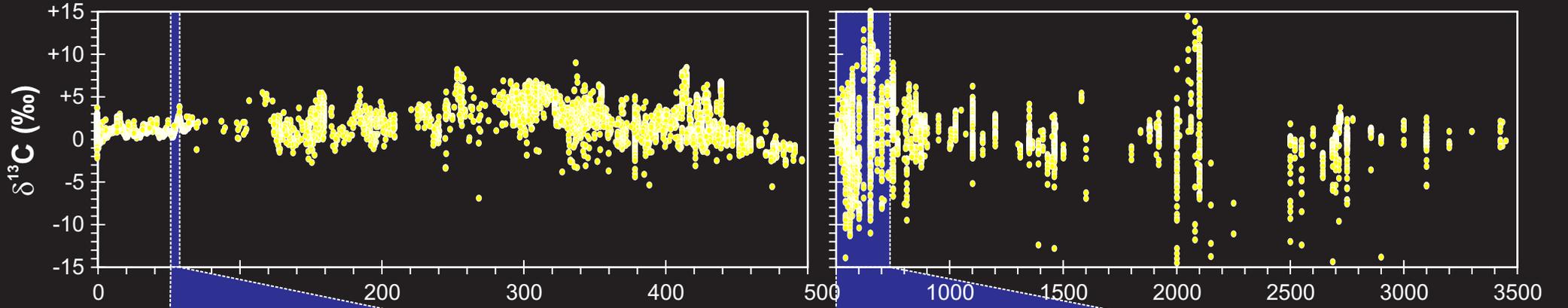
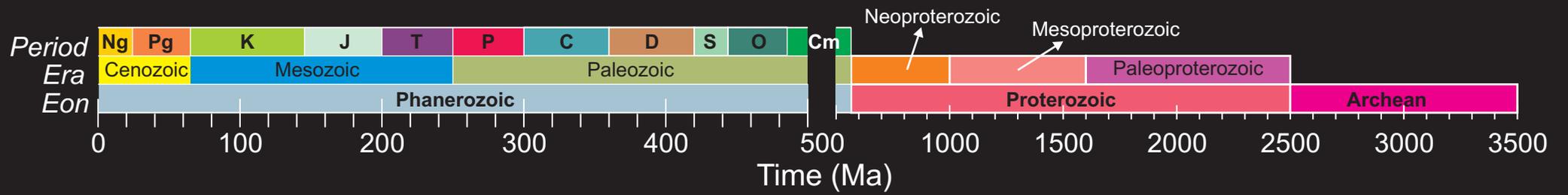


[Best • Proxy • Ever]

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Ocean Carbon Cycling and Models

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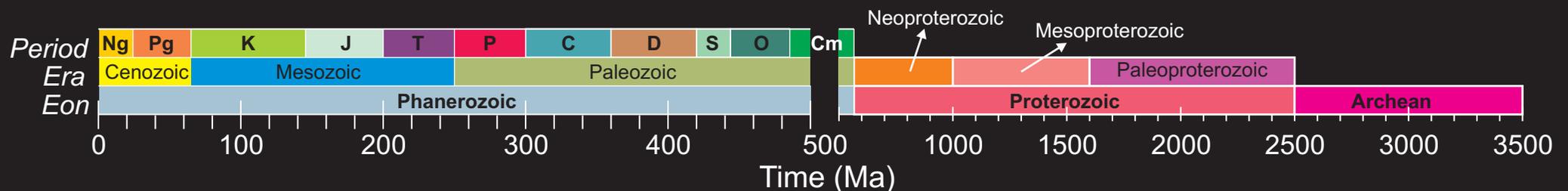
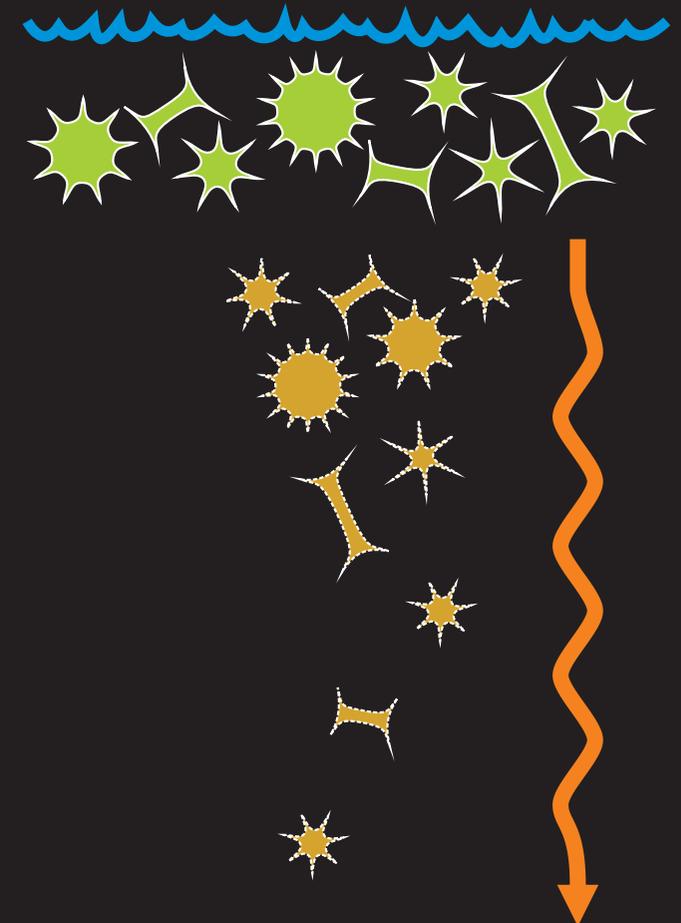
! calculate carbonate alkalinity
loc_ALK_DIC = dum_ALK &
& - loc_H4BO4 - loc_OH - loc_HPO4 - 2.0*loc_PO4 - loc_H3SiO4 - loc_NH3 - loc_HS &
& + loc_H + loc_HSO4 + loc_HF + loc_H3PO4

! estimate the partitioning between the aqueous carbonate species
loc_zed = ( &
& (4.0*loc_ALK_DIC + dum_DIC*dum_carbconst(icc_k) -
loc_ALK_DIC*dum_carbconst(icc_k)**2 + &
& 4.0*(dum_carbconst(icc_k) - 4.0)*loc_ALK_DIC**2 &
& )**0.5      loc_conc_HCO3 = (dum_DIC*dum_carbconst(icc_k) -
loc_zed)/(dum_carbconst(icc_k) - 4.0)

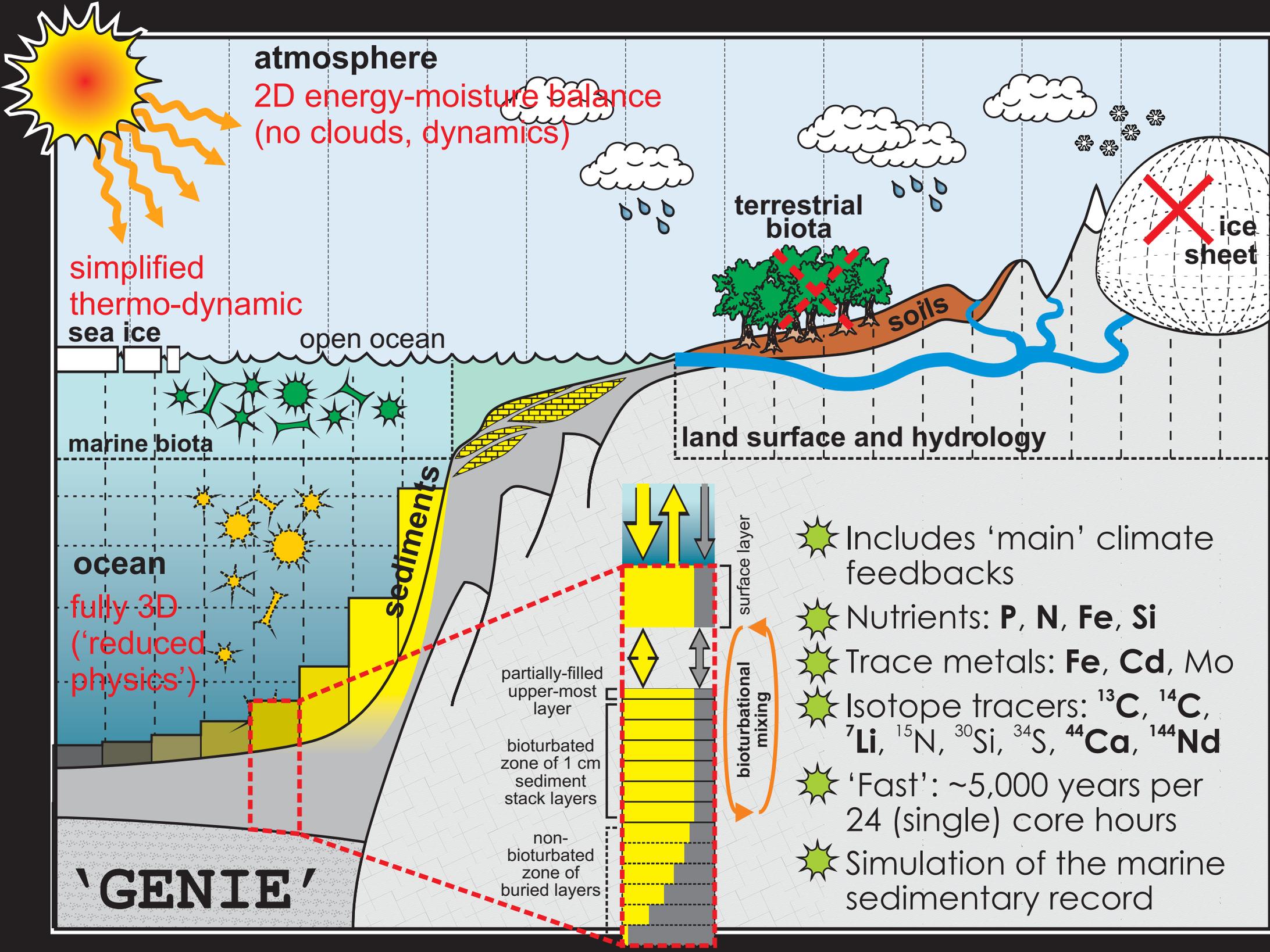
loc_conc_CO3 = &
& ( &
& loc_ALK_DIC*dum_carbconst(icc_k) - dum_DIC*dum_carbconst(icc_k) - &
& 4.0*loc_ALK_DIC + loc_zed &
& ) &
& /(2.0*(dum_carbconst(icc_k) - 4.0))

loc_conc_CO2 = dum_DIC - loc_ALK_DIC + &
& ( &
& loc_ALK_DIC*dum_carbconst(icc_k) - dum_DIC*dum_carbconst(icc_k) - &
& 4.0*loc_ALK_DIC + loc_zed &
& ) &
& /(2.0*(dum_carbconst(icc_k) - 4.0))

loc_H1 = dum_carbconst(icc_k1)*loc_conc_CO2/loc_conc_HCO3
loc_H2 = dum_carbconst(icc_k2)*loc_conc_HCO3/loc_conc_CO3
    
```







atmosphere
 2D energy-moisture balance
 (no clouds, dynamics)

simplified thermo-dynamic sea ice

open ocean

marine biota

ocean
 fully 3D ('reduced physics')

'GENIE'

terrestrial biota

soils

~~ice sheet~~

land surface and hydrology

sediments

partially-filled upper-most layer

bioturbated zone of 1 cm sediment stack layers

non-bioturbated zone of buried layers

surface layer

bioturbational mixing

- ☀ Includes 'main' climate feedbacks
- ☀ Nutrients: **P, N, Fe, Si**
- ☀ Trace metals: **Fe, Cd, Mo**
- ☀ Isotope tracers: ^{13}C , ^{14}C , ^7Li , ^{15}N , ^{30}Si , ^{34}S , ^{44}Ca , ^{144}Nd
- ☀ 'Fast': ~5,000 years per 24 (single) core hours
- ☀ Simulation of the marine sedimentary record

<https://svn.ggy.bris.ac.uk/subversion/genie/tags/cgenie.Harvard2014>

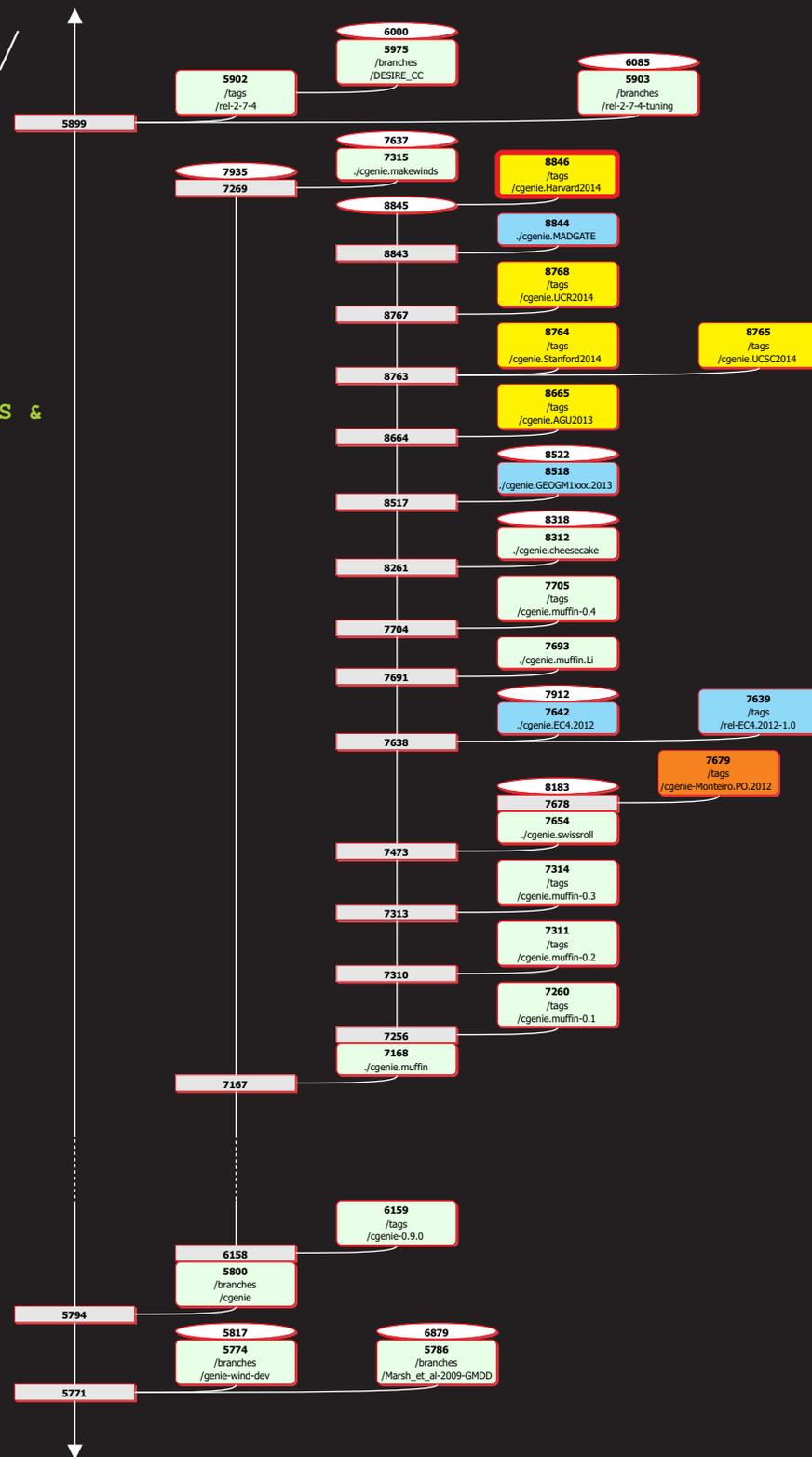
```
! calculate carbonate alkalinity
loc_ALK_DIC = dum_ALK &
& - loc_H4BO4 - loc_OH - loc_HPO4 - 2.0*loc_PO4 - loc_H3SiO4 - loc_NH3 - loc_HS &
& + loc_H + loc_HSO4 + loc_HF + loc_H3PO4

! estimate the partitioning between the aqueous carbonate species
loc_zed = ( &
& (4.0*loc_ALK_DIC + dum_DIC*dum_carbconst(icc_k) -
loc_ALK_DIC*dum_carbconst(icc_k))**2 + &
& 4.0*(dum_carbconst(icc_k) - 4.0)*loc_ALK_DIC**2 &
& )**0.5
loc_conc_HCO3 = (dum_DIC*dum_carbconst(icc_k) -
loc_zed)/(dum_carbconst(icc_k) - 4.0)

loc_conc_CO3 = &
& ( &
& loc_ALK_DIC*dum_carbconst(icc_k) - dum_DIC*dum_carbconst(icc_k) - &
& 4.0*loc_ALK_DIC + loc_zed &
& ) &
& /(2.0*(dum_carbconst(icc_k) - 4.0))

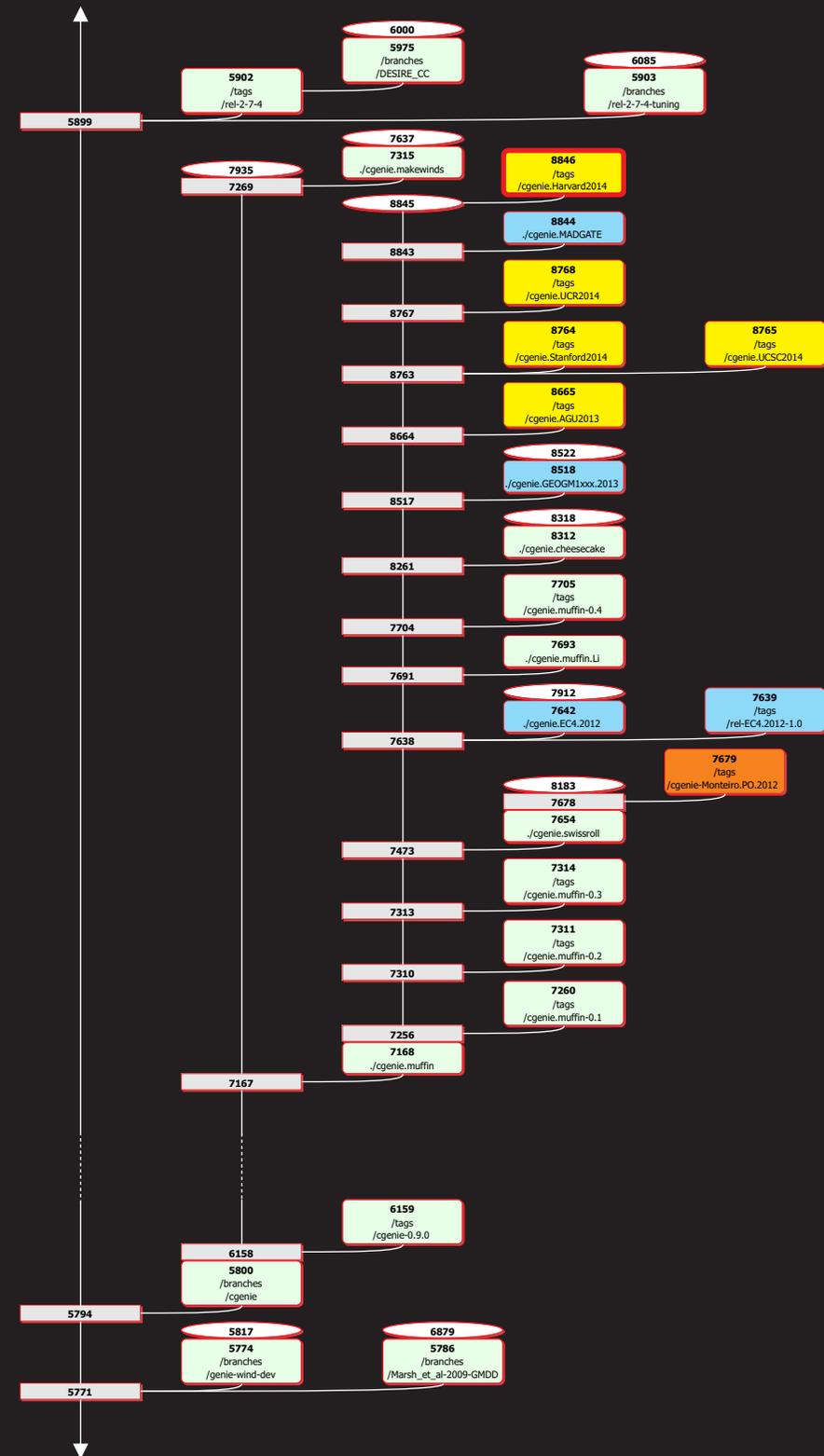
loc_conc_CO2 = dum_DIC - loc_ALK_DIC + &
& ( &
& loc_ALK_DIC*dum_carbconst(icc_k) - dum_DIC*dum_carbconst(icc_k) - &
& 4.0*loc_ALK_DIC + loc_zed &
& ) &
& /(2.0*(dum_carbconst(icc_k) - 4.0))

loc_H1 = dum_carbconst(icc_k1)*loc_conc_CO2/loc_conc_HCO3
loc_H2 = dum_carbconst(icc_k2)*loc_conc_HCO3/loc_conc_CO3
```

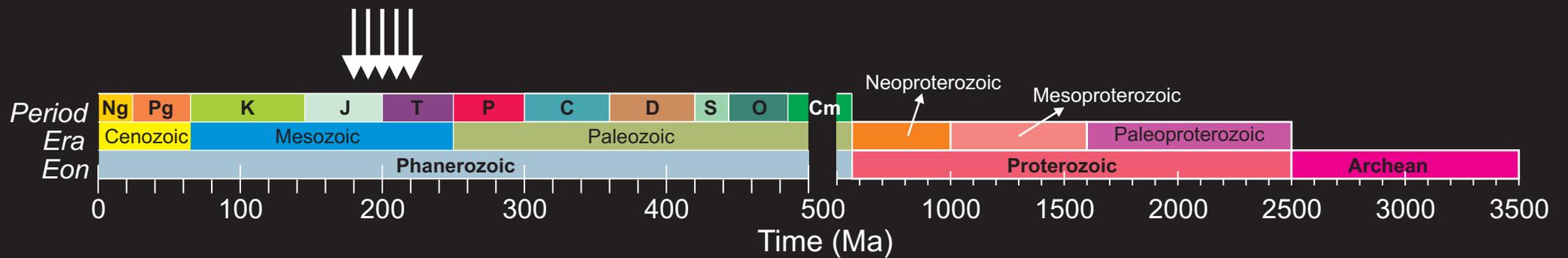




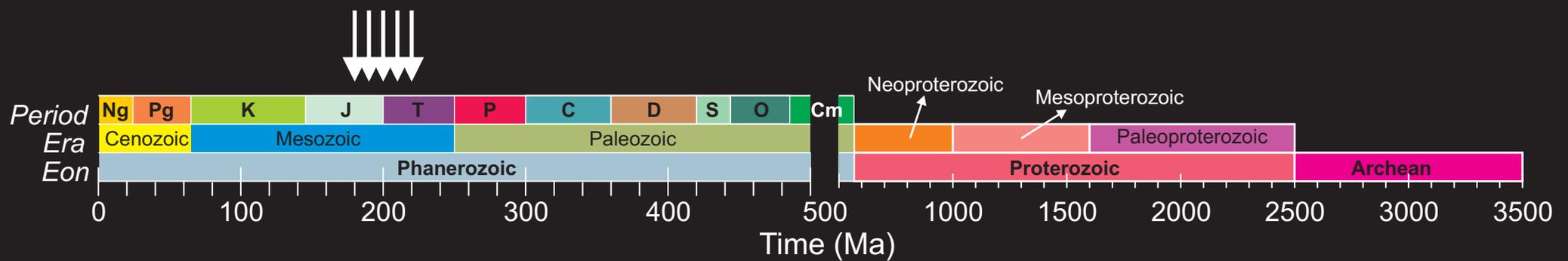
www.seao2.info/misc_harvard2014.html



Not the PETM ...



Not the PETM ...

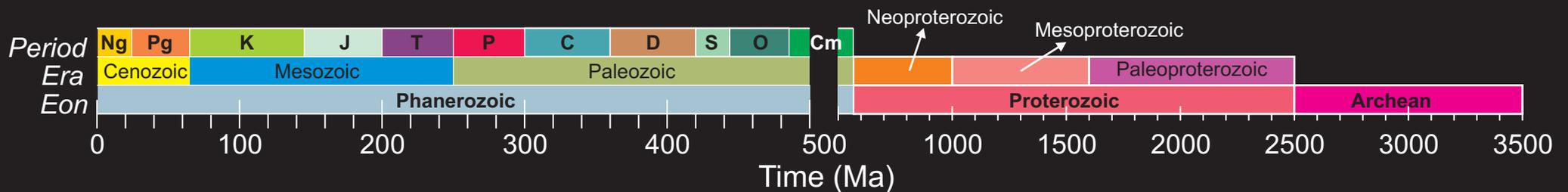


CaCO₃ cycling through time

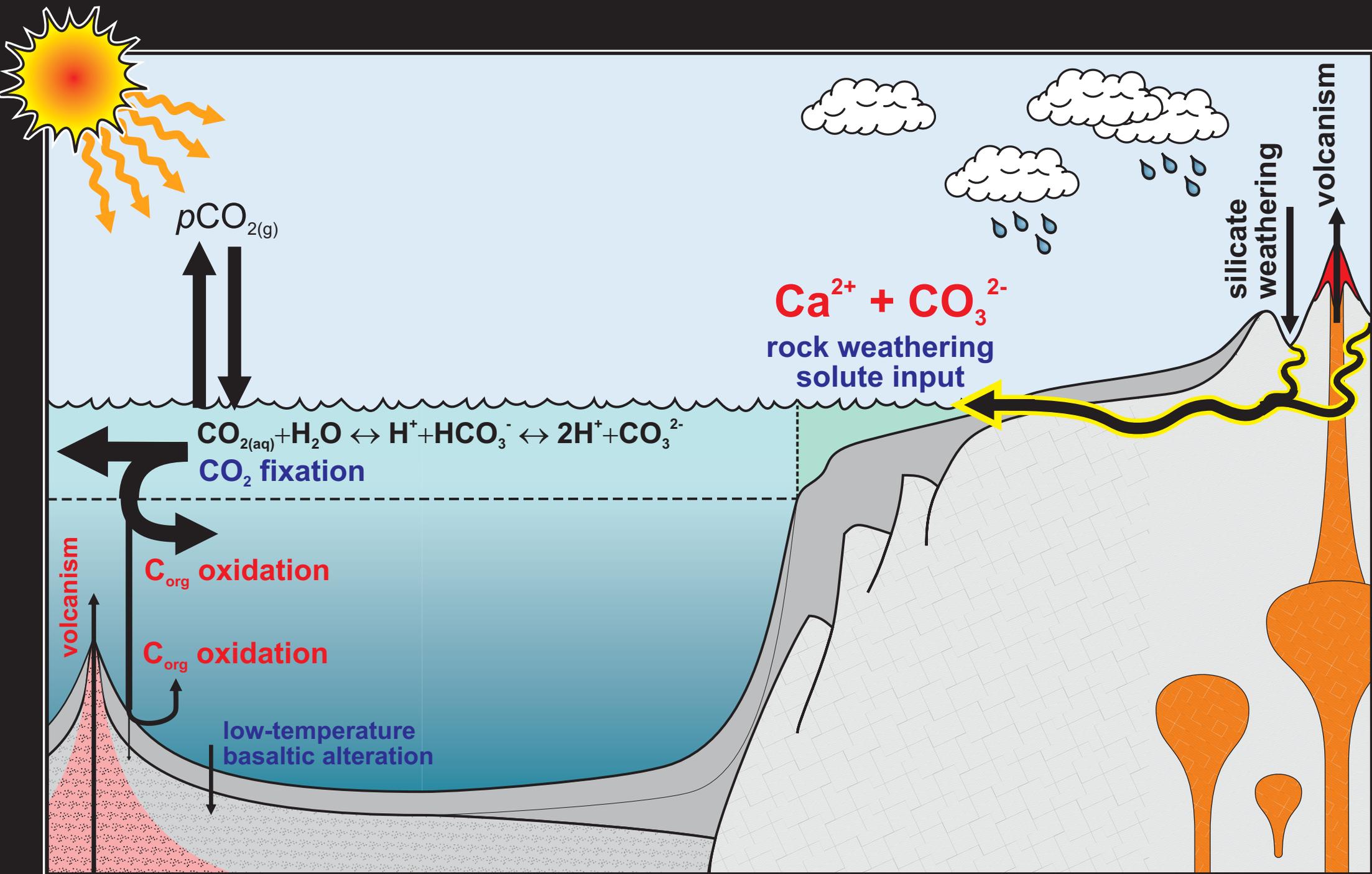


Major changes in plankton assemblage

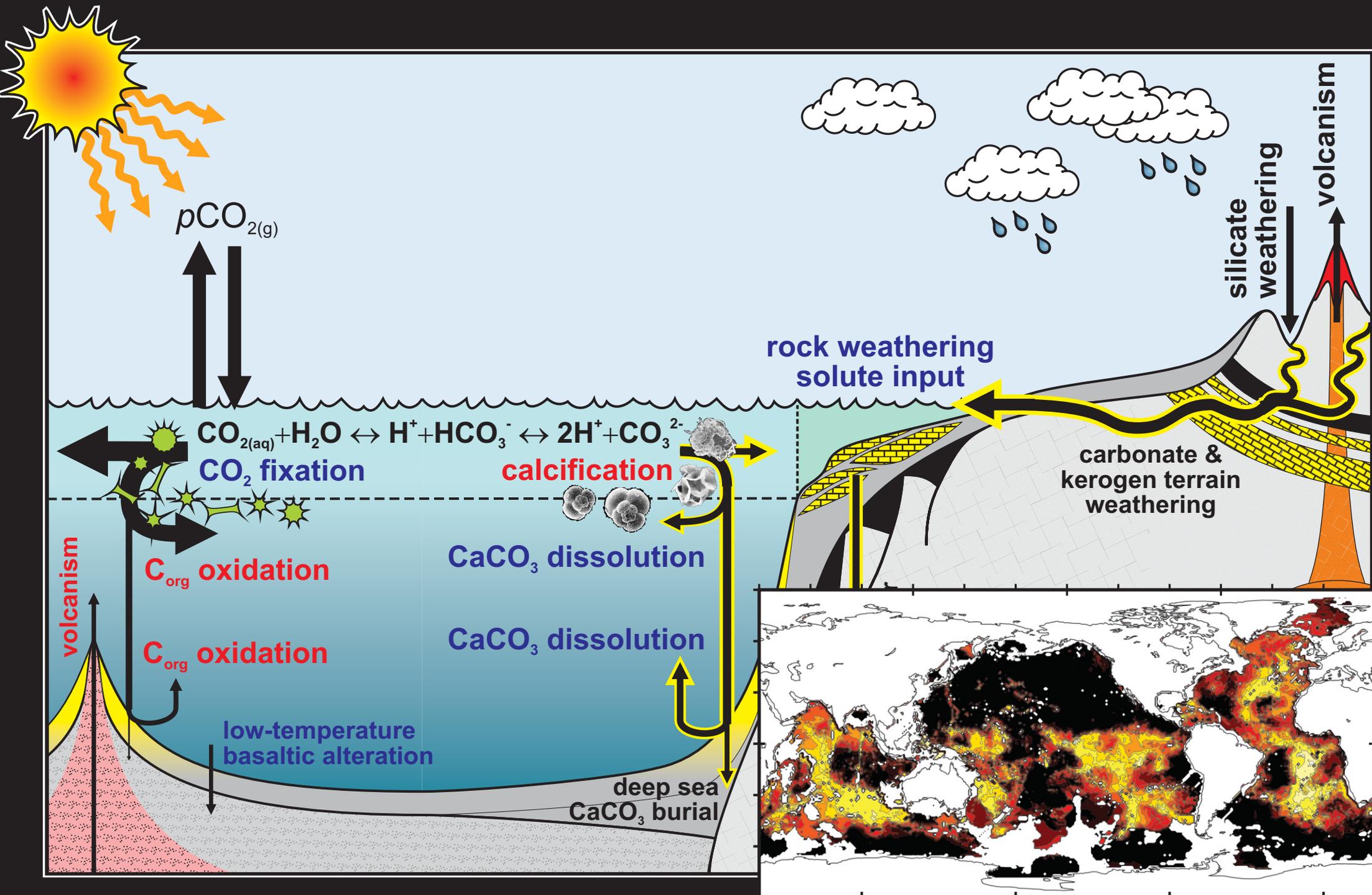
Martin [1995]



CaCO₃ cycling through time

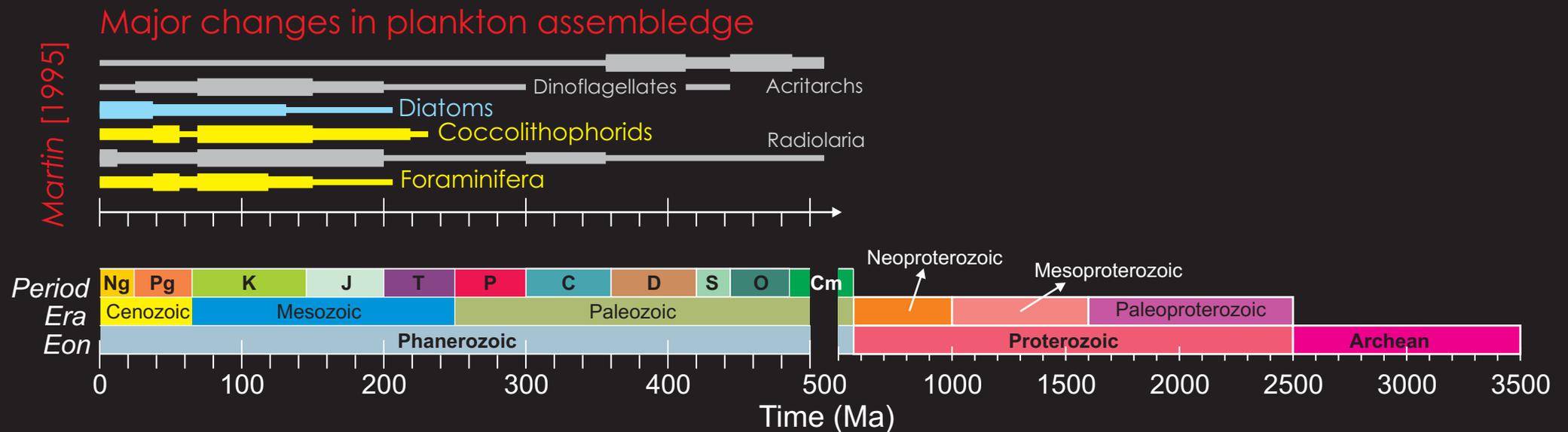


CaCO₃ cycling through time



CaCO₃ cycling through time

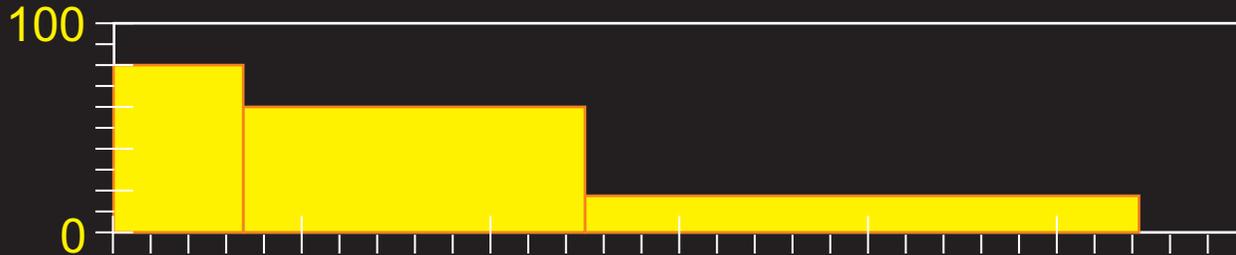
What do we not 'have' prior to about ~180 Ma?



CaCO₃ cycling through time

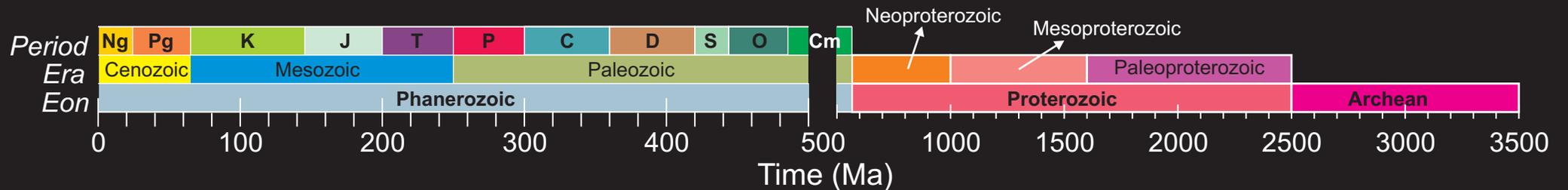
Boss and Wilkinson [1991]

% occurrence of carbonate in ophiolite suites

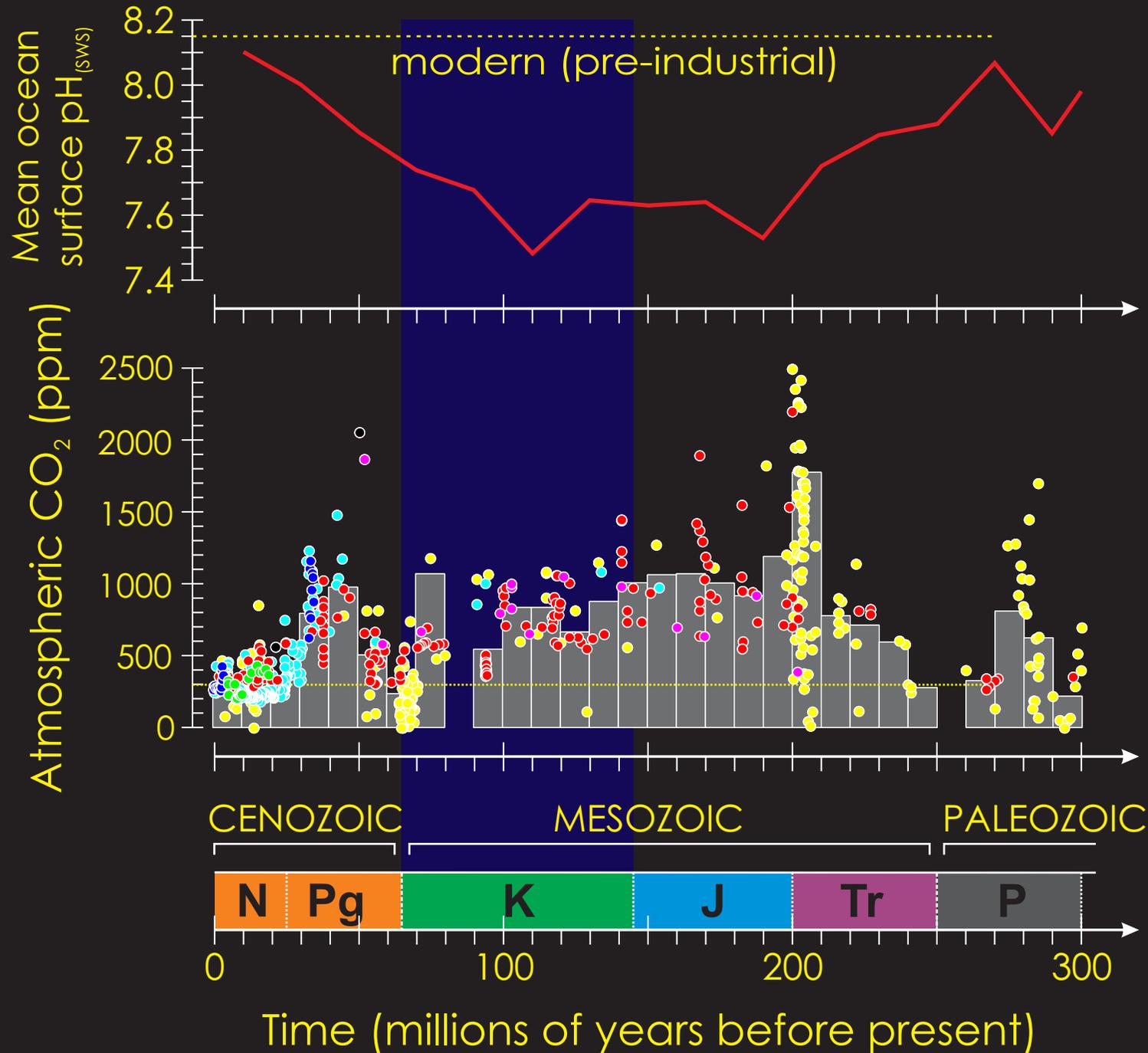


Martin [1995]

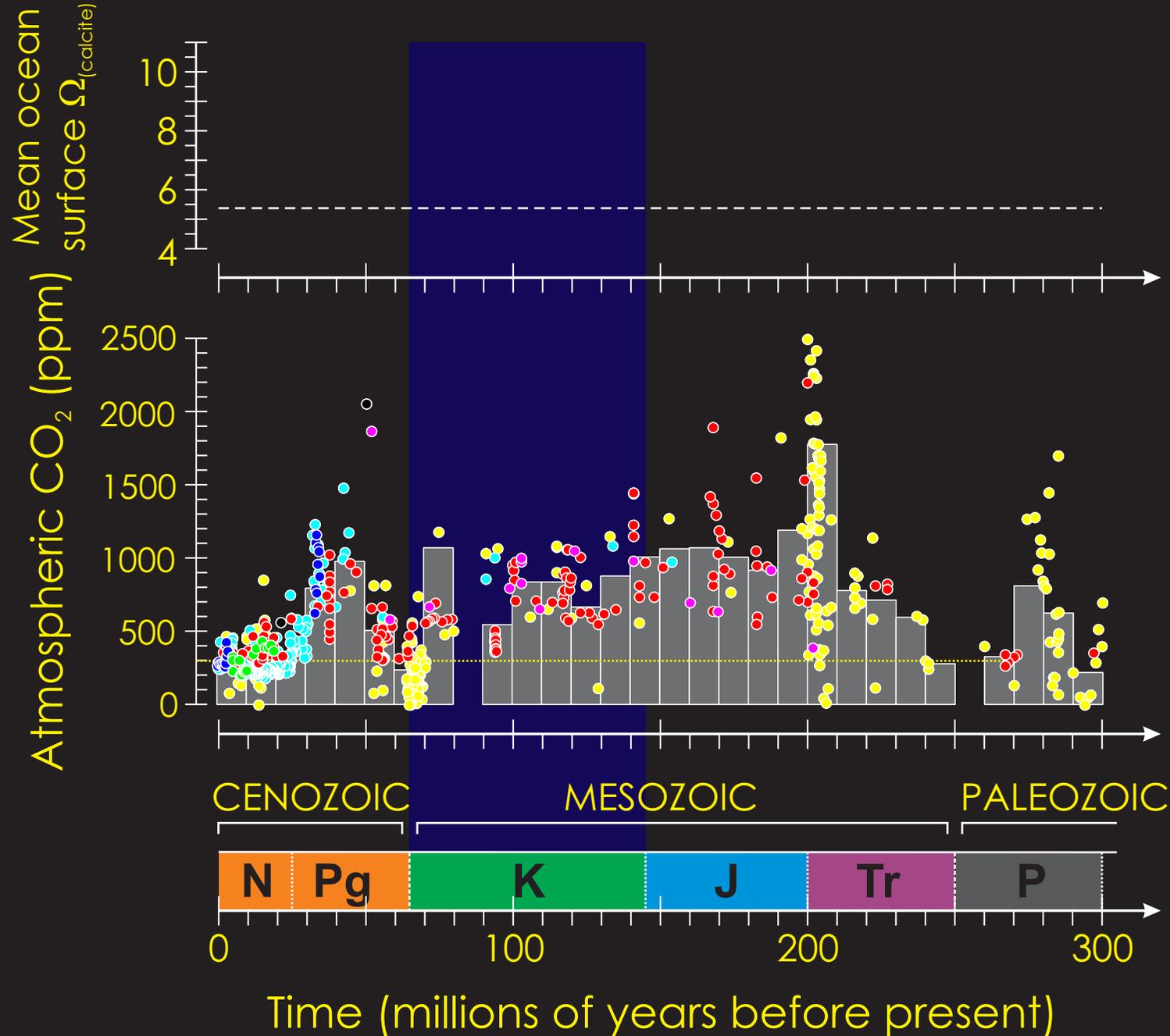
Major changes in plankton assemblage



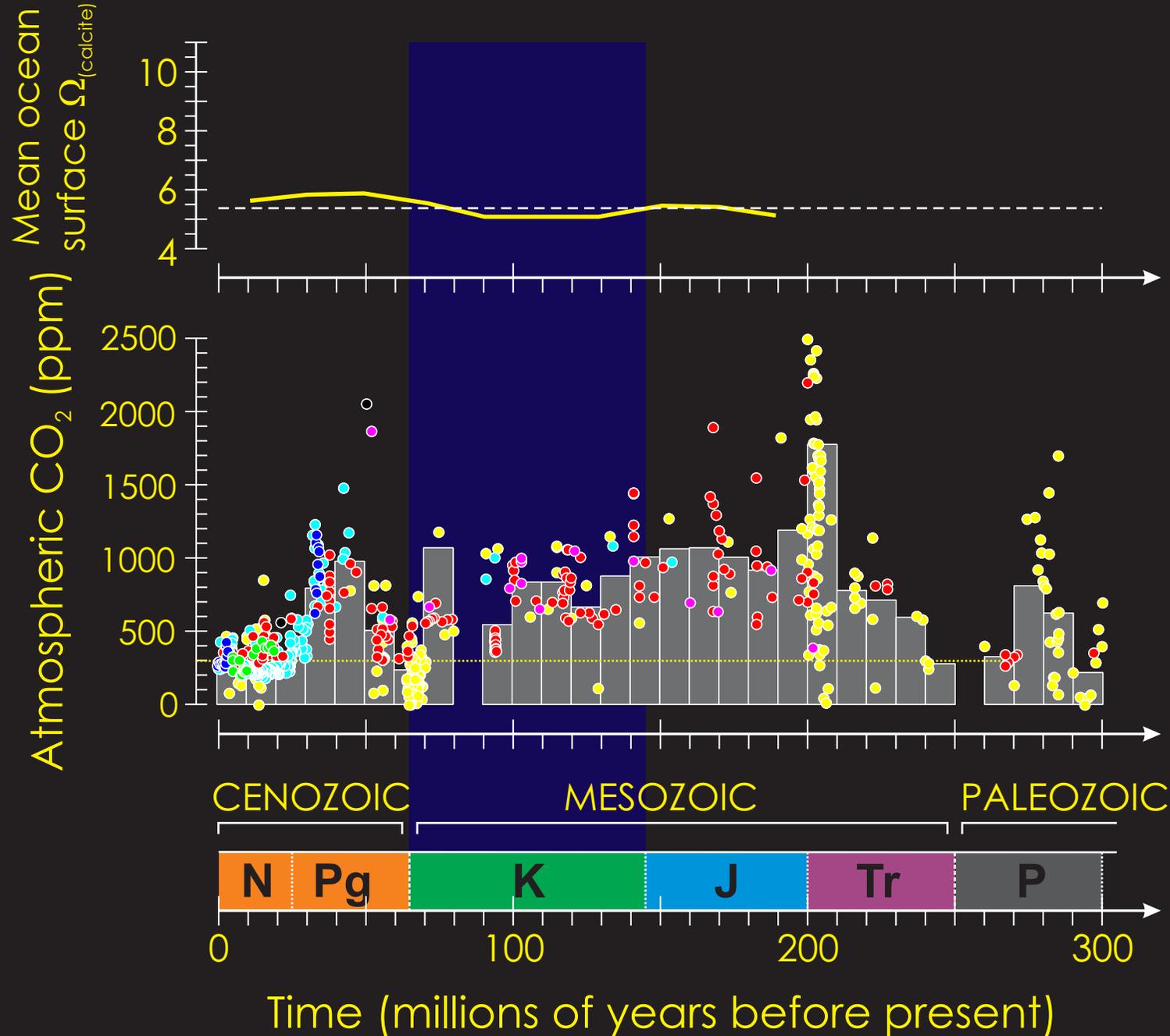
CaCO₃ cycling through time



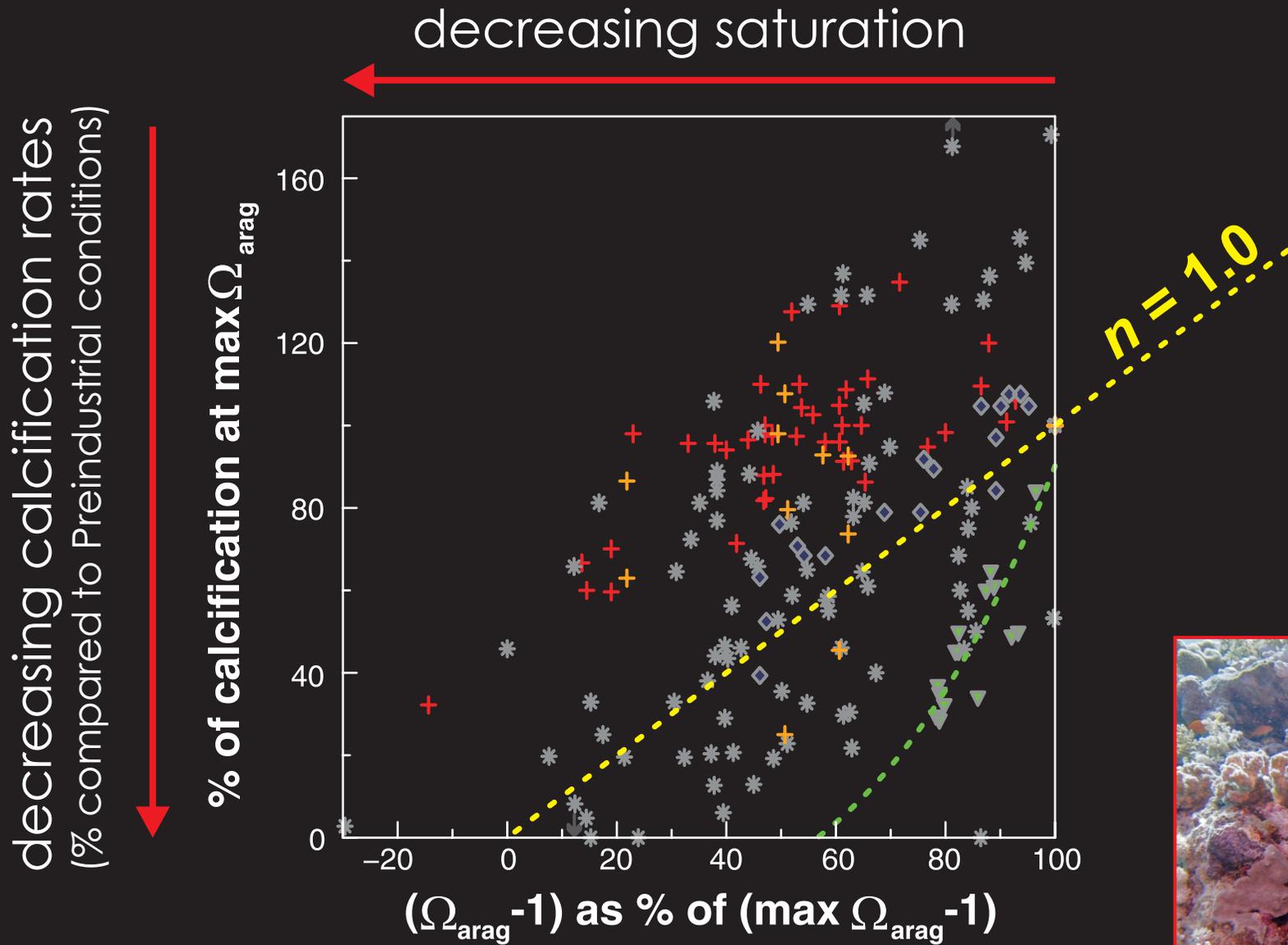
CaCO₃ cycling through time



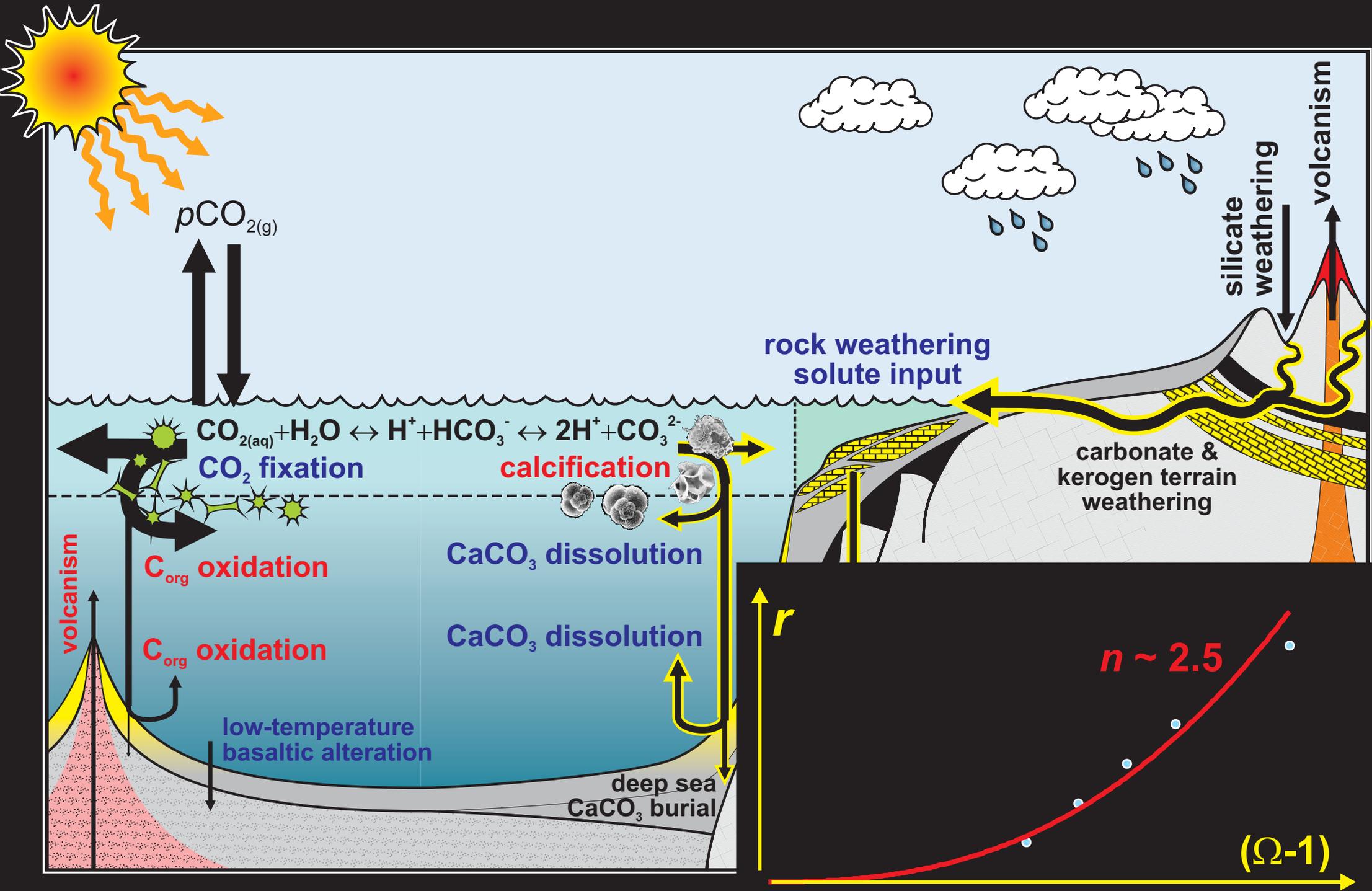
CaCO₃ cycling through time



CaCO₃ cycling through time



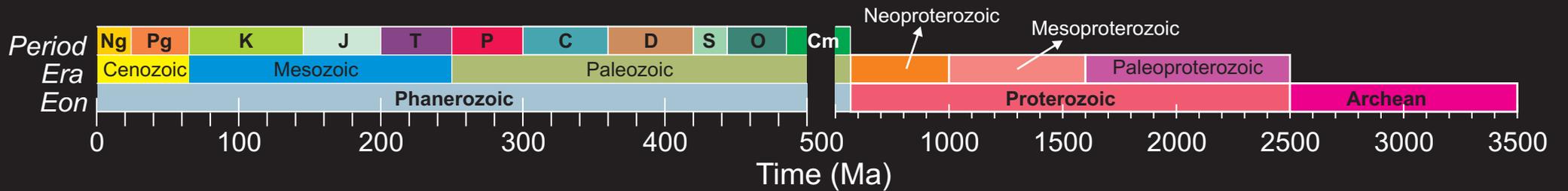
CaCO₃ cycling through time

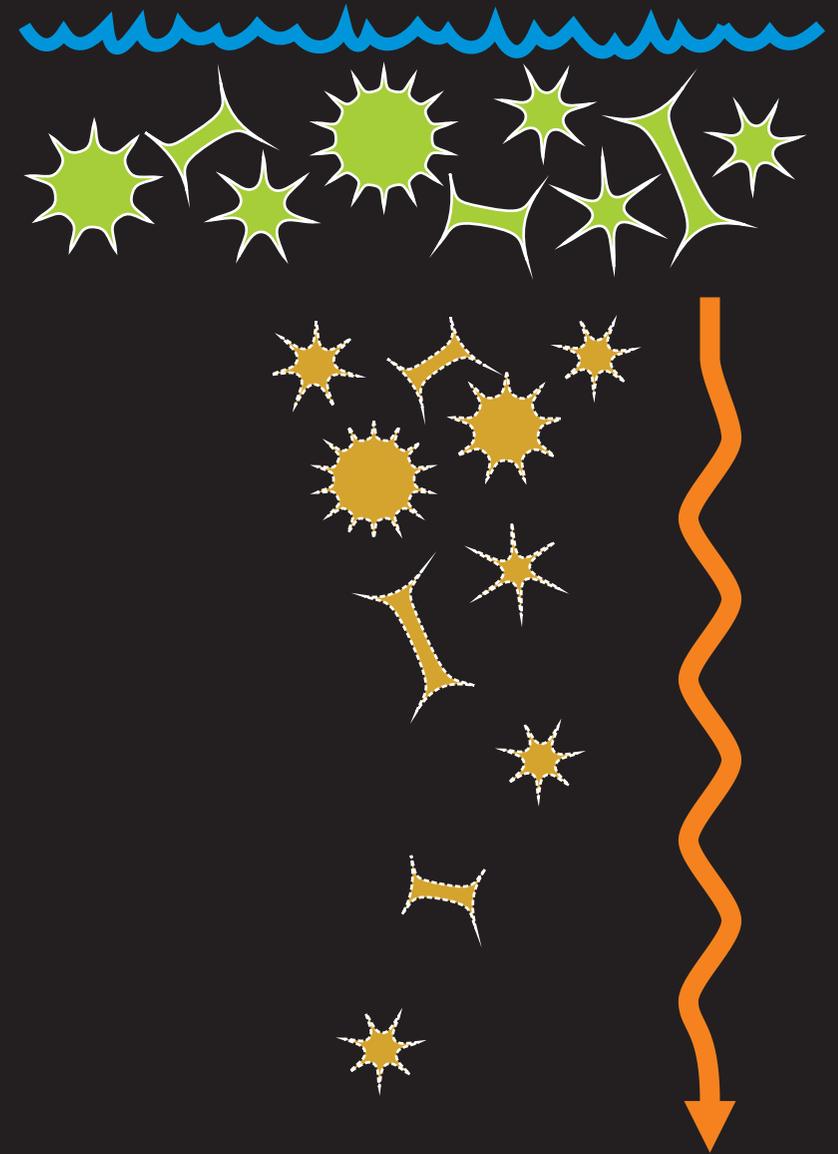
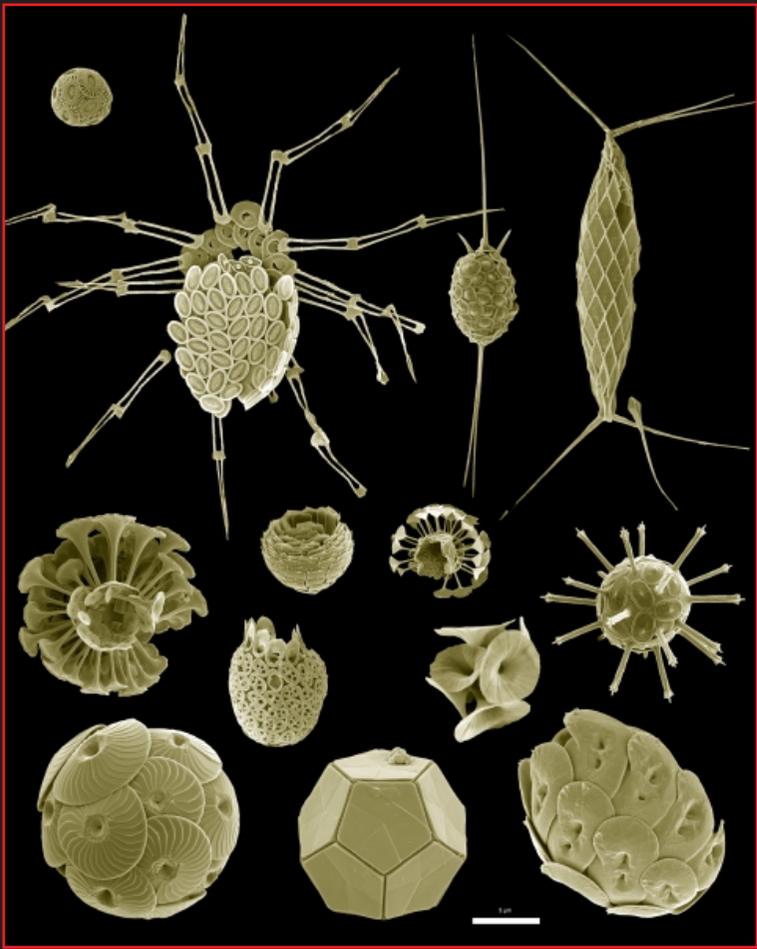




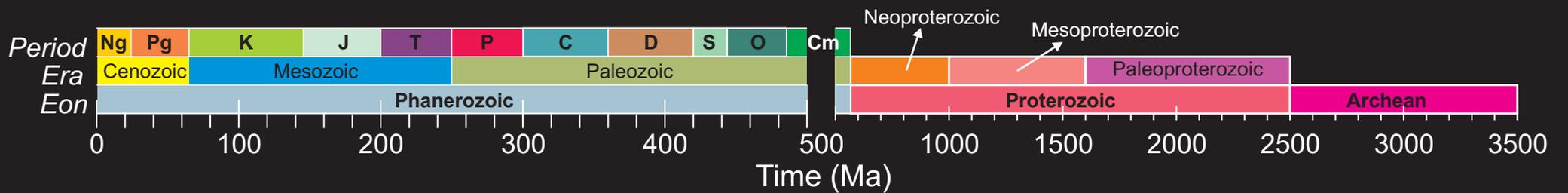
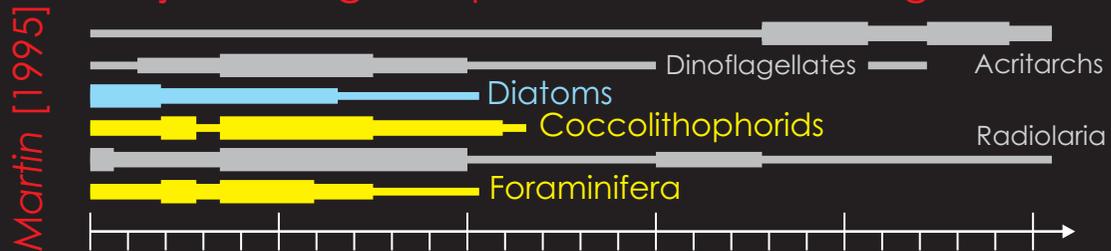
Major changes in plankton assemblage

Martin [1995]





Major changes in plankton assemblage



CaCO₃ cycling through time:

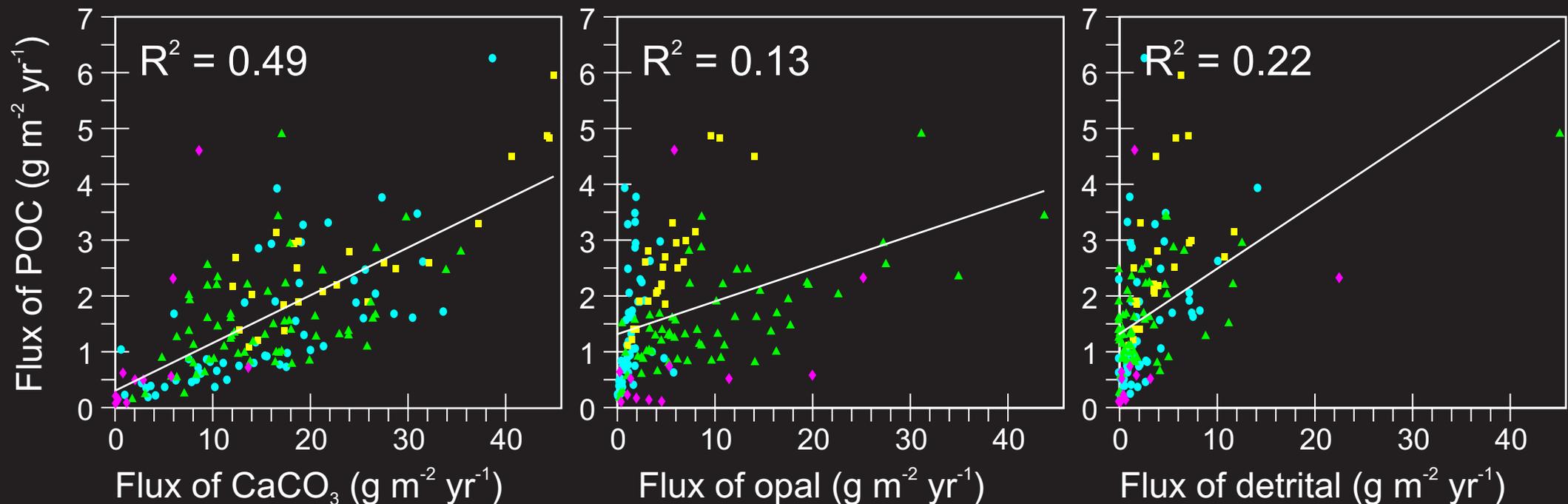
Planktic carbonate production and 'ballasting'

Compilation of sediment trap observations:

depths ≥ 2000 m (to exclude hydrodynamically distorted fluxes and relationships) and differentiated by basin:

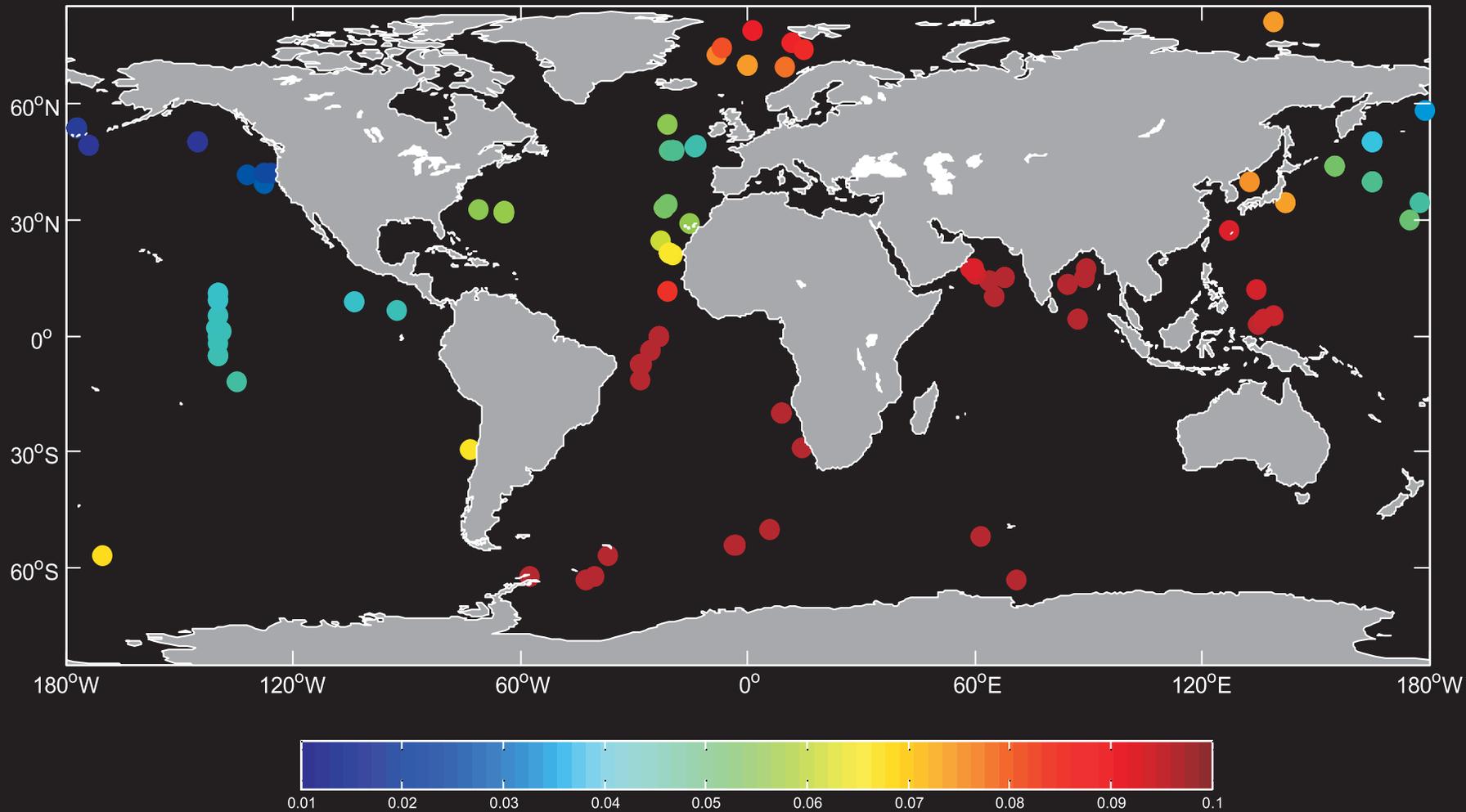
cyan == Atl, yellow == Ind, green == Pac, magenta == SO.

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



CaCO₃ cycling through time:

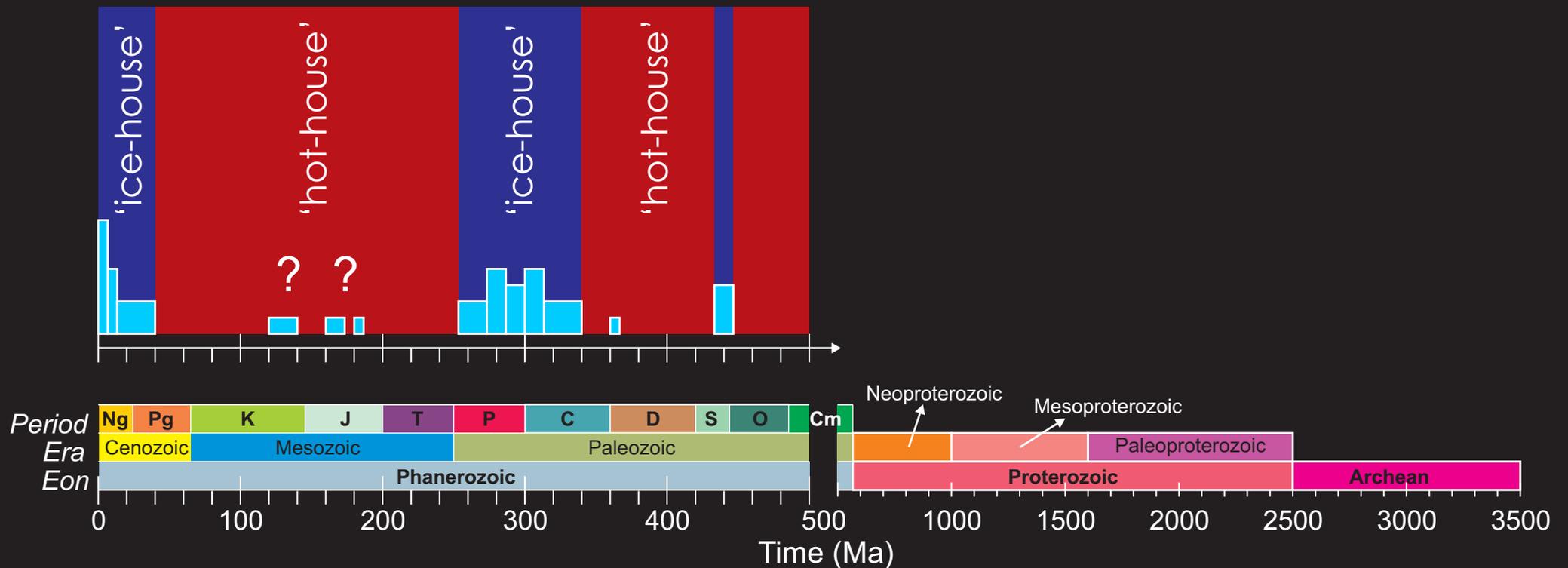
Planktic carbonate production and 'ballasting'



Spatial distribution of carrying capacity (ballasting) coefficients calculated using geographically weighted regression analysis for CaCO₃.

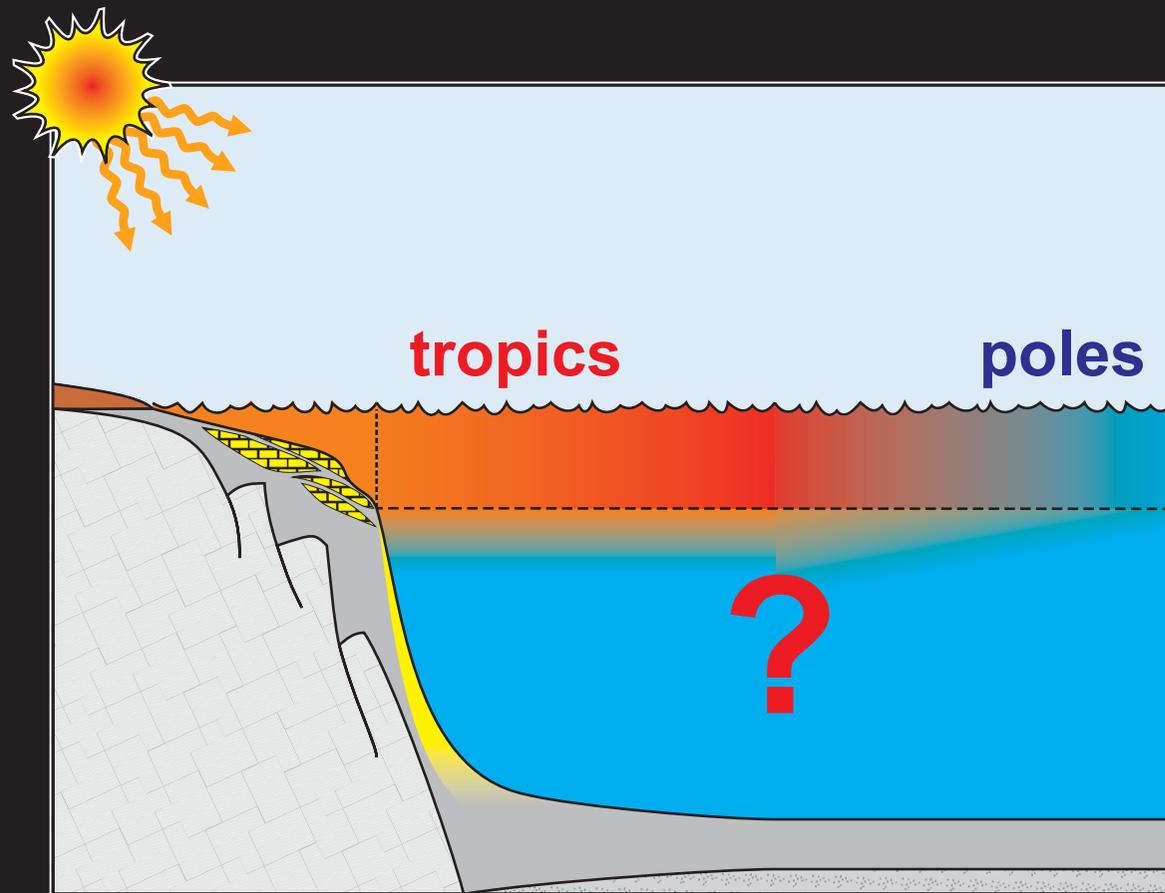
Ocean Carbon Cycling and Oxygenation in Warm Climates

(Not necessarily the PETM)



Ocean Carbon Cycling and Oxygenation in Warm Climates

(Not necessarily the PETM)



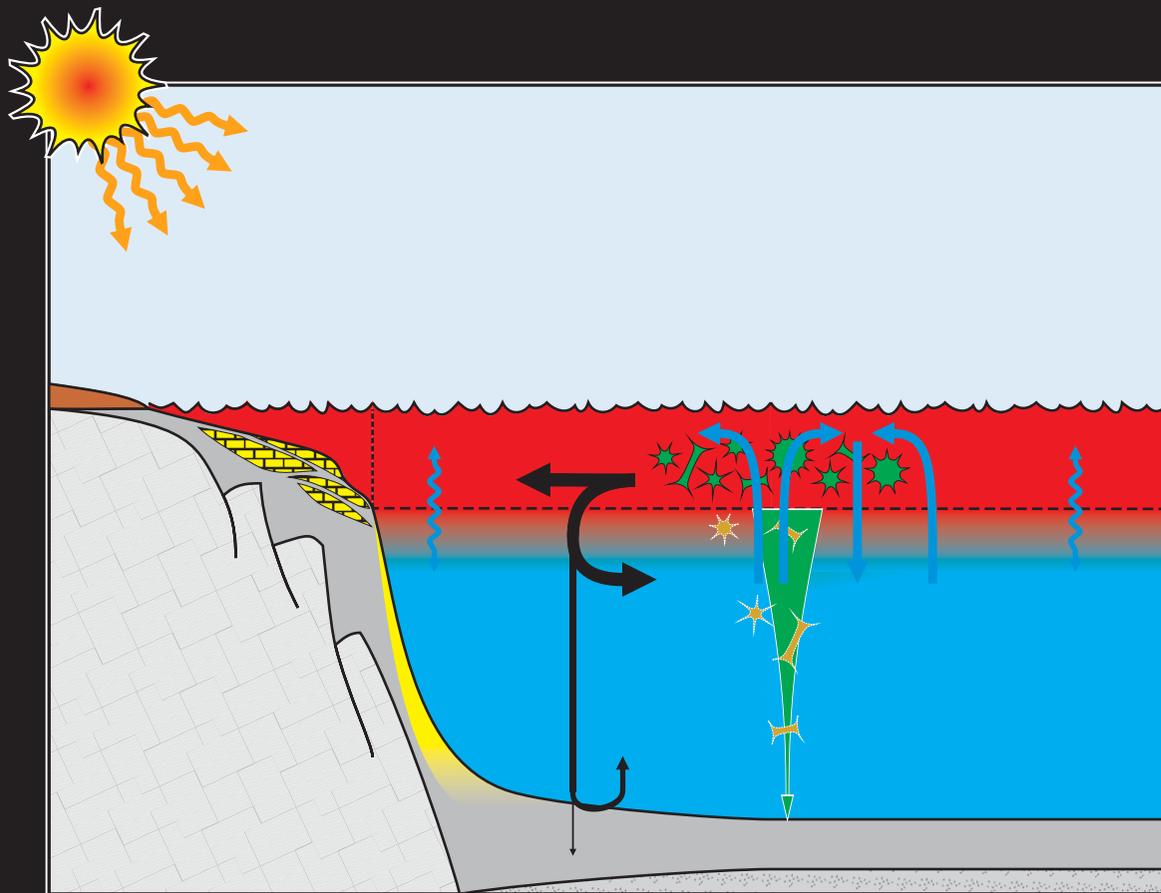
Ocean Carbon Cycling and Oxygenation in Warm Climates

(Not necessarily the PETM)

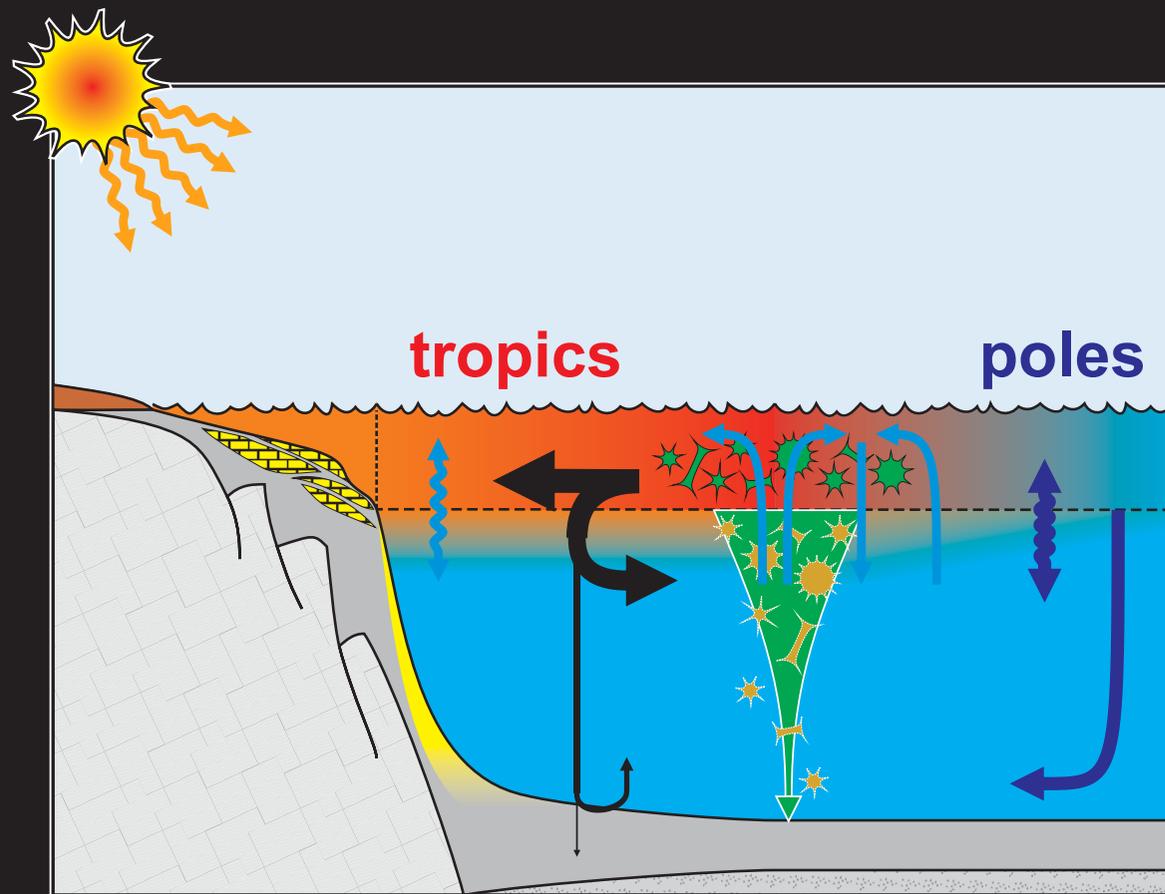
(warm == stratified) && (stratified == anoxic) == .true.

???

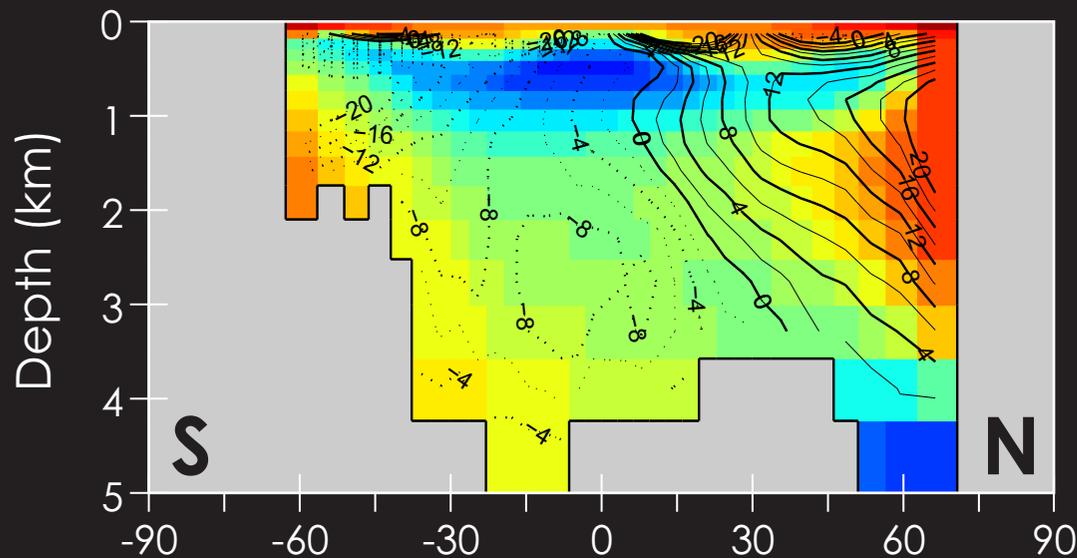
('stratified' || 'sluggish' || 'stagnant')



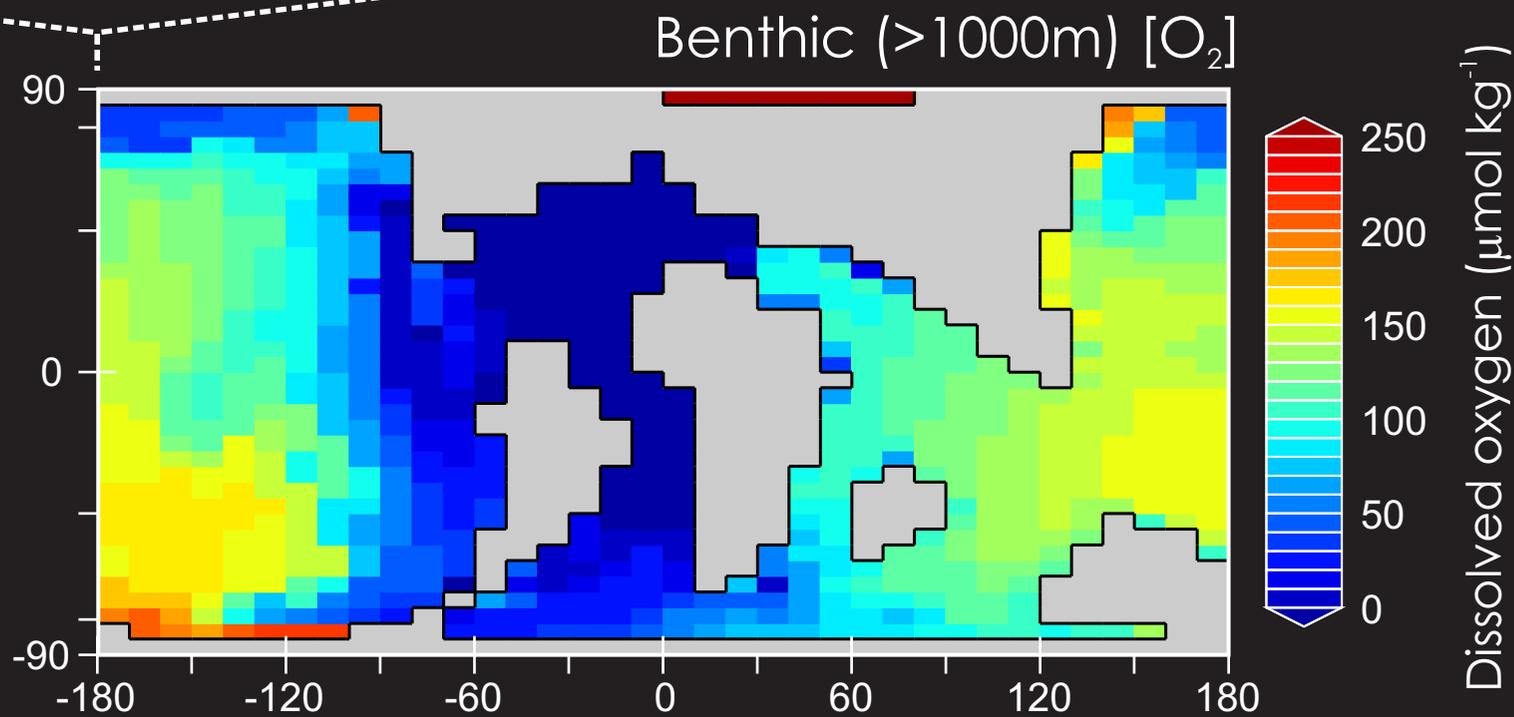
Ocean Carbon Cycling and Oxygenation in Warm Climates (Not necessarily the PETM)



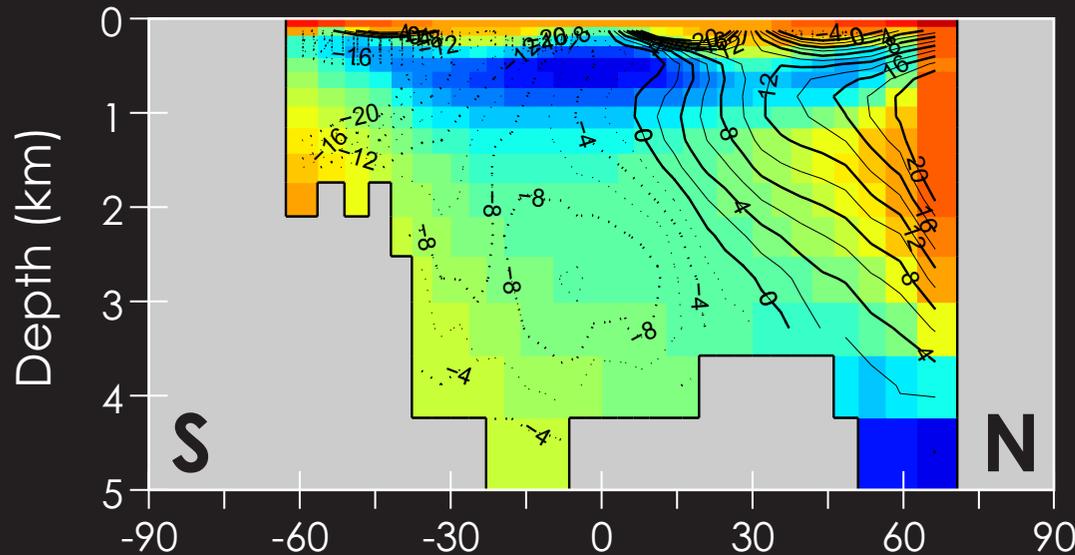
Ocean Carbon Cycling and Oxygenation in Warm Climates (Not the PETM)



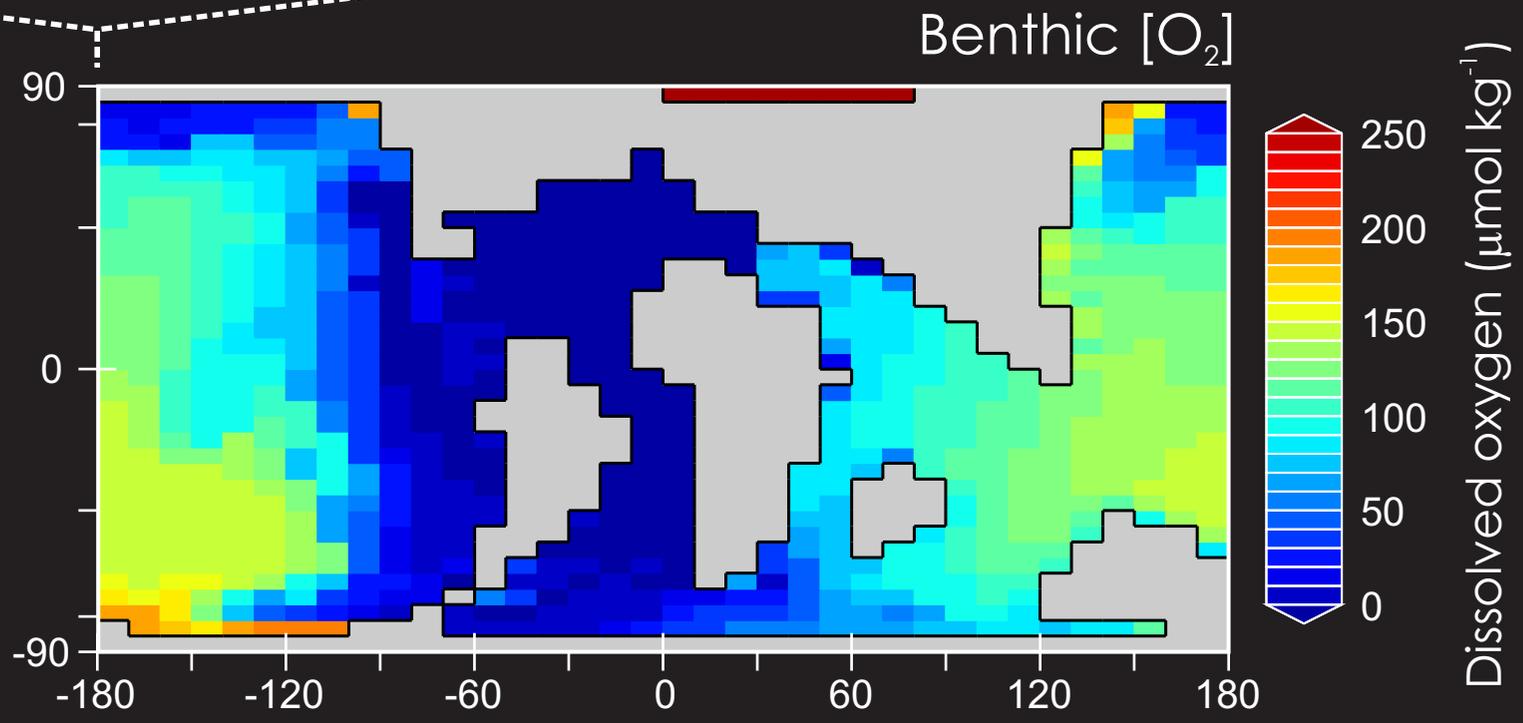
x4 CO₂ reference simulation



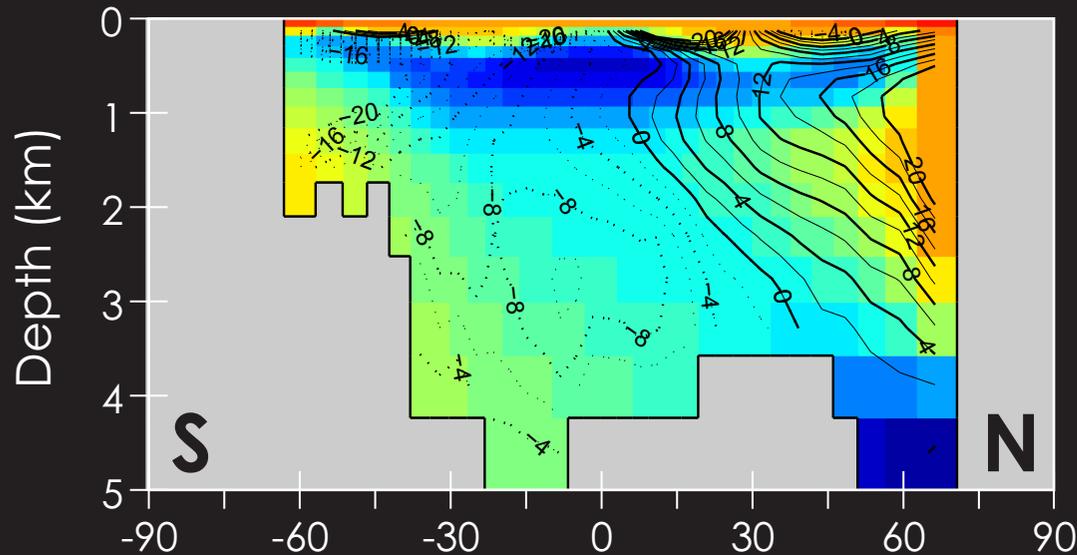
Ocean Carbon Cycling and Oxygenation in Warm Climates



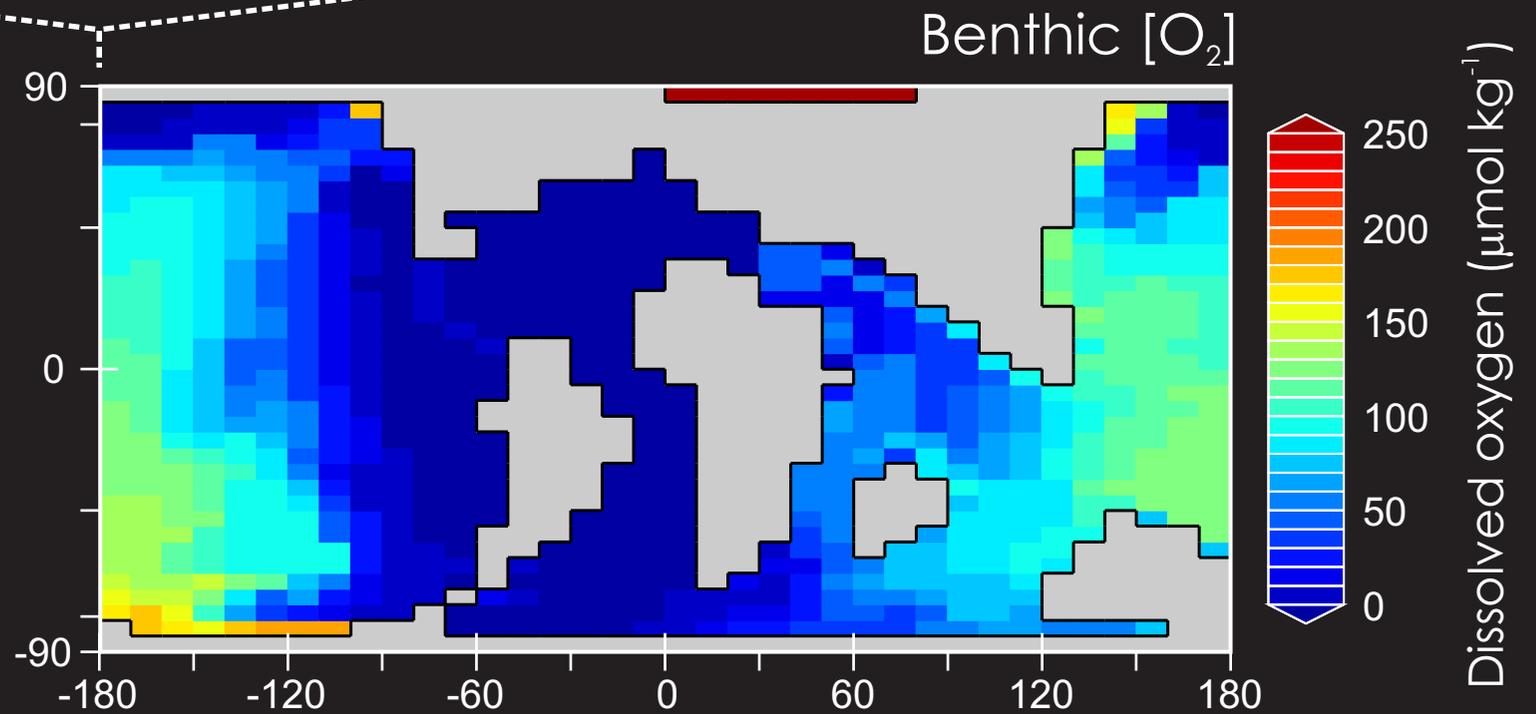
x8 CO₂ @ 10,000 yrs
(started from end of the x4 simulation)



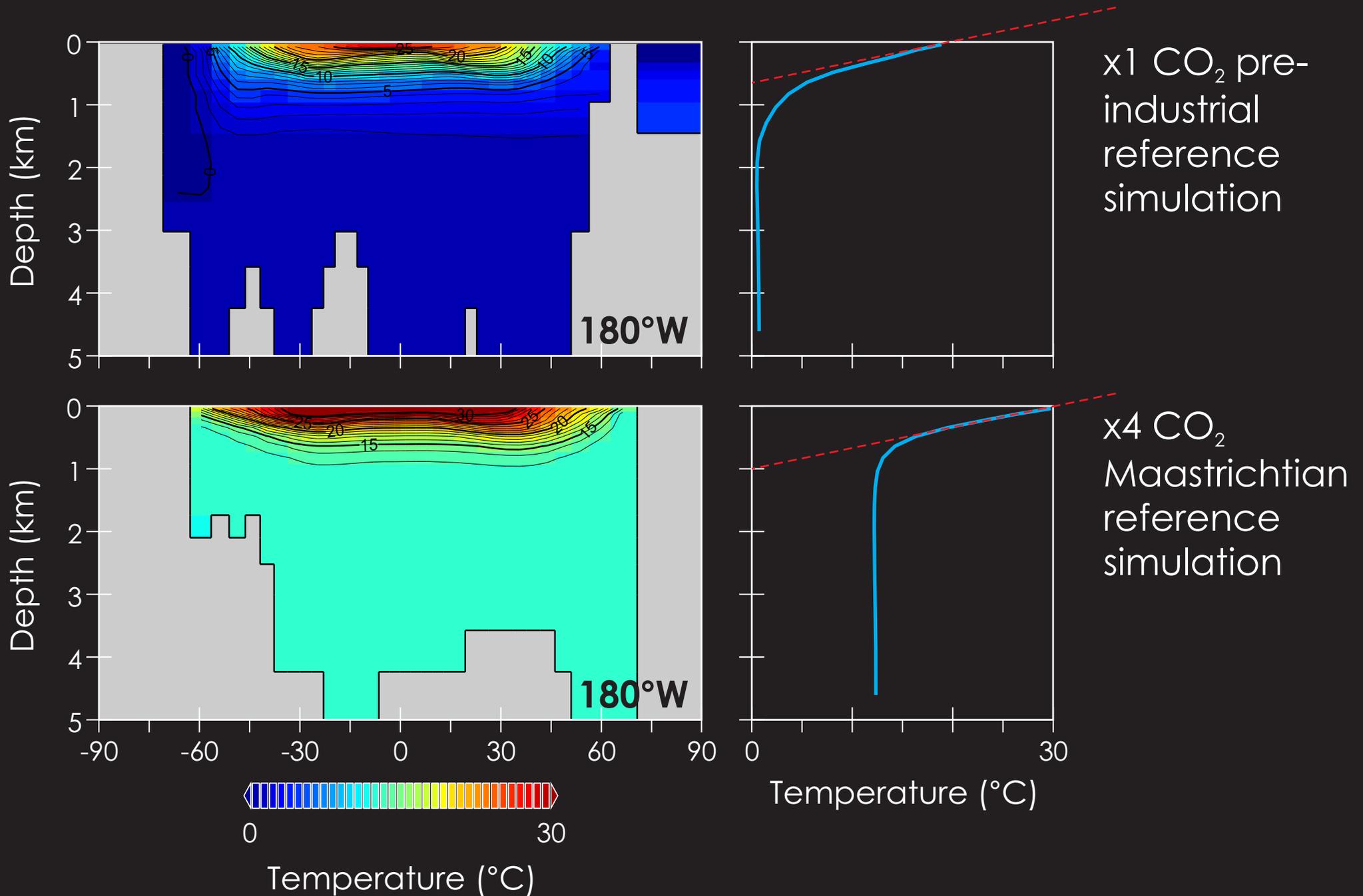
Ocean Carbon Cycling and Oxygenation in Warm Climates



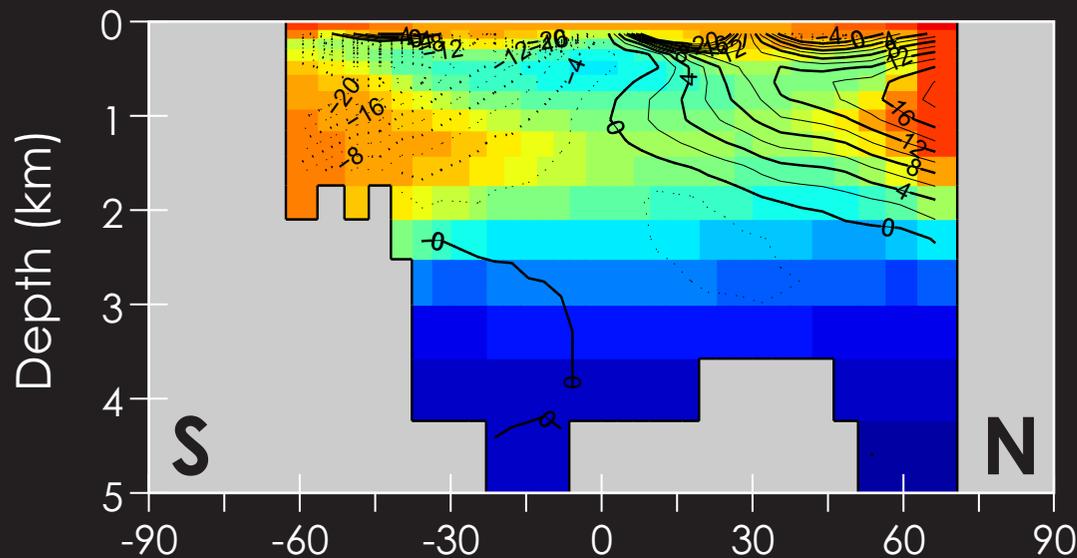
x16 CO₂ @ 10,000 yrs
(started from end of the x4 simulation)



Ocean Carbon Cycling and Oxygenation in Warm Climates

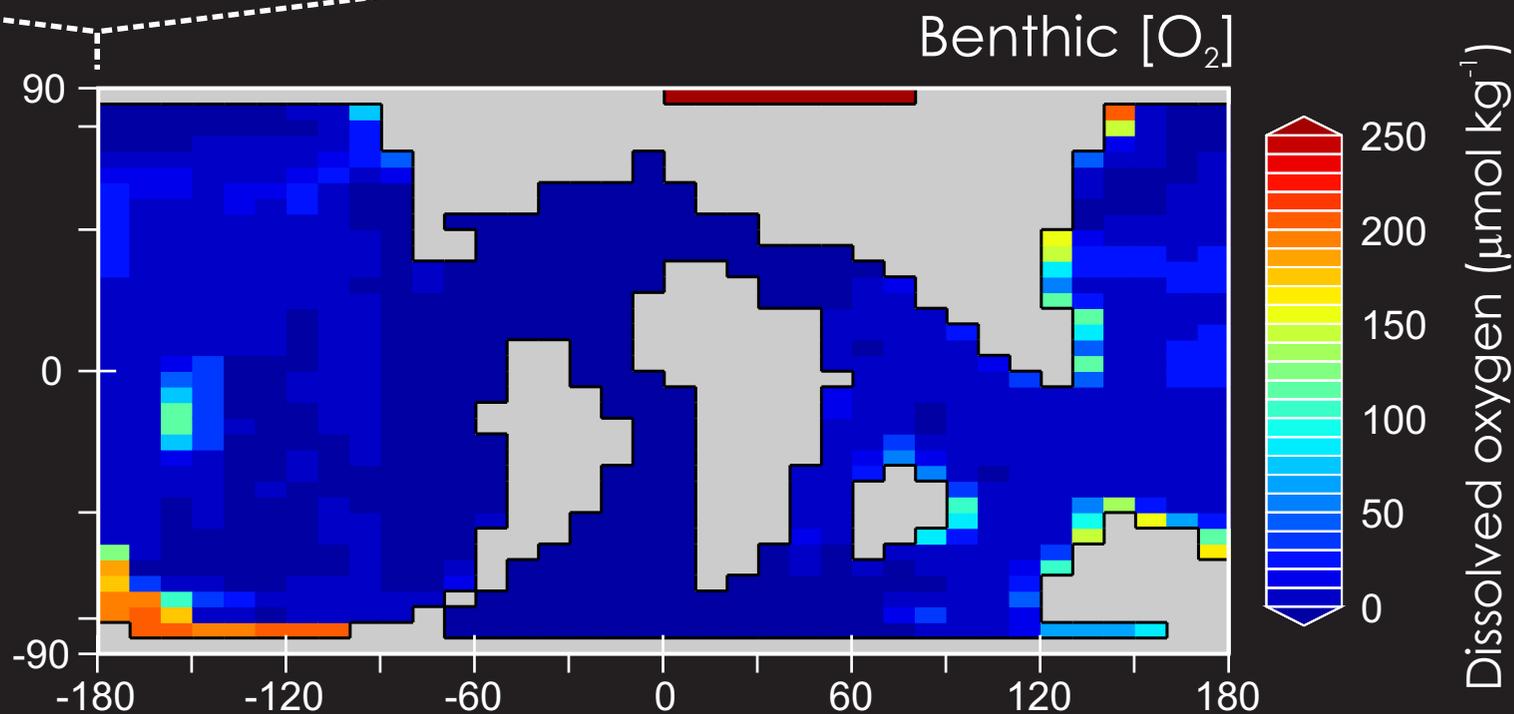


Ocean Carbon Cycling and Oxygenation in Warm Climates

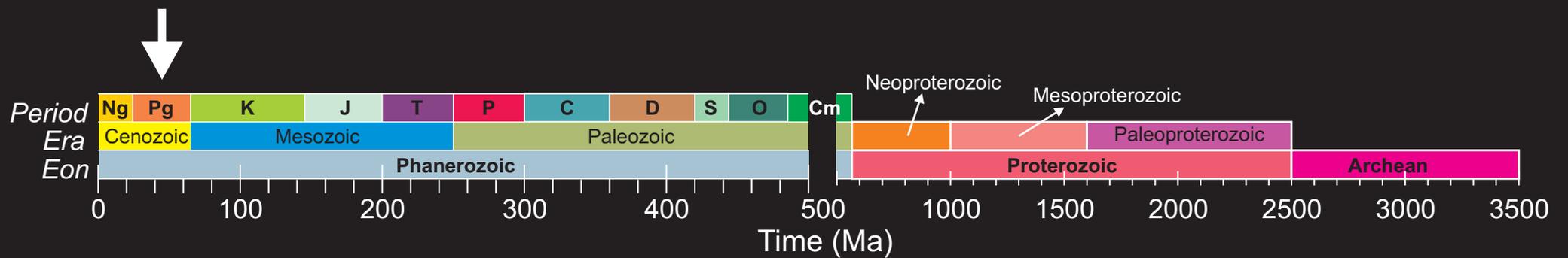


x16 CO₂ @ 2,000 yrs

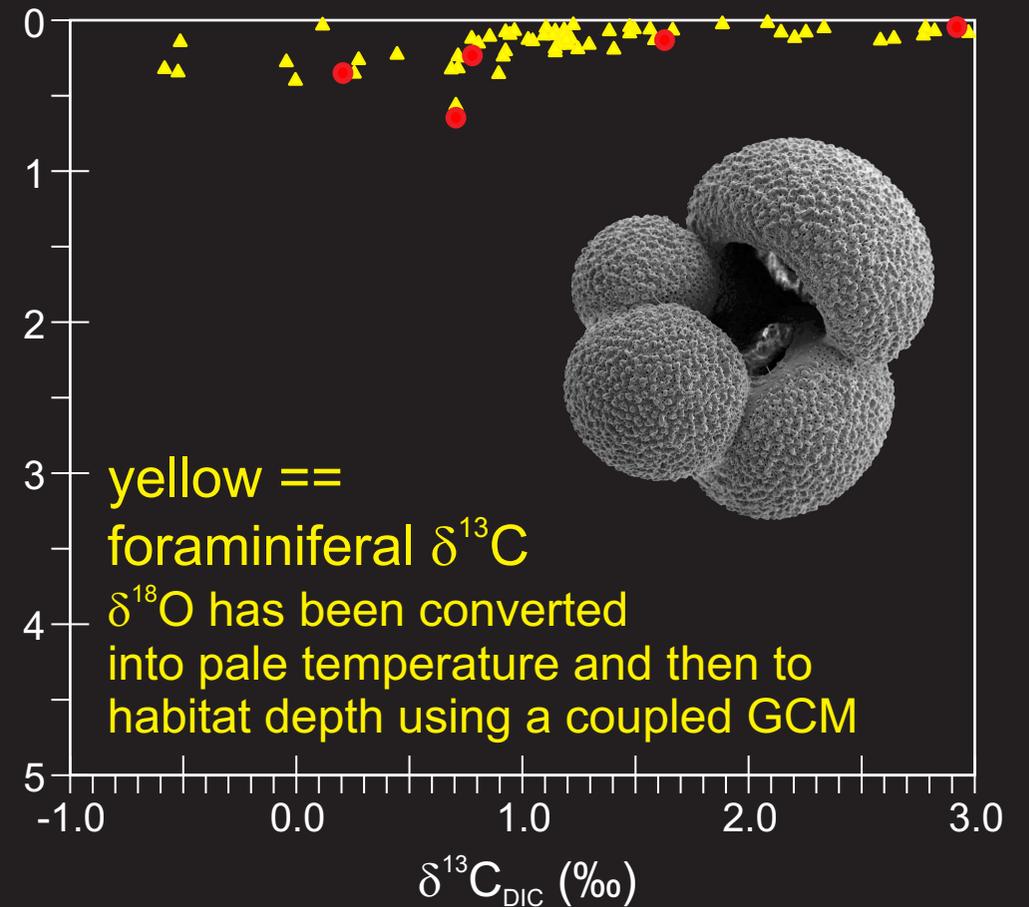
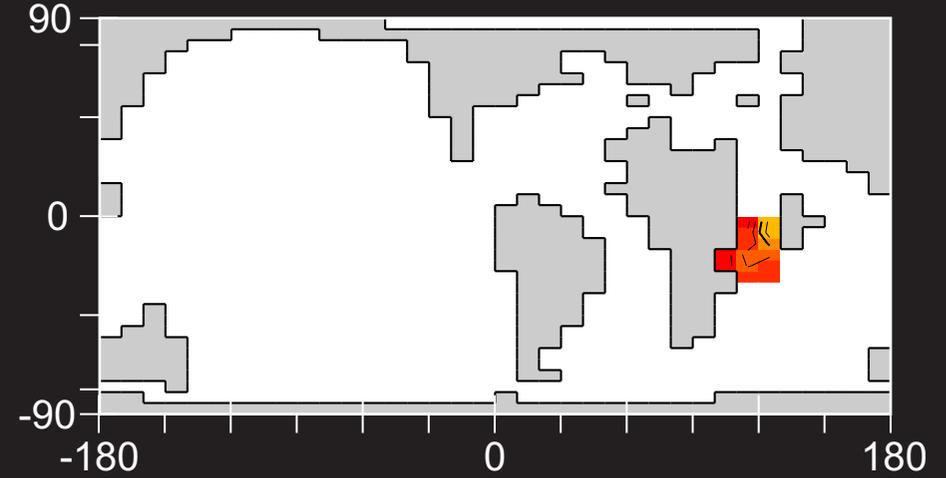
transient state
(incomplete adjustment to
increased radiative forcing)



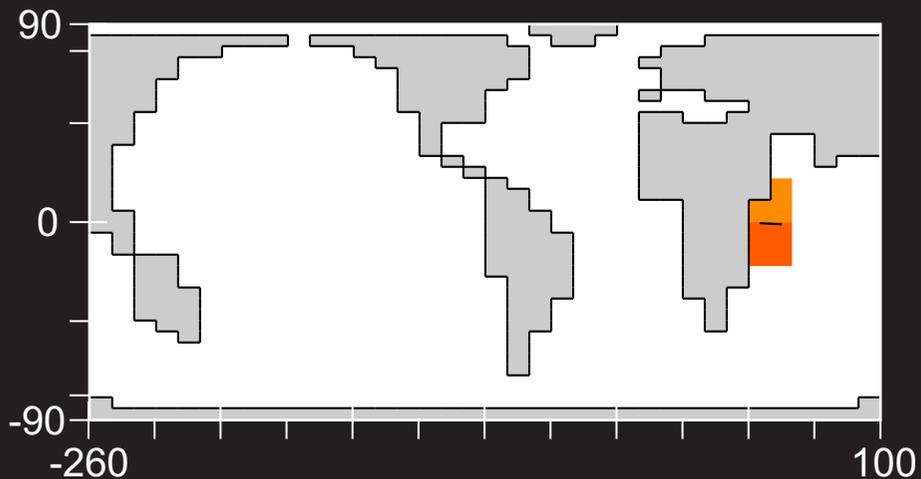
Not quite PETM ...



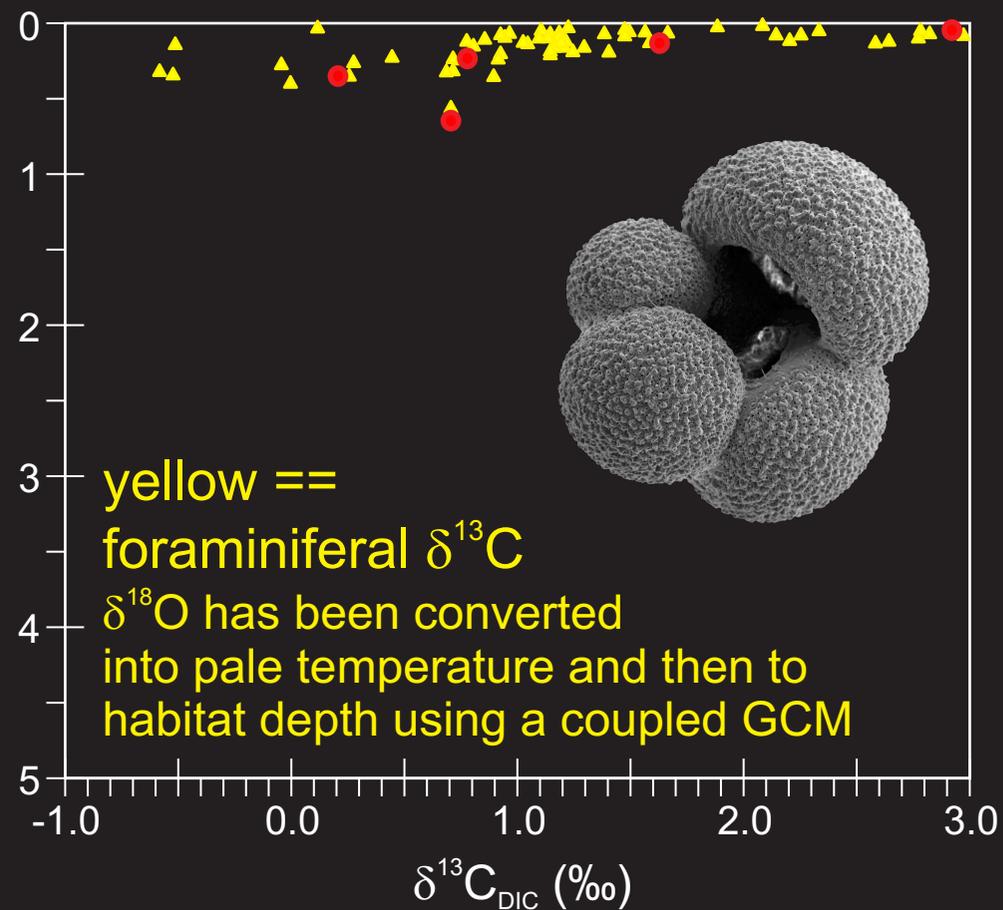
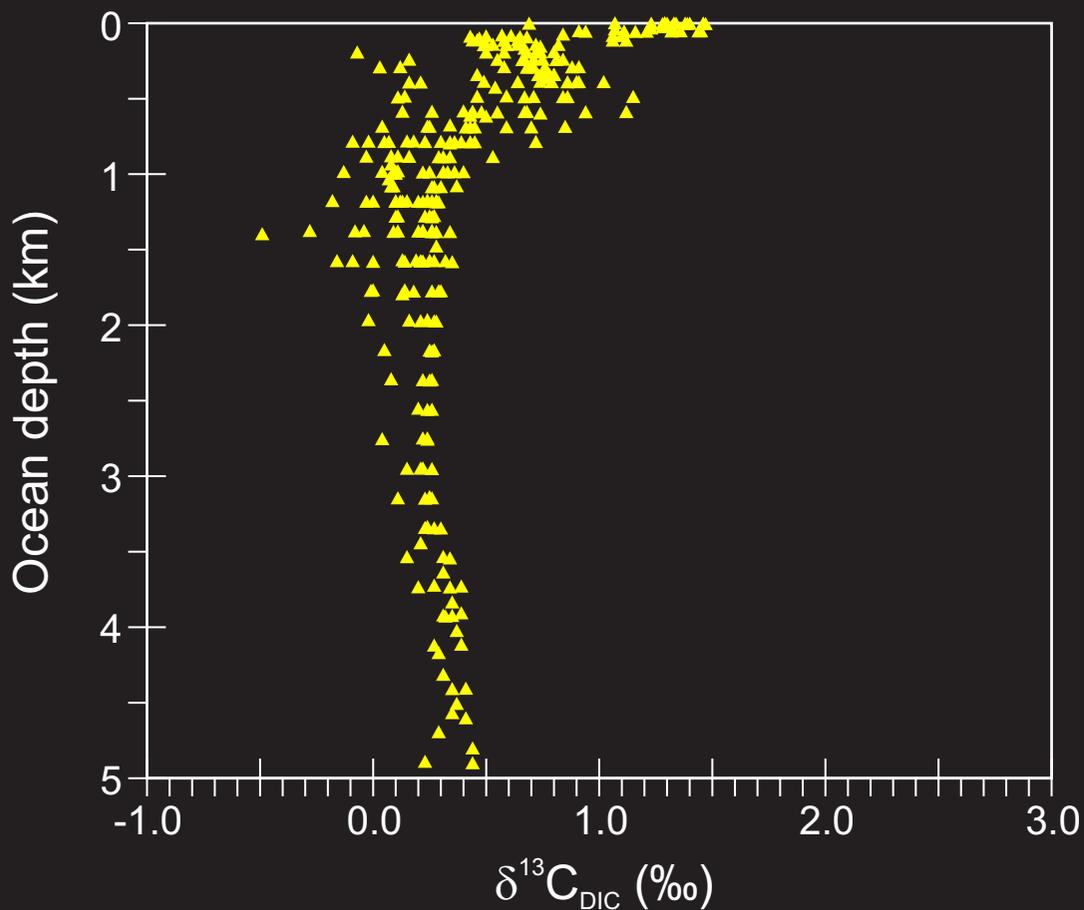
Planktic foraminiferal $\delta^{13}\text{C}$ from early Eocene Tanzania



Open ocean $\delta^{13}\text{C}_{\text{DIC}}$ adjacent to modern Tanzania

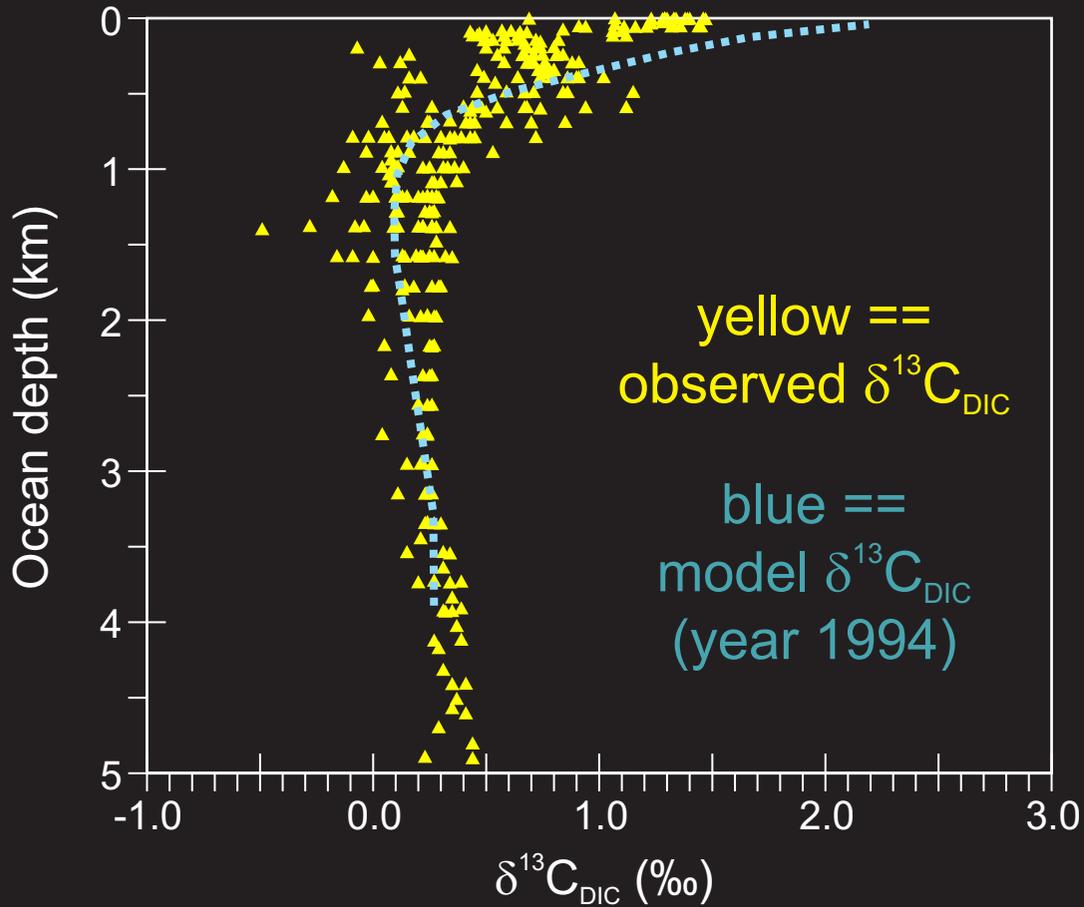
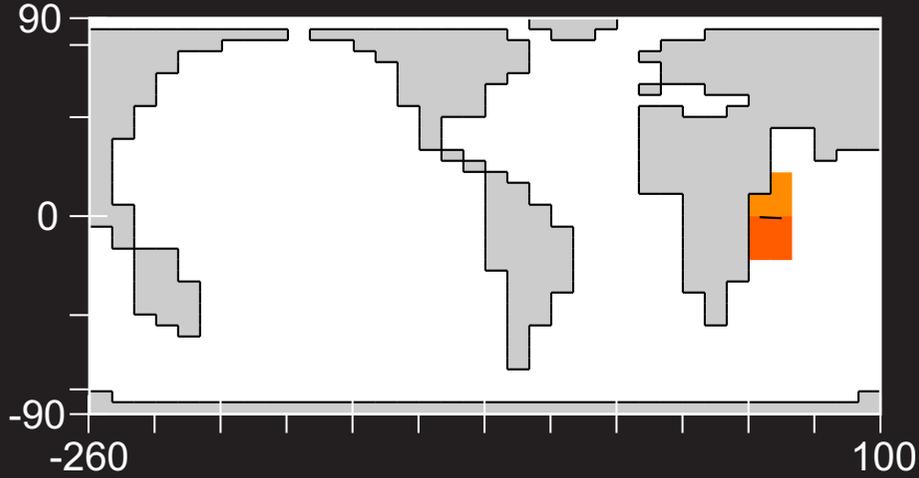


Planktic foraminiferal $\delta^{13}\text{C}$ from early Eocene Tanzania



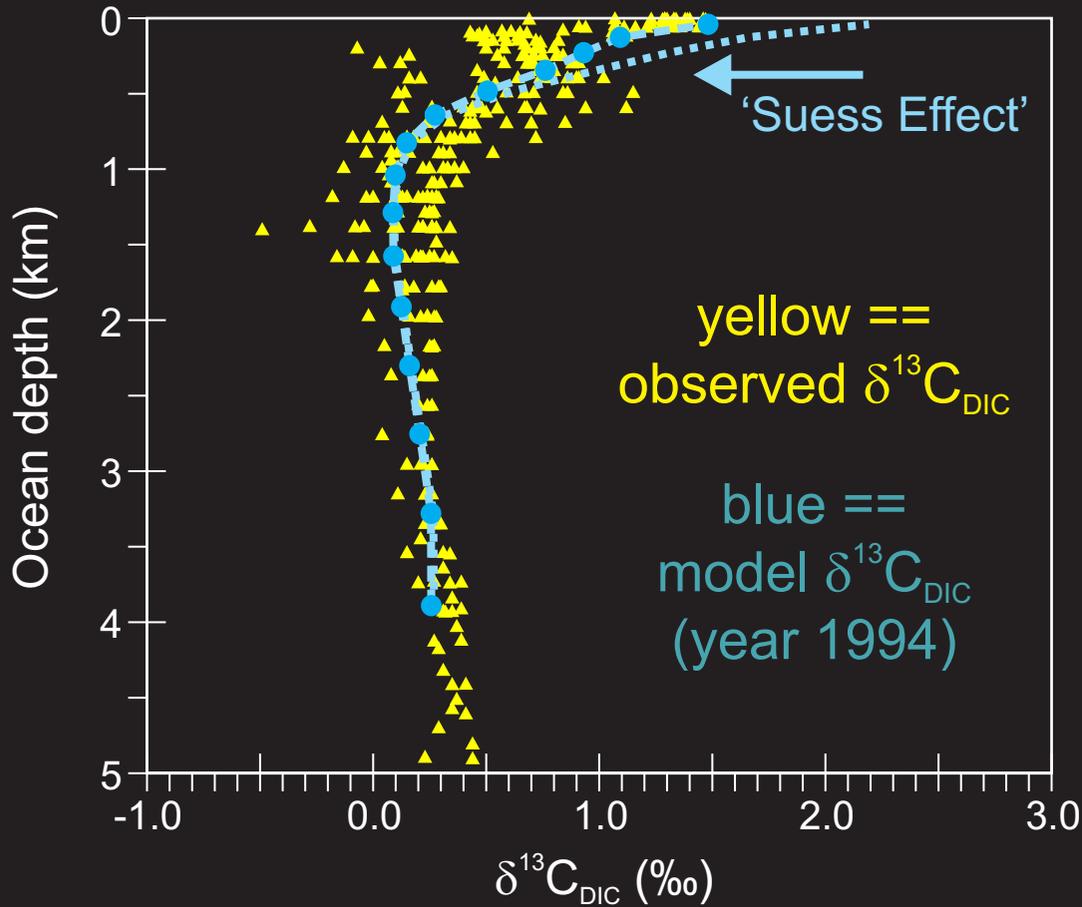
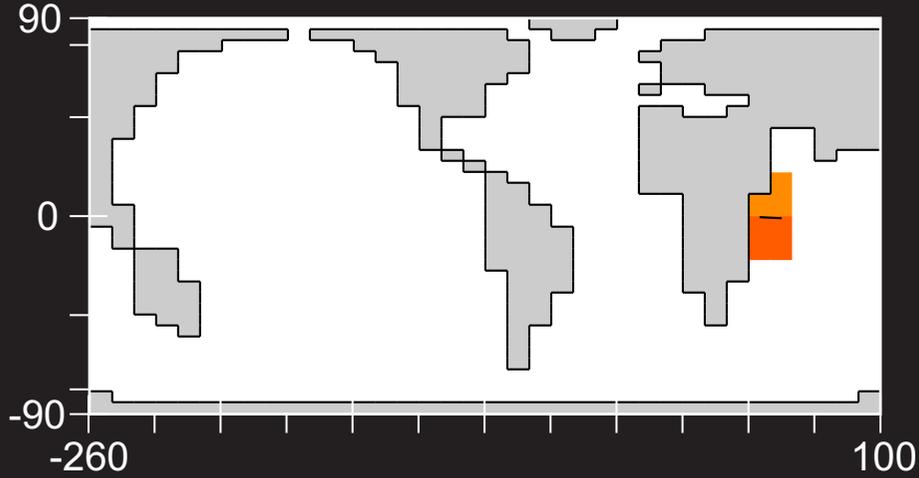


Open ocean $\delta^{13}\text{C}_{\text{DIC}}$ adjacent to modern Tanzania

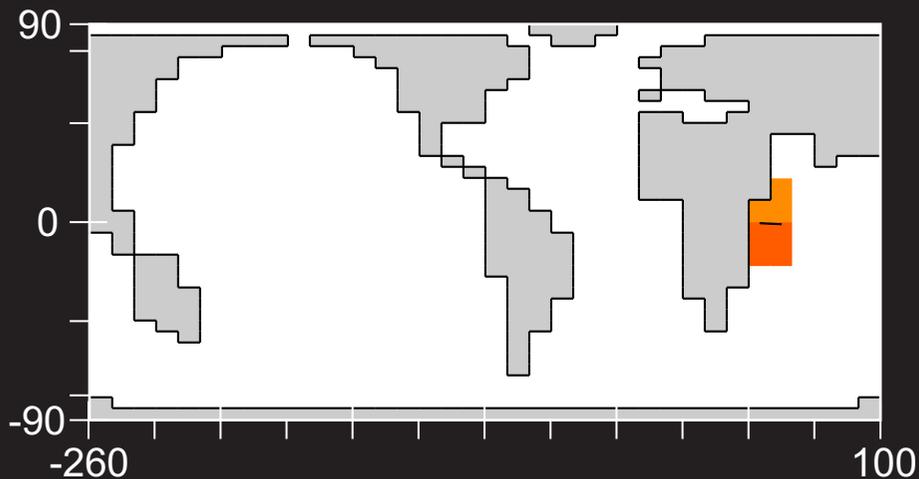




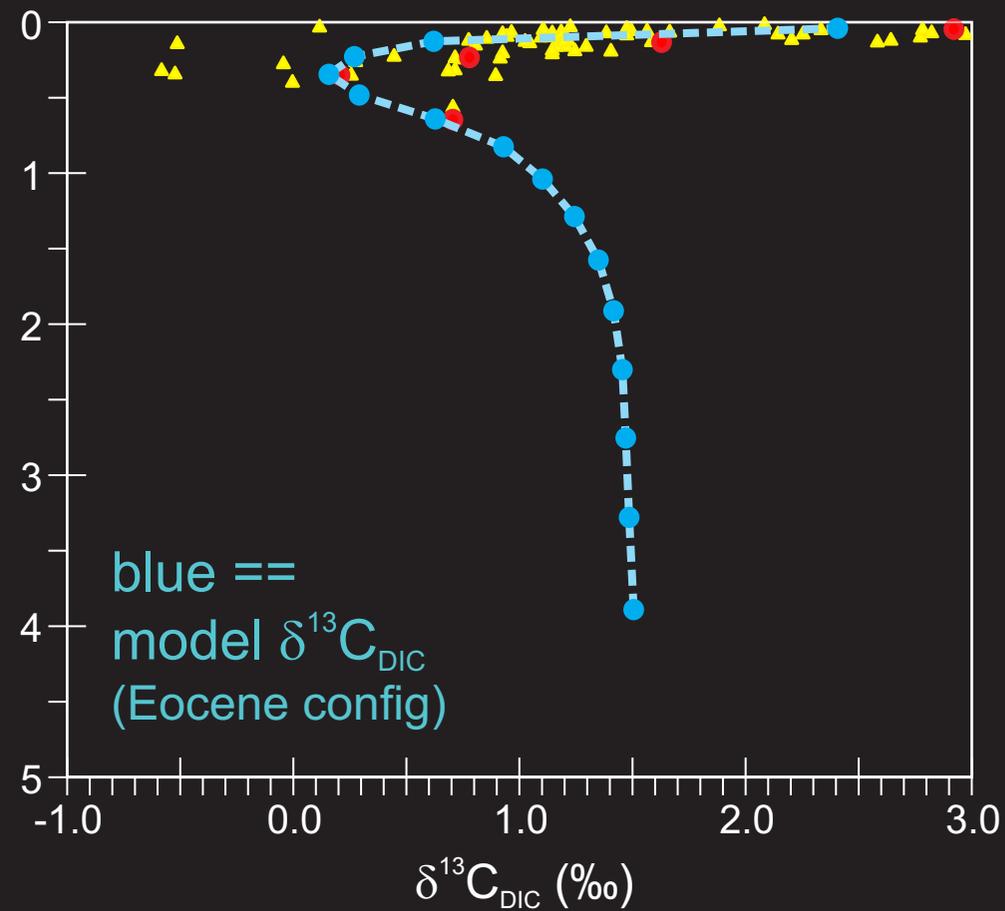
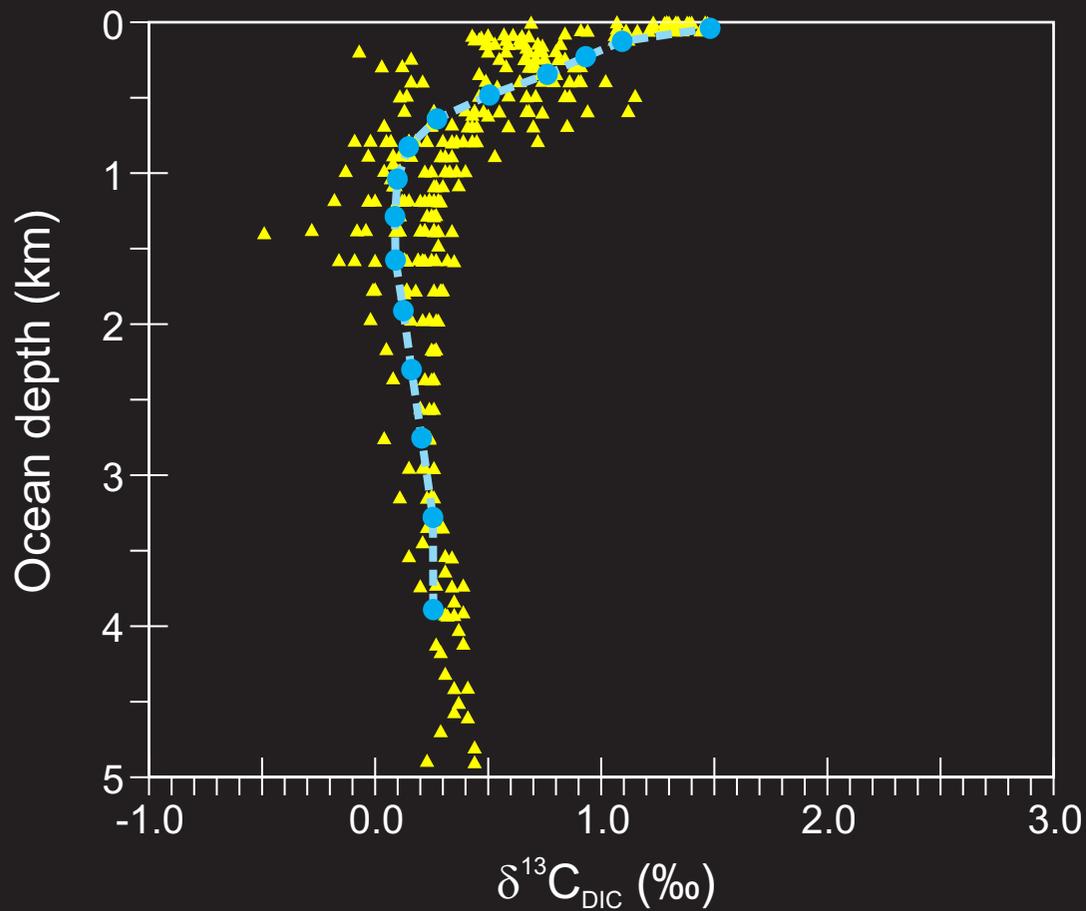
Open ocean $\delta^{13}\text{C}_{\text{DIC}}$ adjacent to modern Tanzania



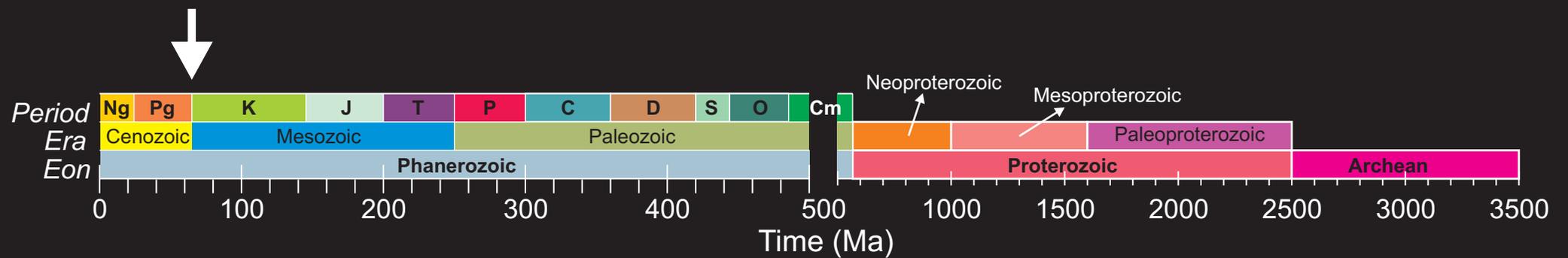
Open ocean $\delta^{13}\text{C}_{\text{DIC}}$ adjacent to modern Tanzania



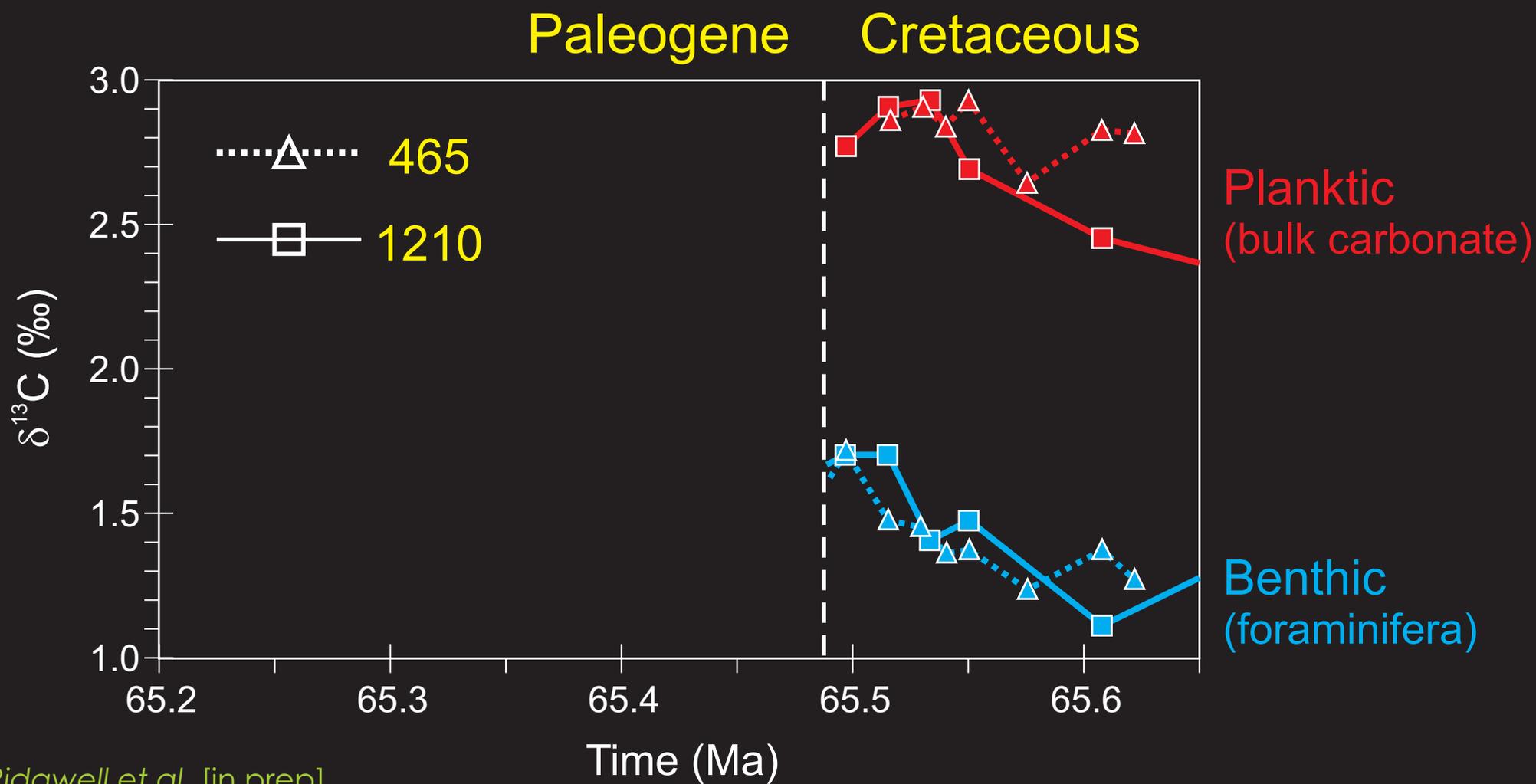
Planktic foraminiferal $\delta^{13}\text{C}$ from early Eocene Tanzania



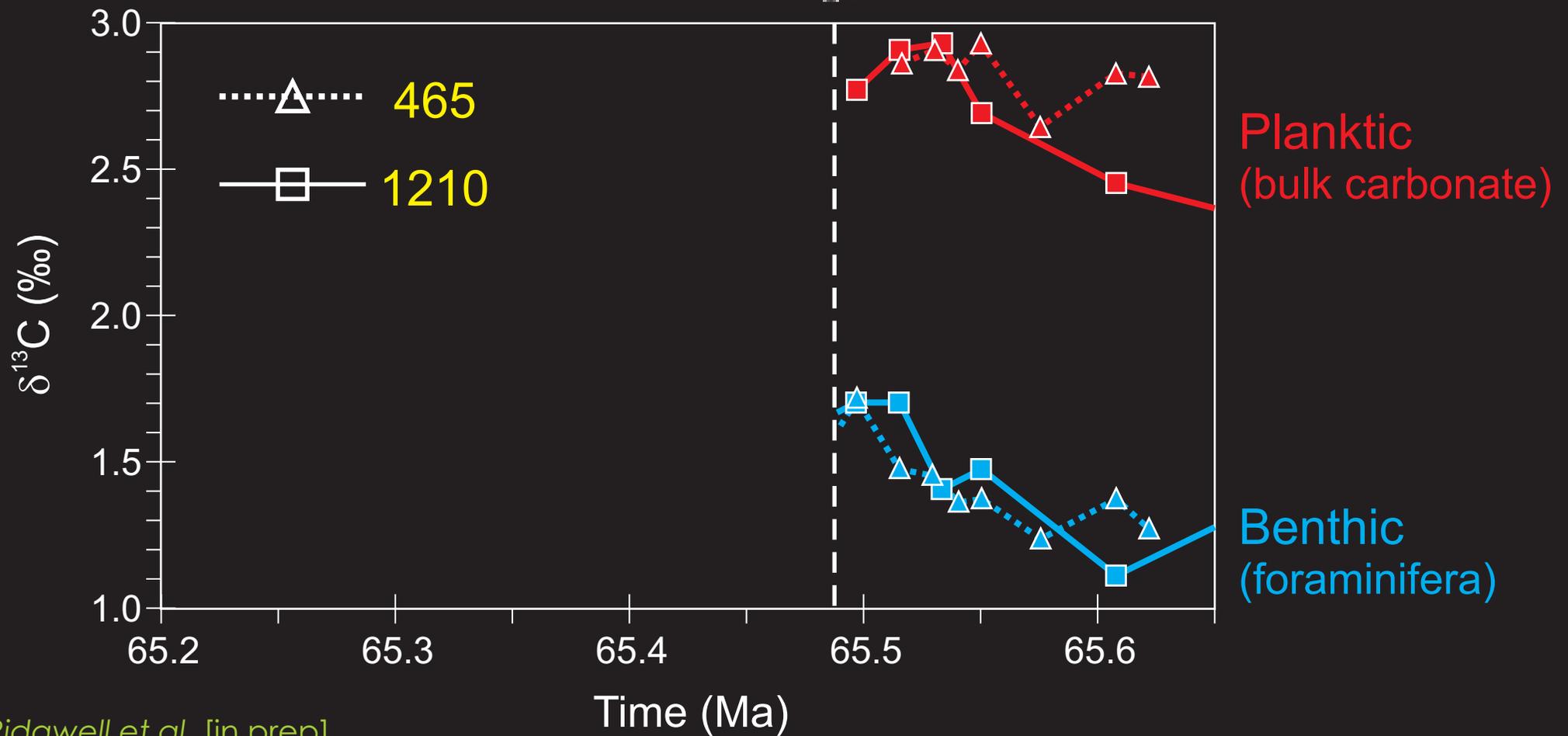
More, not-the-PETM ...



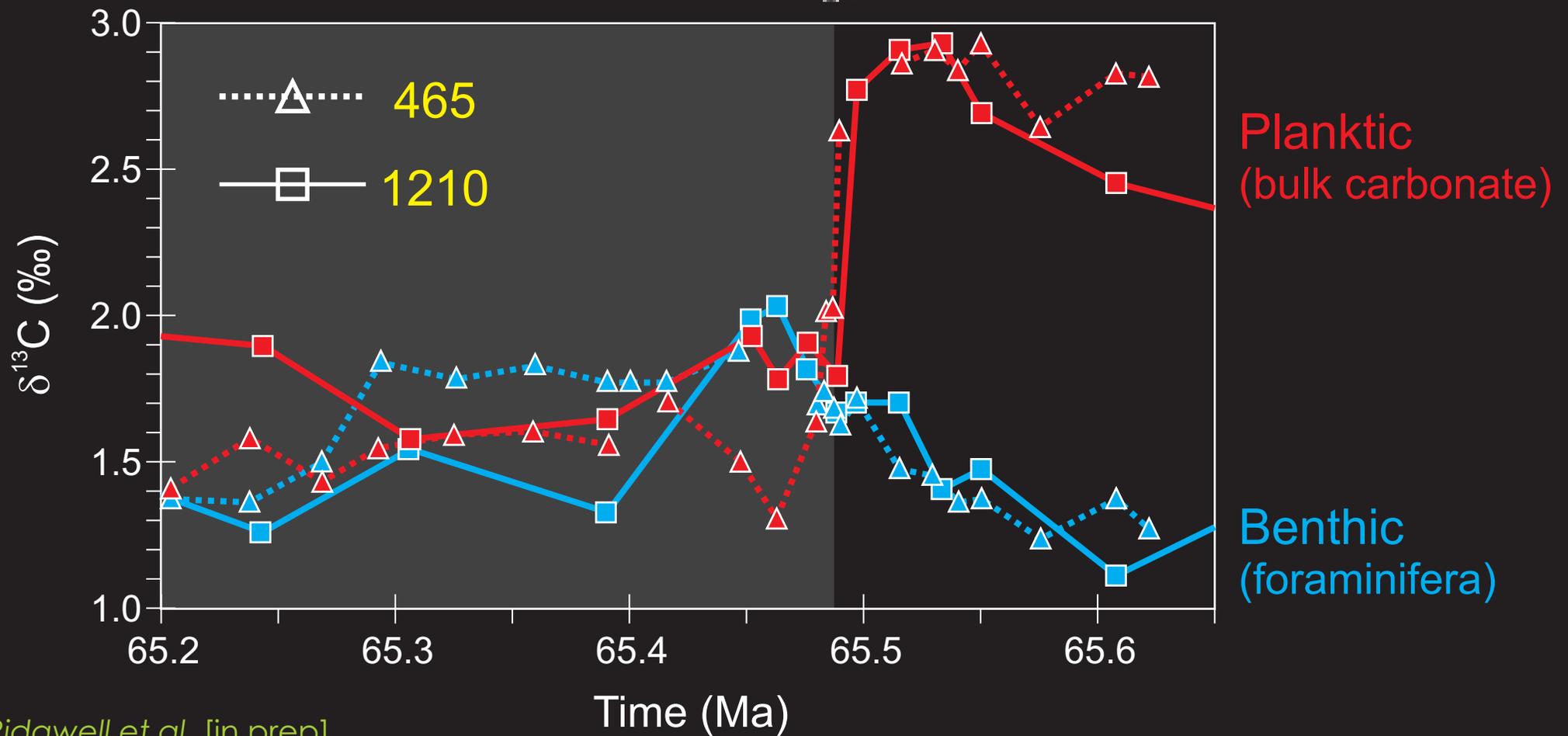
Disruption in marine carbon cycling



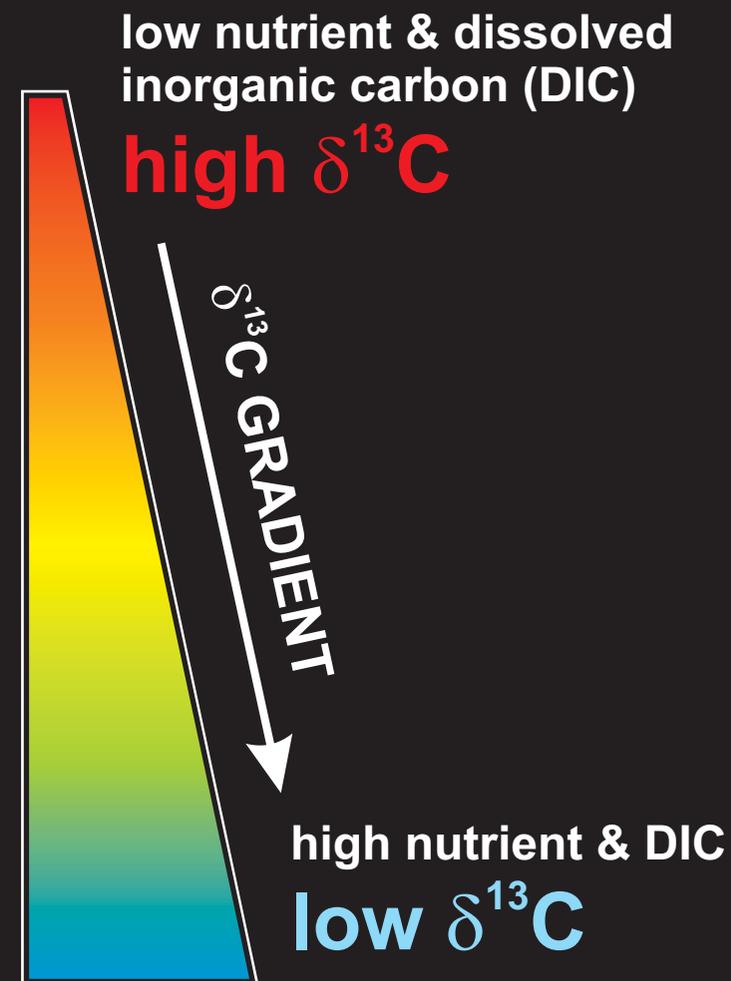
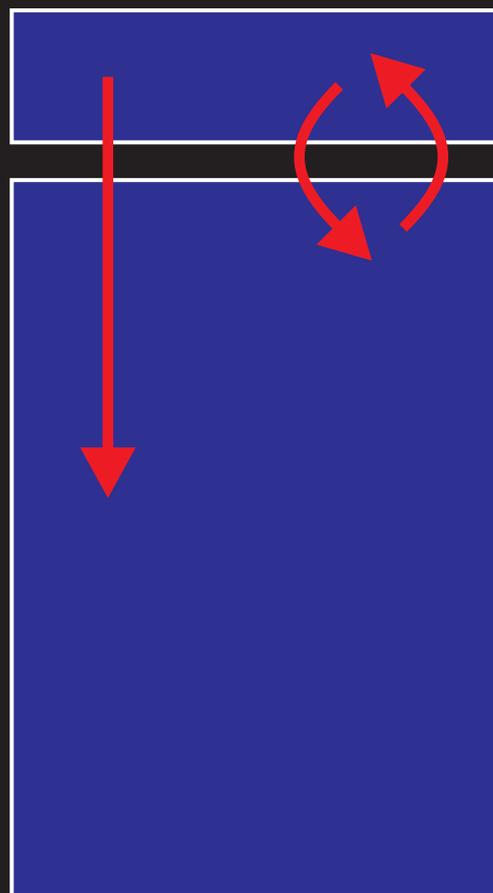
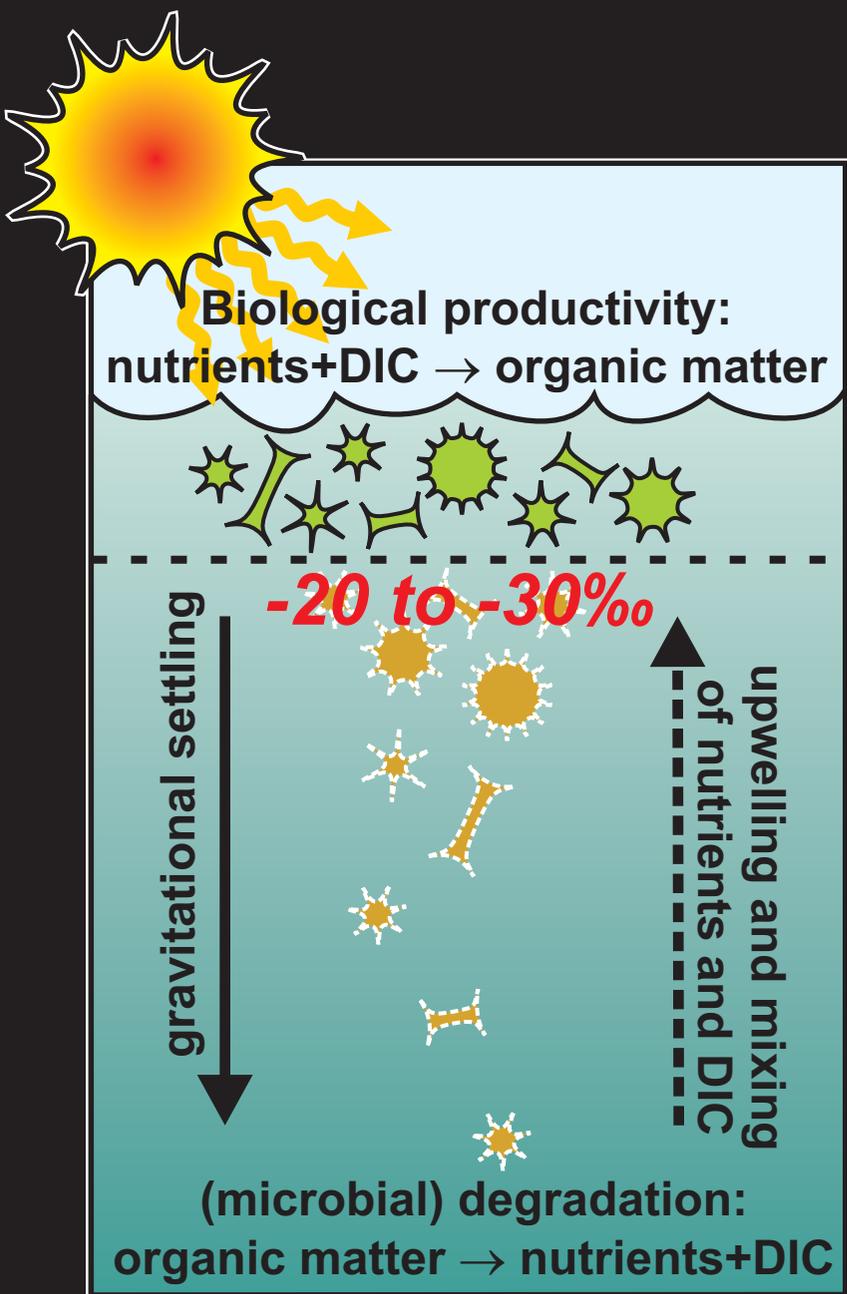
Disruption in marine carbon cycling



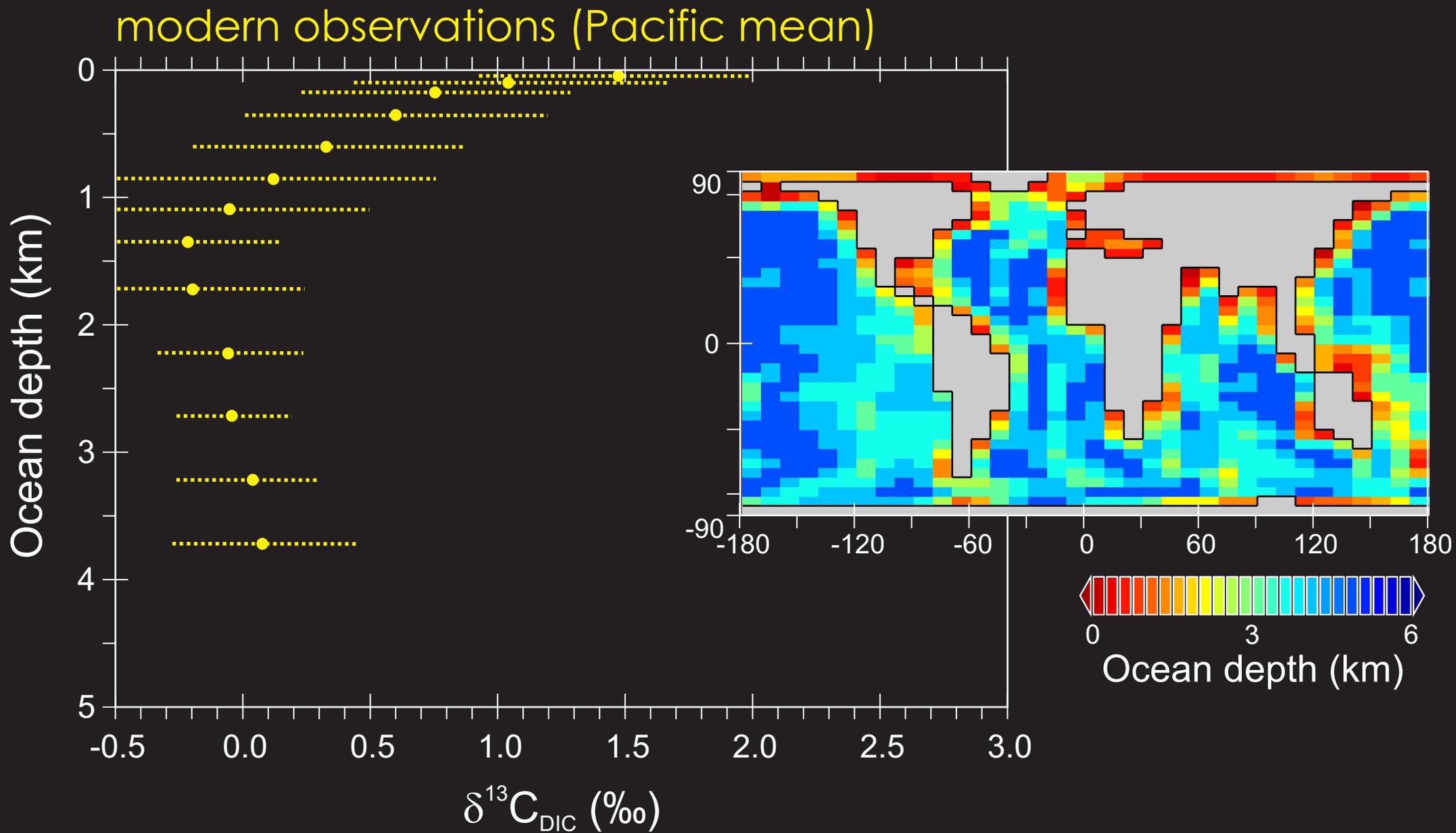
Disruption in marine carbon cycling



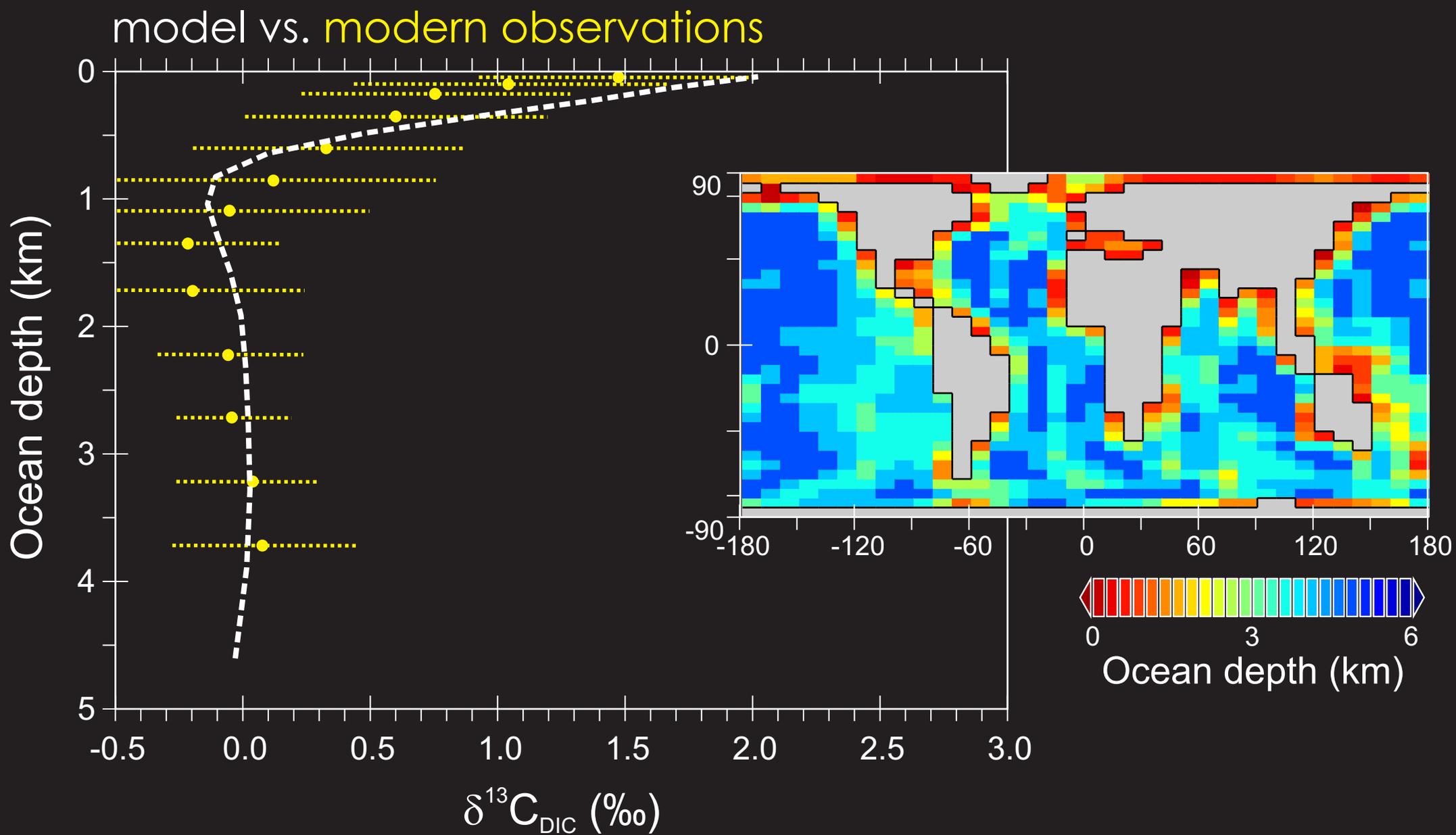
Disruption in marine carbon cycling



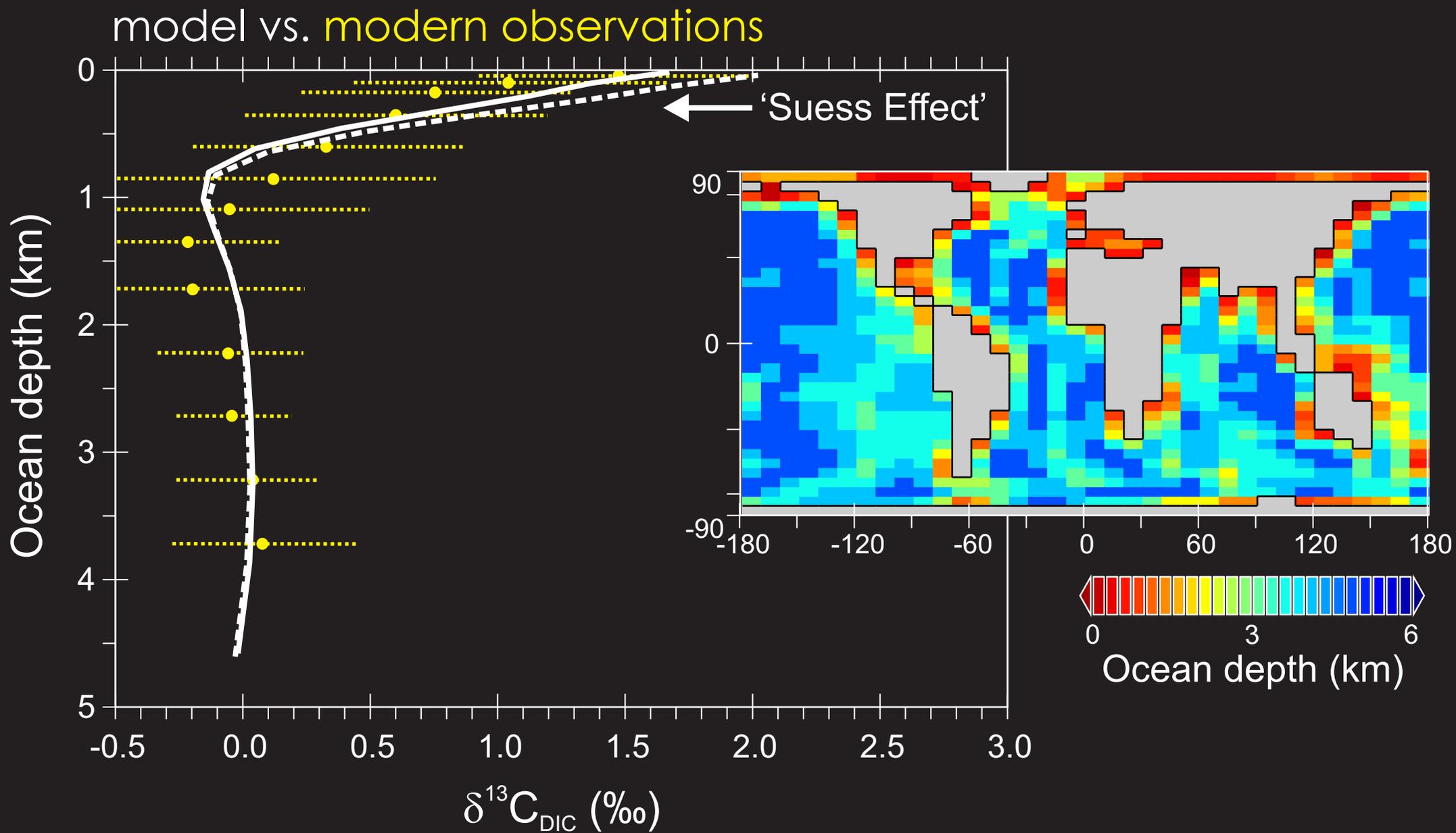
Disruption in marine carbon cycling



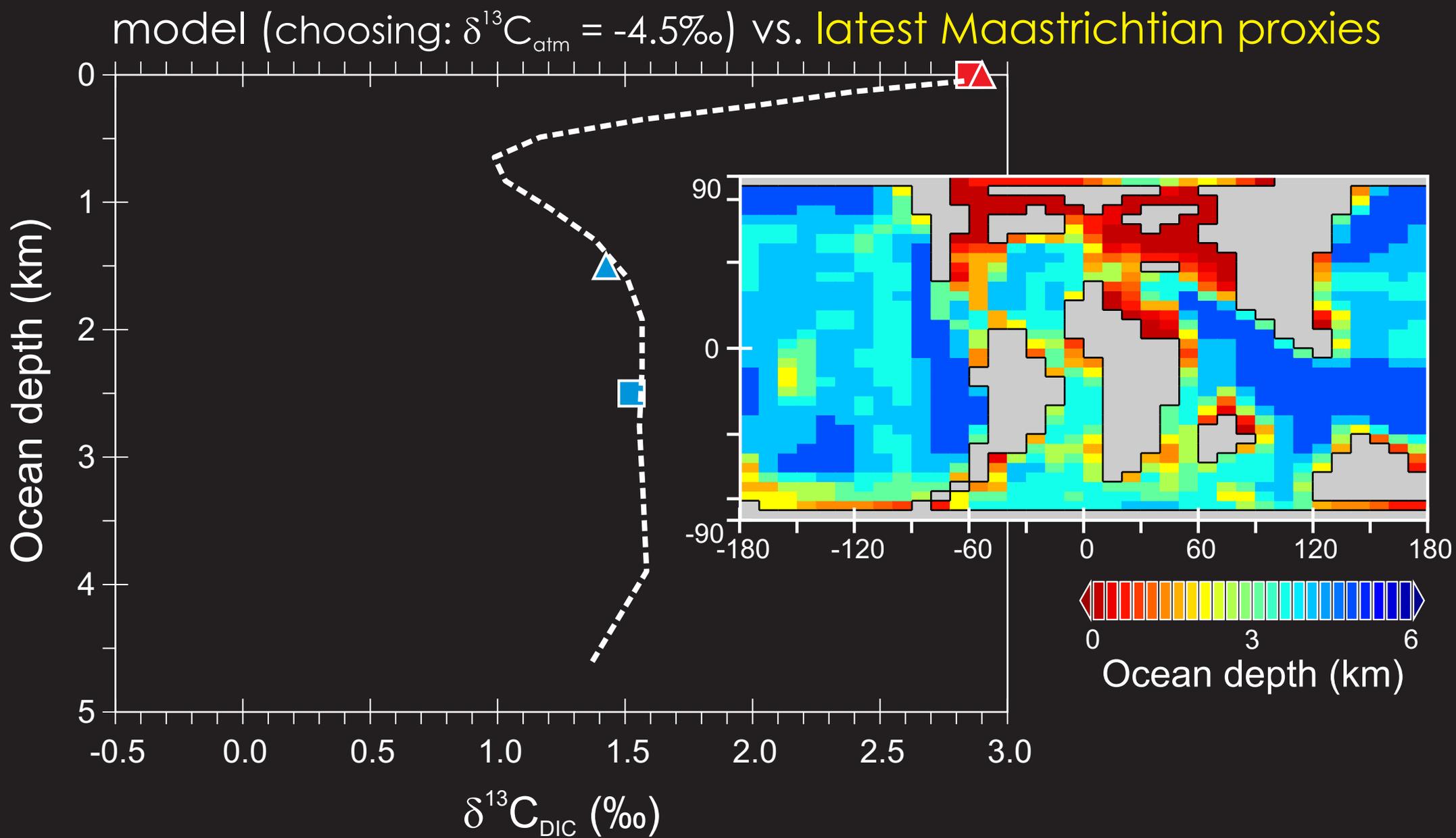
Disruption in marine carbon cycling



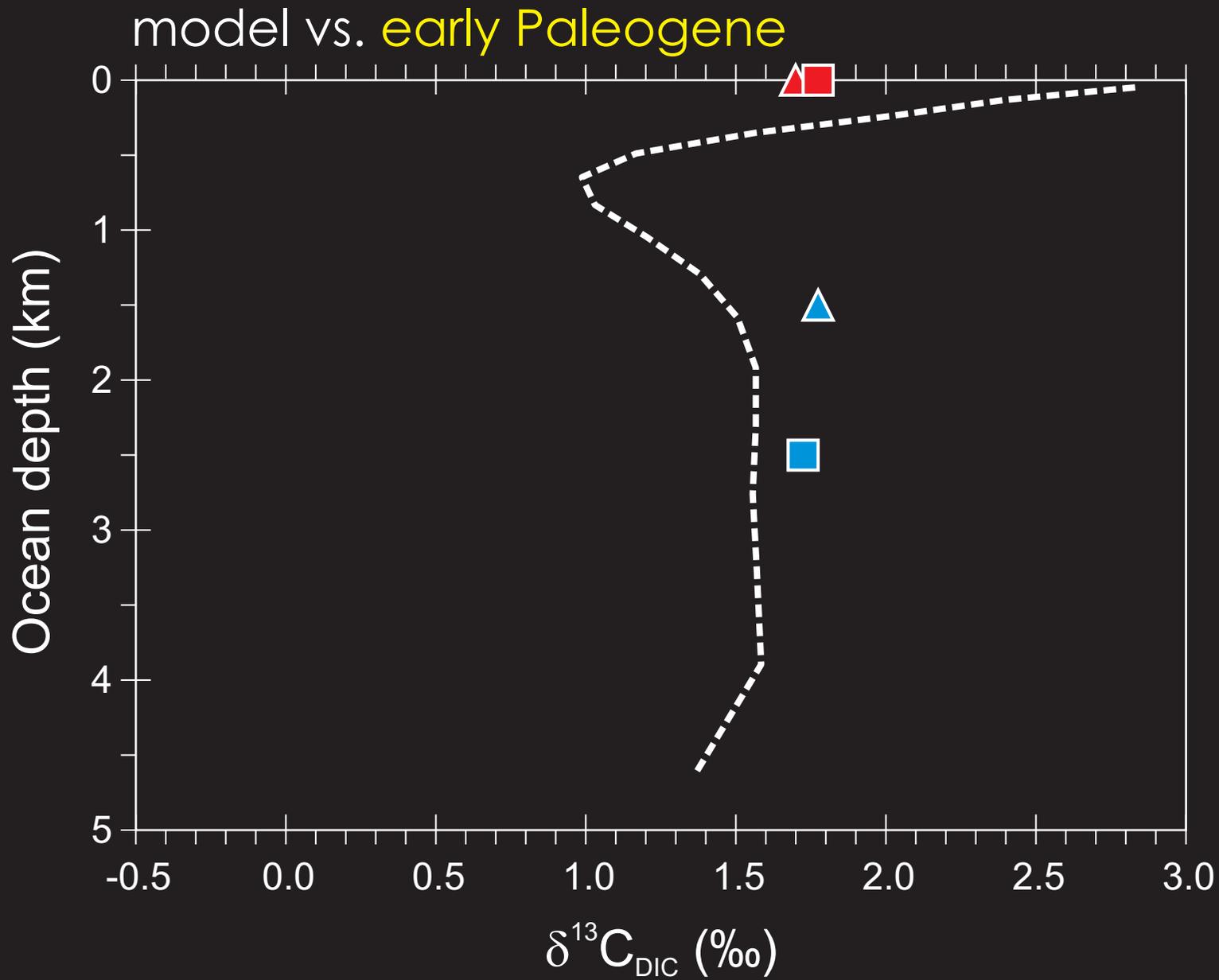
Disruption in marine carbon cycling



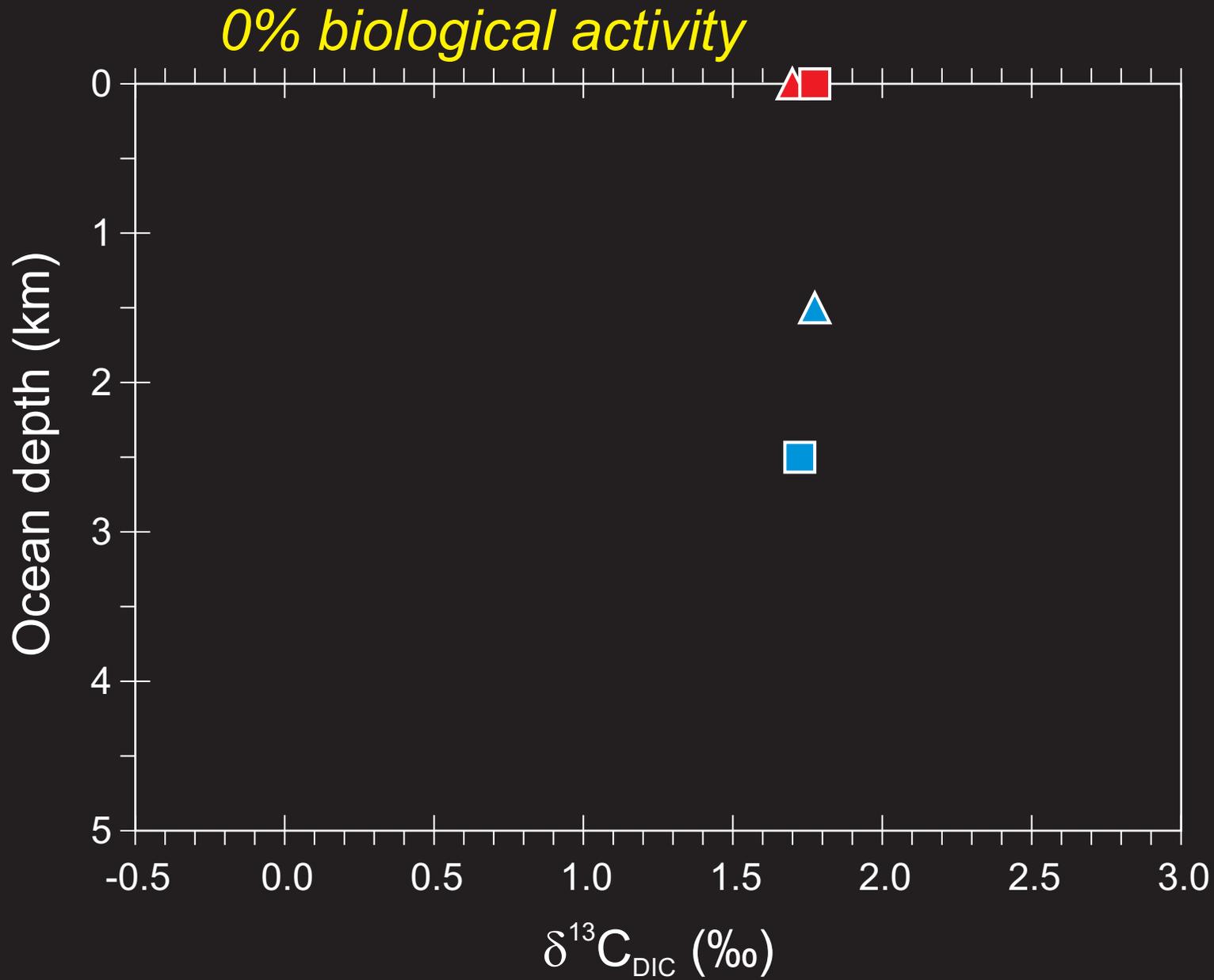
Disruption in marine carbon cycling



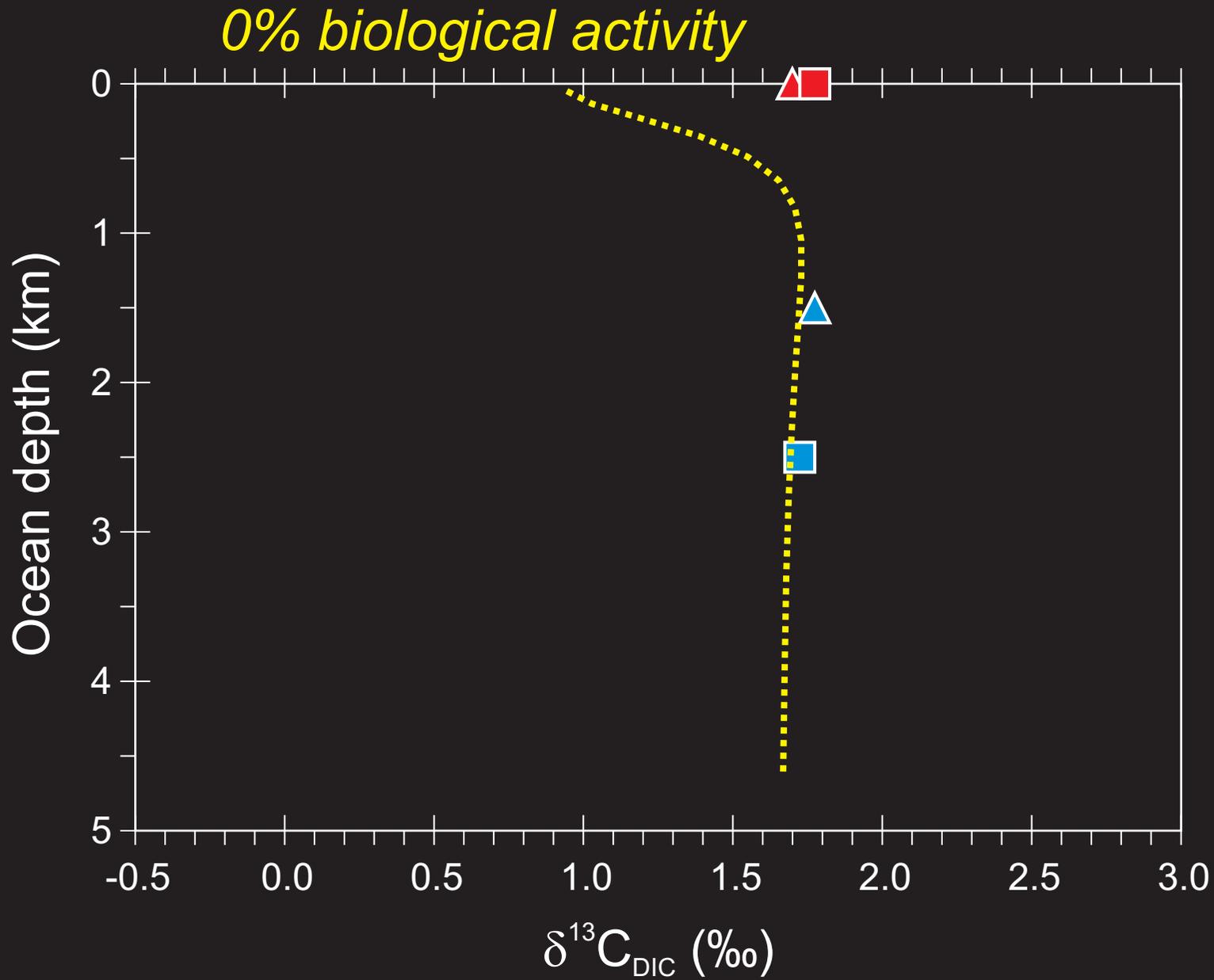
Disruption in marine carbon cycling



Disruption in marine carbon cycling



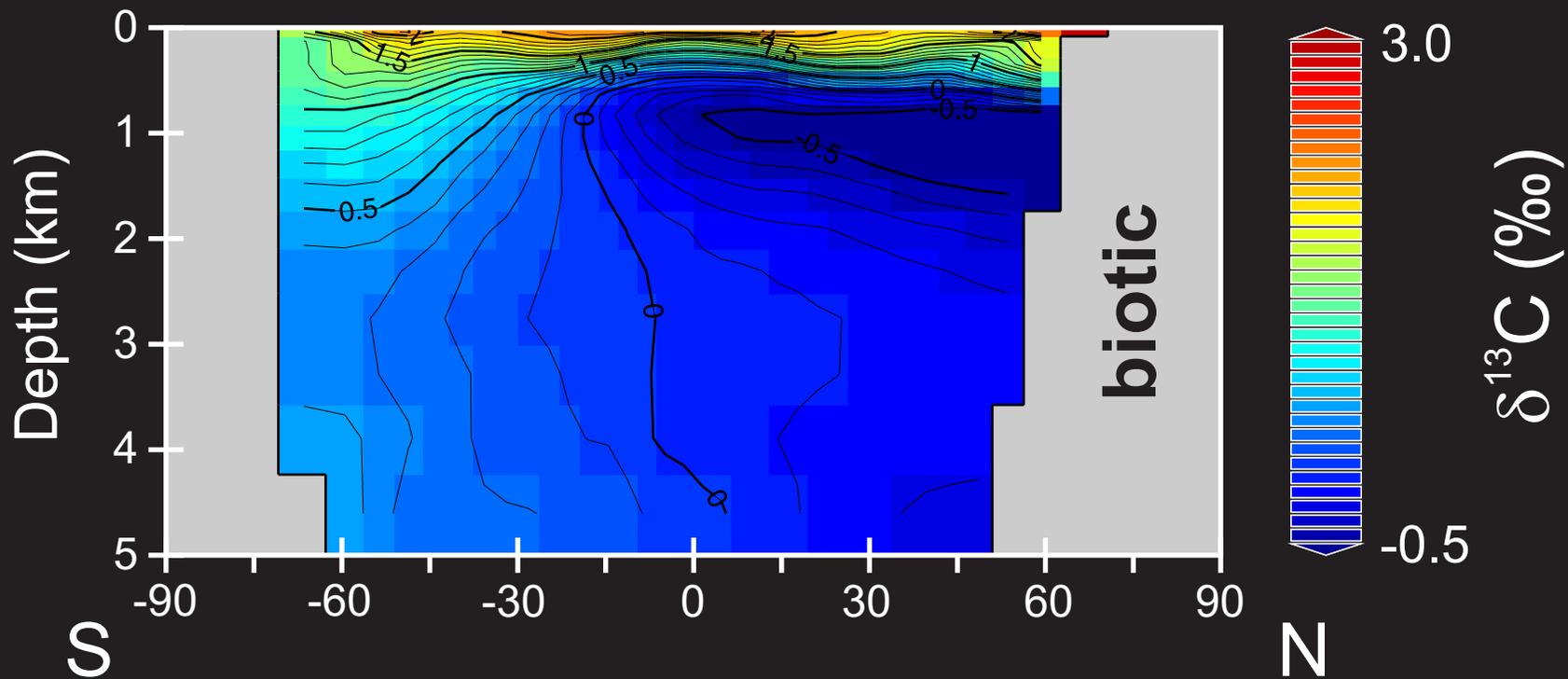
Disruption in marine carbon cycling



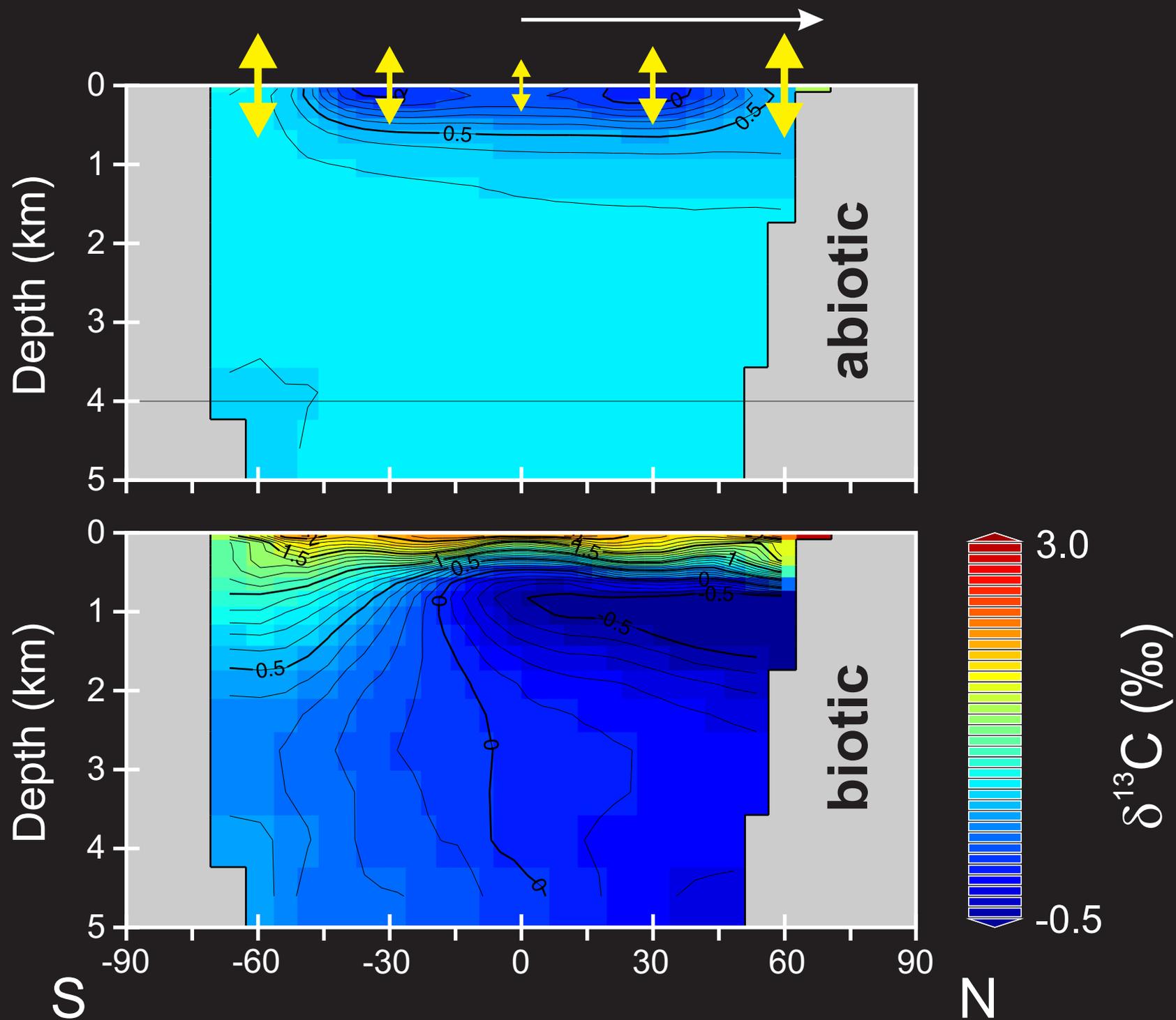
Disruption in marine carbon cycling



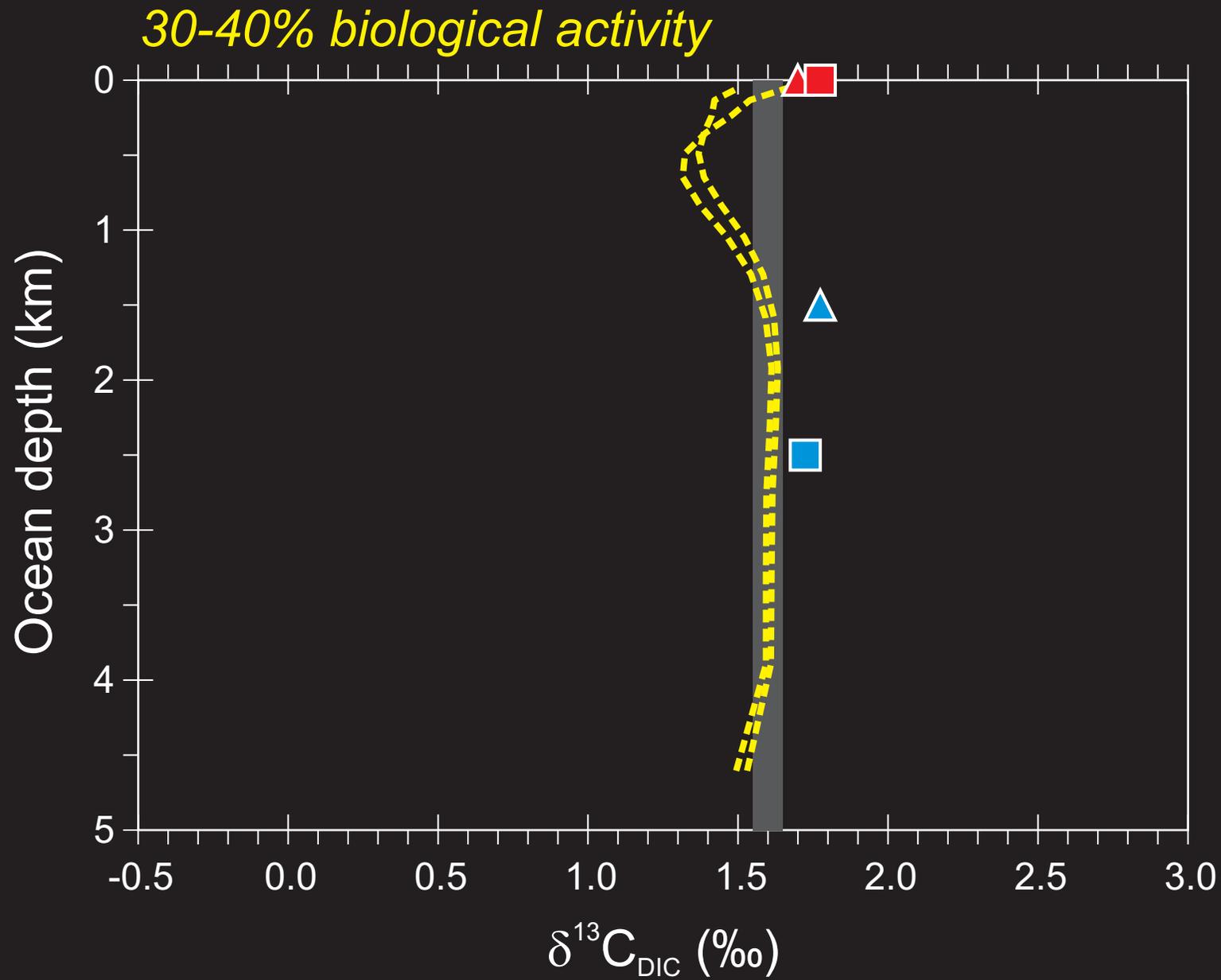
Modern Pacific zonal $\delta^{13}\text{C}_{(\text{DIC})}$ profile



increasing fractionation between $p\text{CO}_2$ and $[\text{CO}_2]$
with decreasing temperature towards to poles

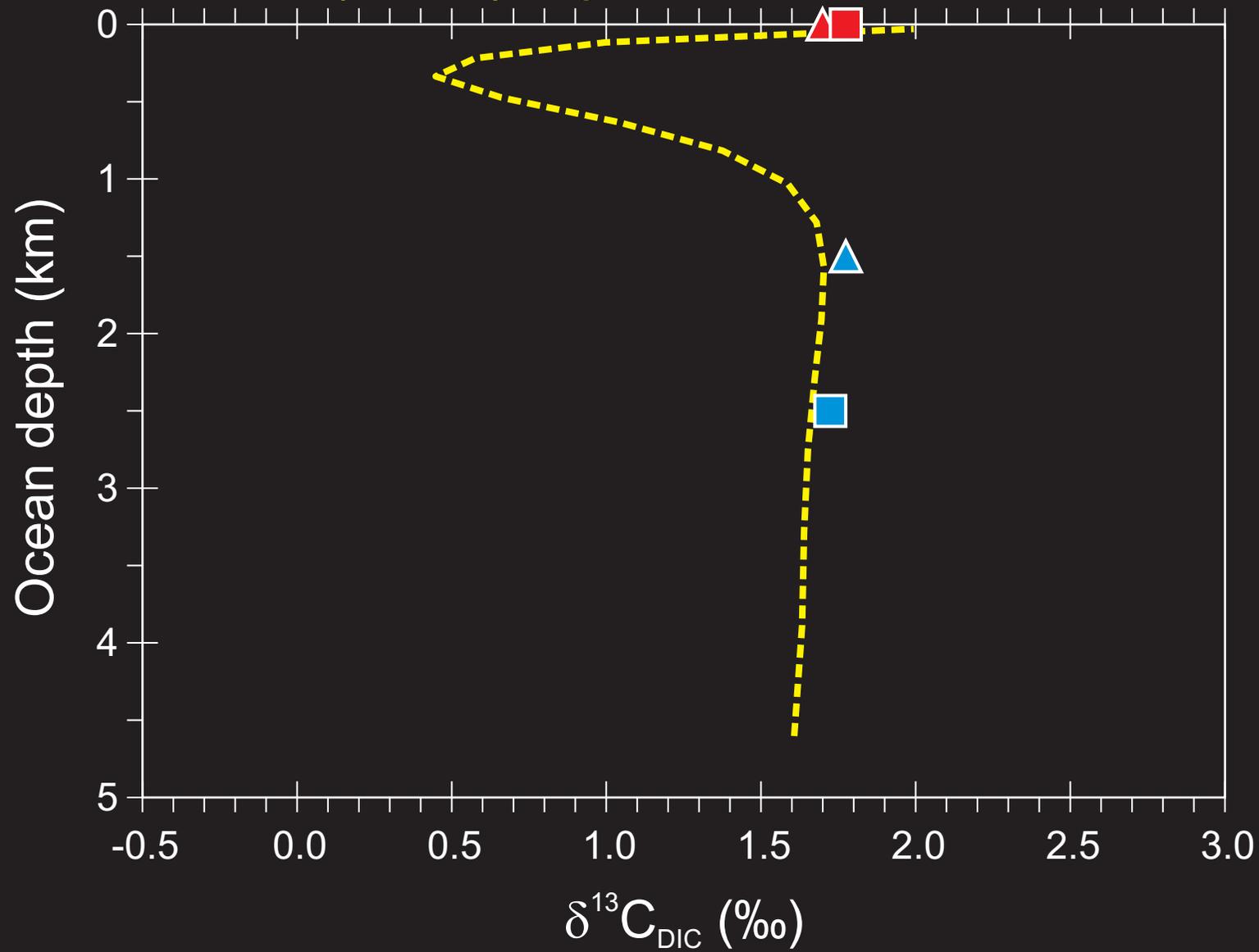


Disruption in marine carbon cycling

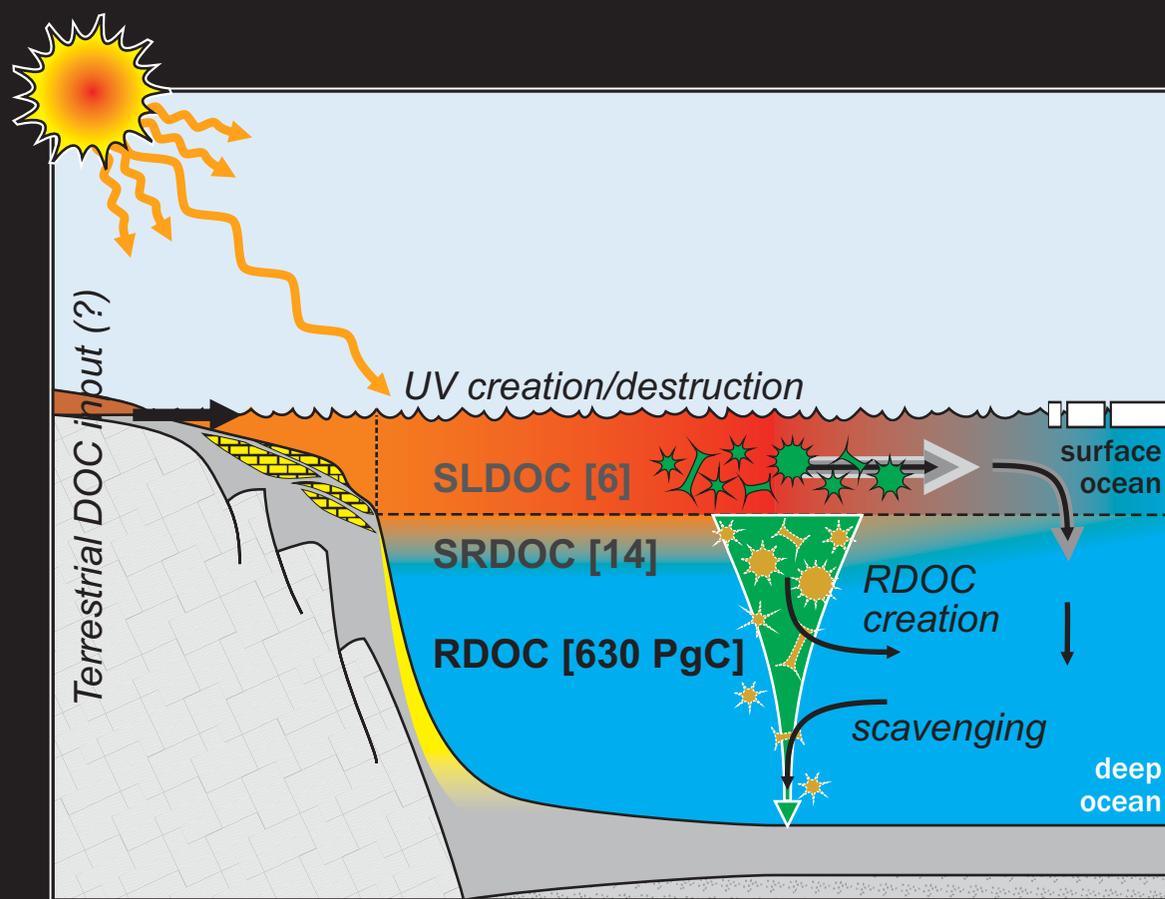


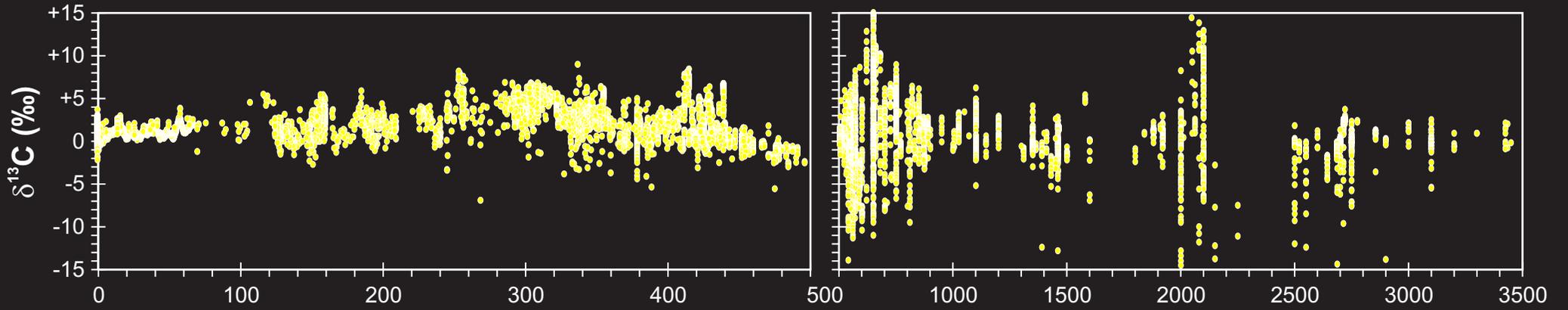
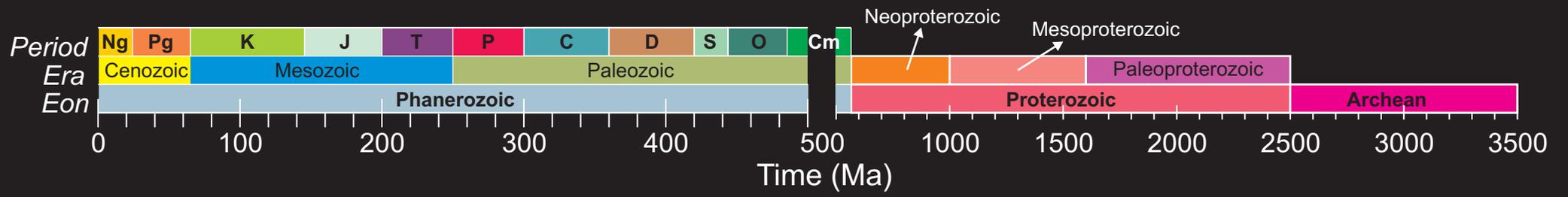
Disruption in marine carbon cycling

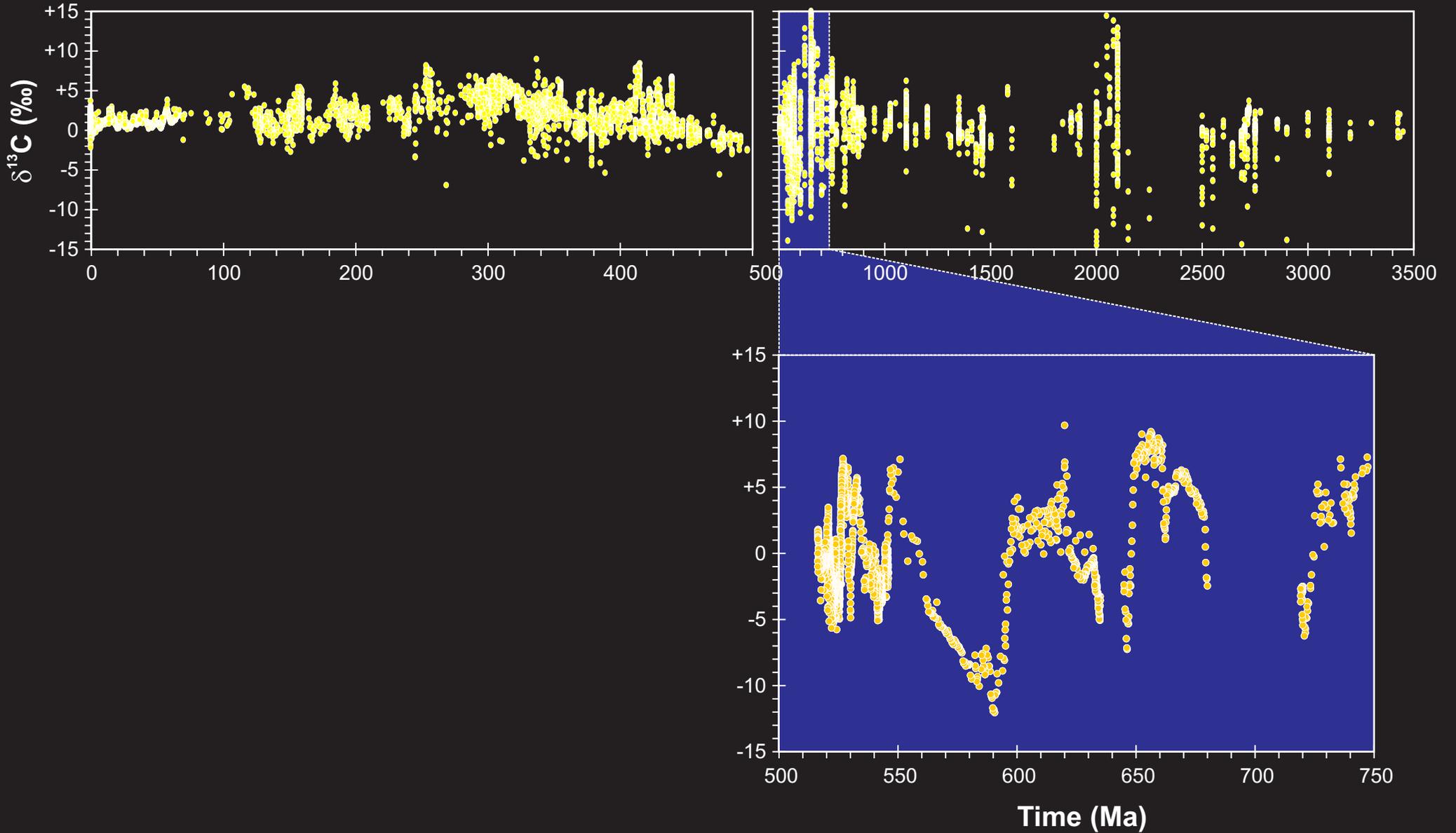
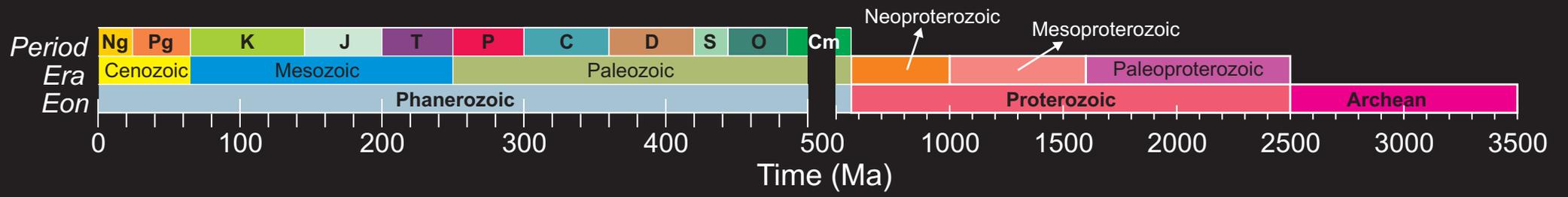
shallow (150 m) organic matter remineralization



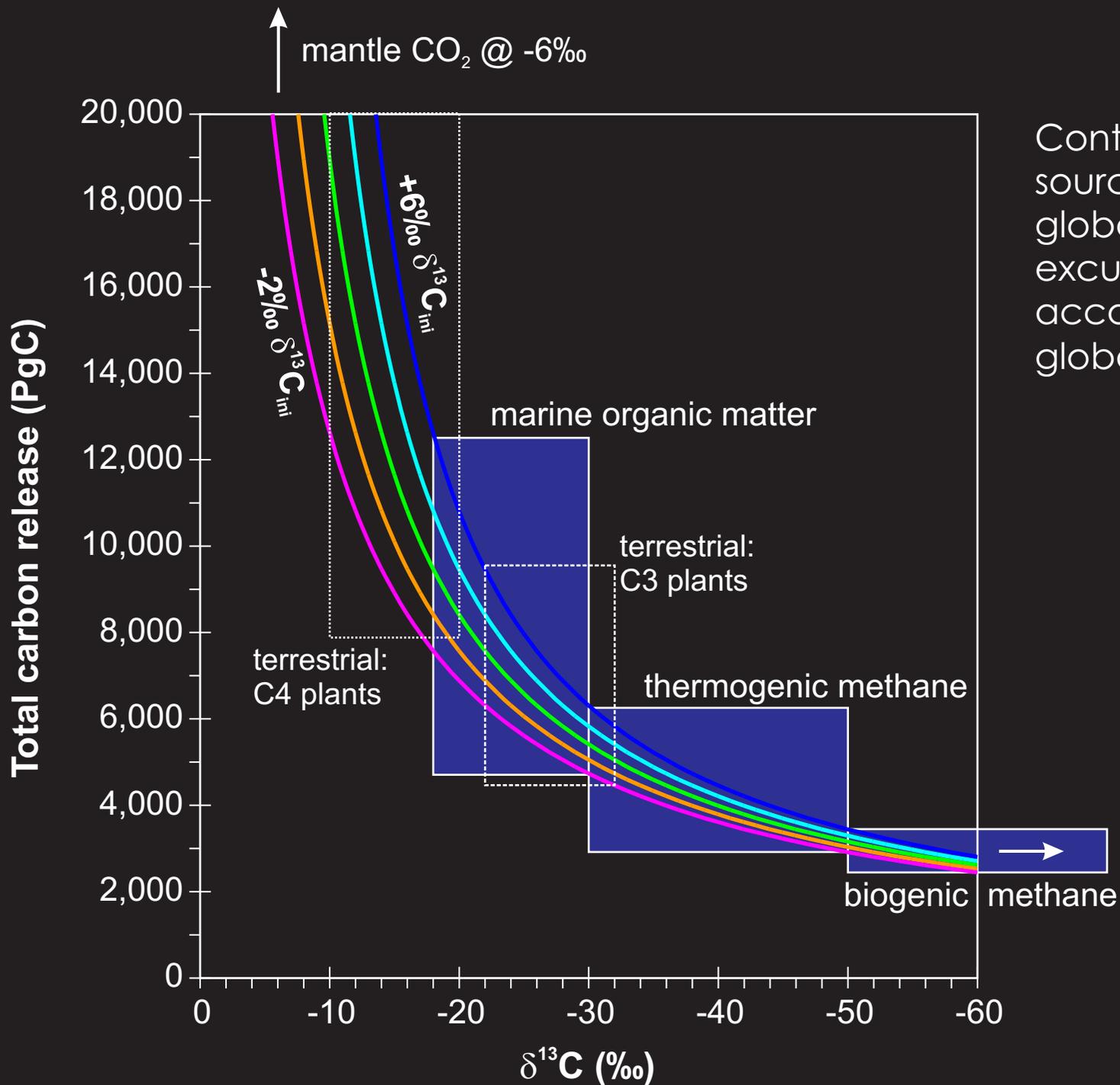
Marine carbon cycling: DOM





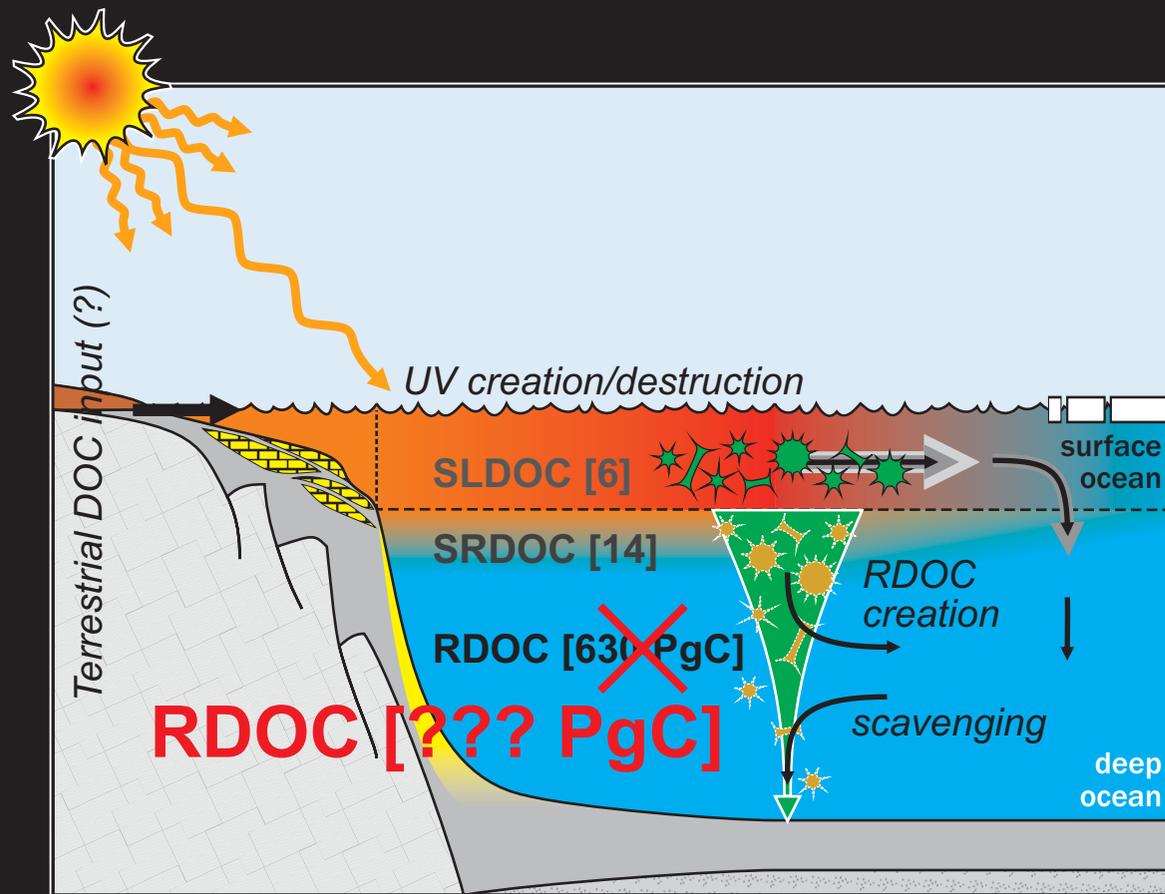
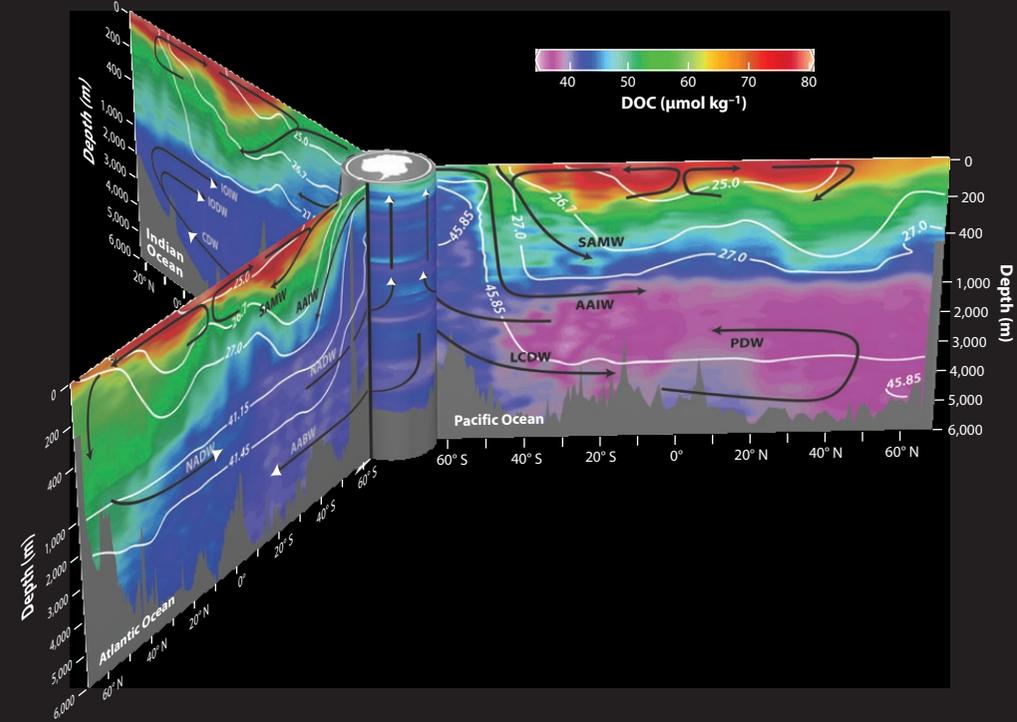


Marine carbon cycling: DOM

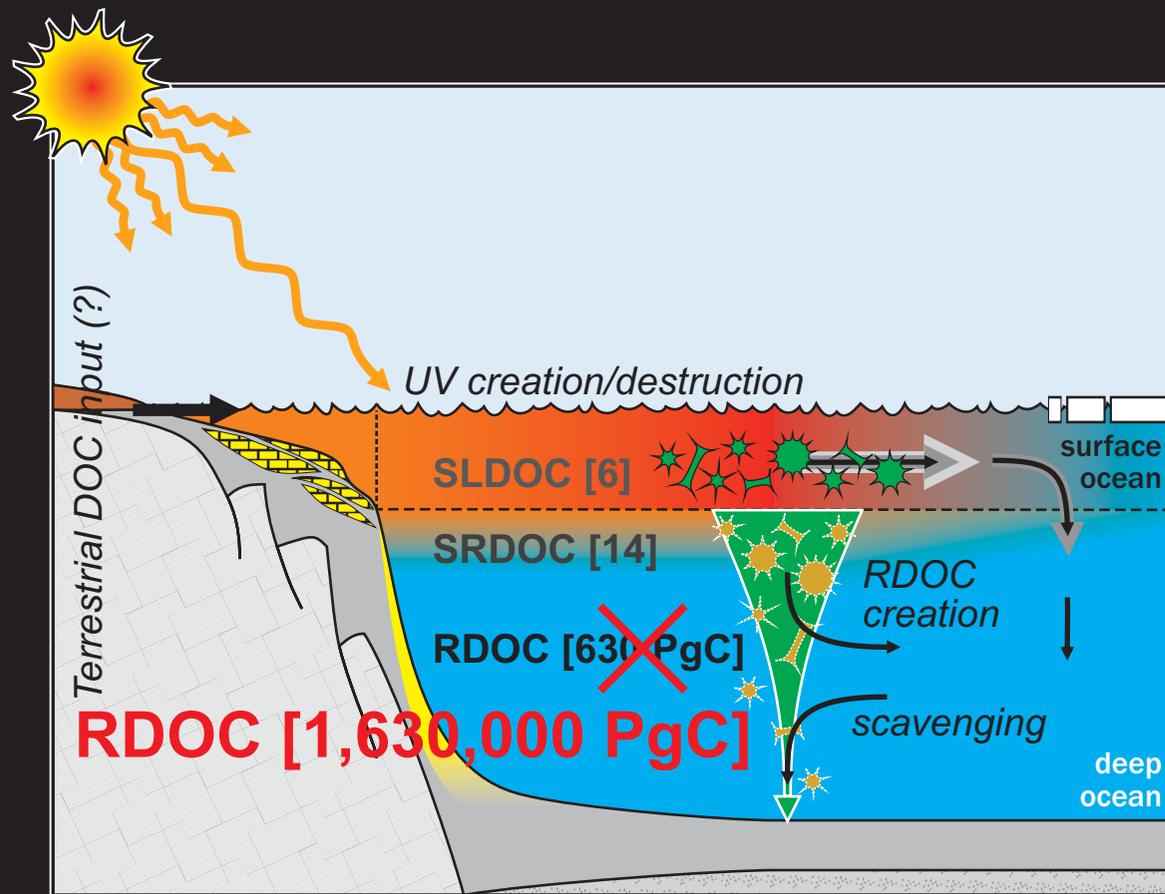
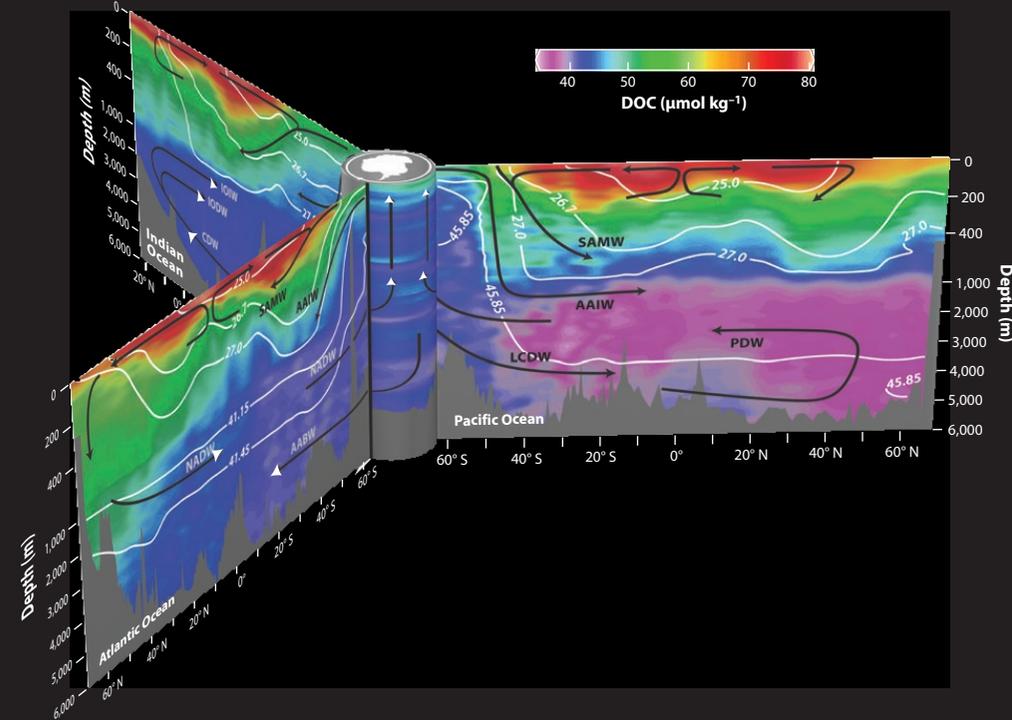


Contours of carbon release vs. source isotopic signature for a global -4‰ carbon isotopic excursion. Contours differ according to the initial mean global $\delta^{13}\text{C}$.

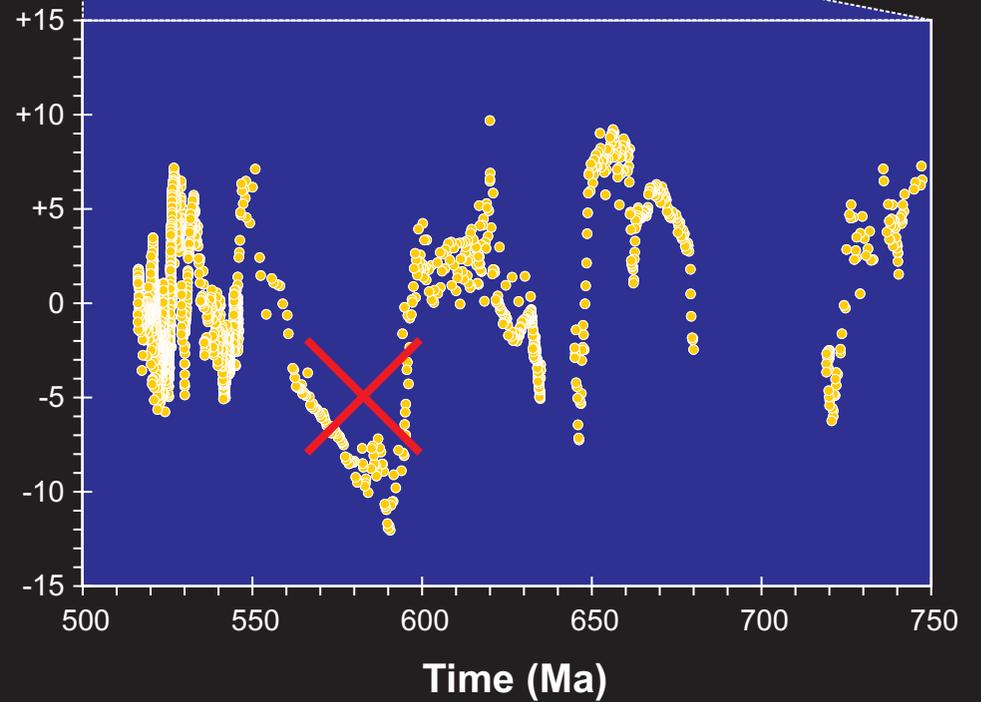
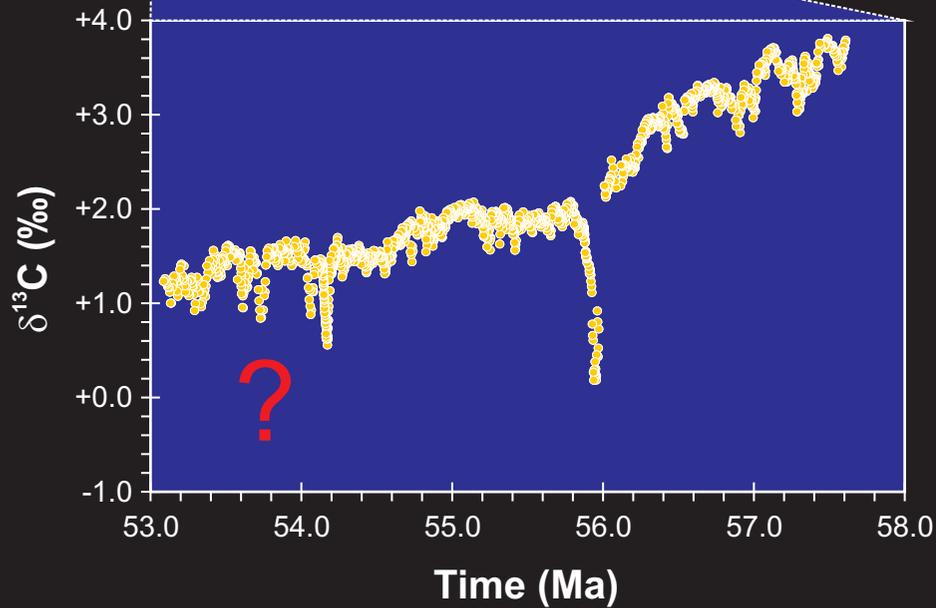
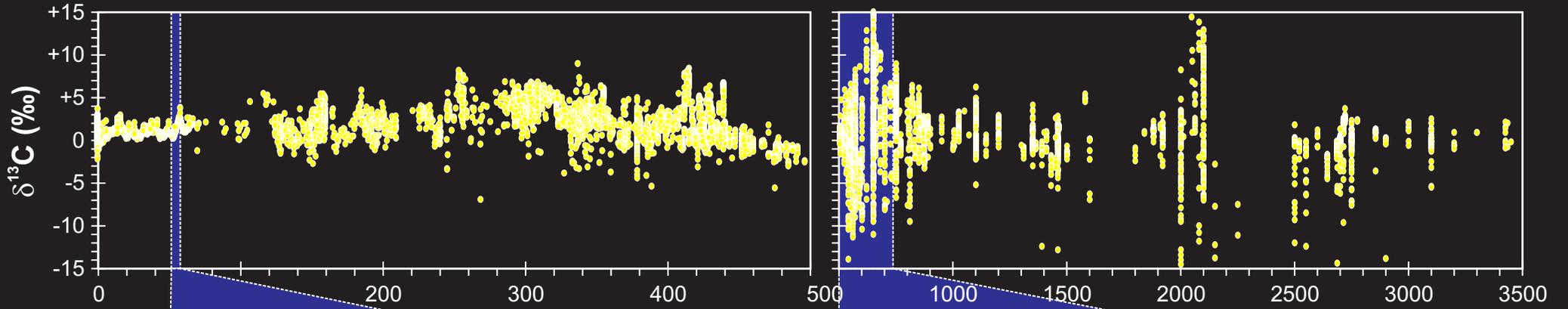
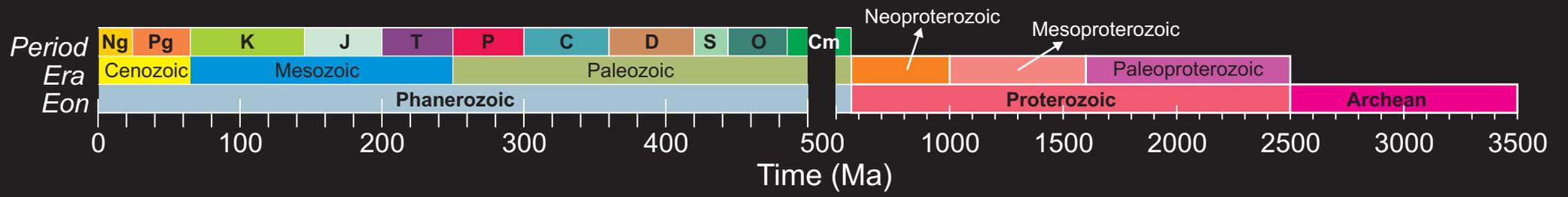
Marine carbon cycling: DOM



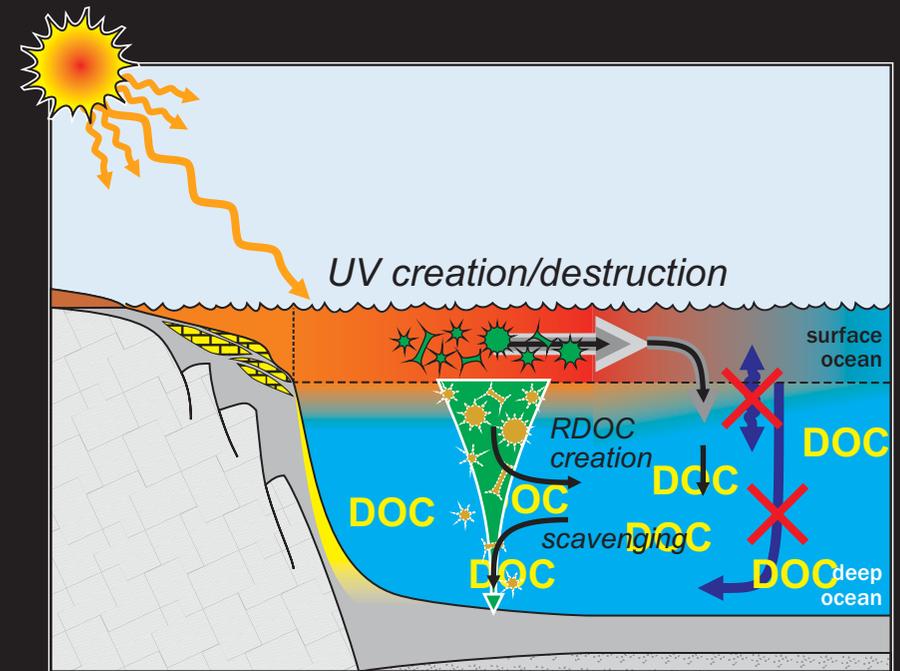
Marine carbon cycling: DOM



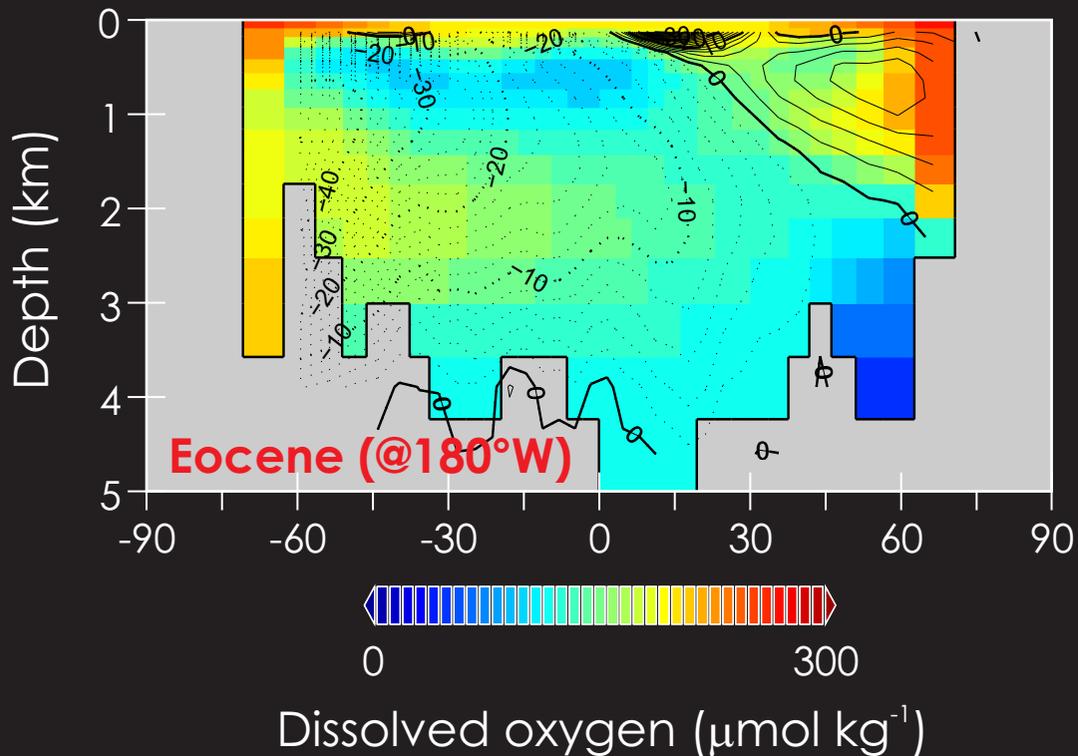
In the Rothman *et al.* [2003] model, the RDOC reservoir is assumed to have been at least 10 times the size of the inorganic (ocean DIC + atmospheric pCO_2) reservoir. For a modern DIC + pCO_2 reservoir of 39,000 PgC, this mean 390,000 PgC of DOC – more than 500 times larger than modern). For a higher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



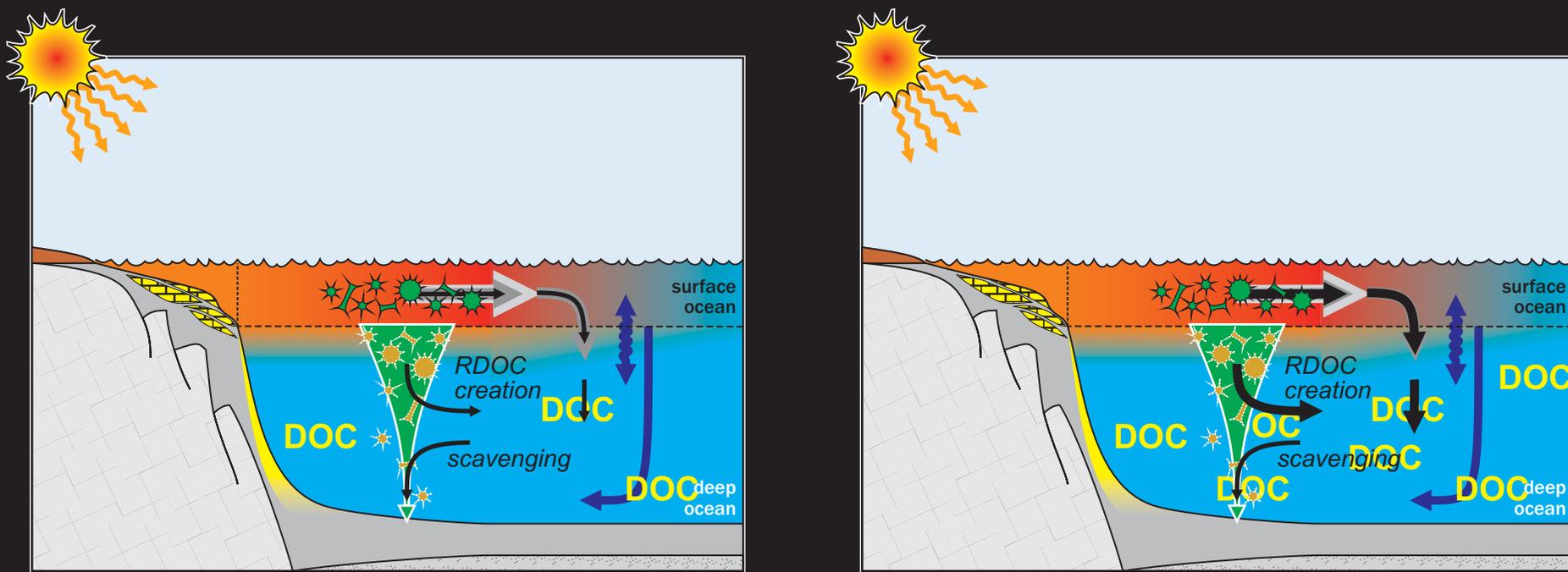
A DOC-dominated carbon cycle?



Sexton et al. [2011]



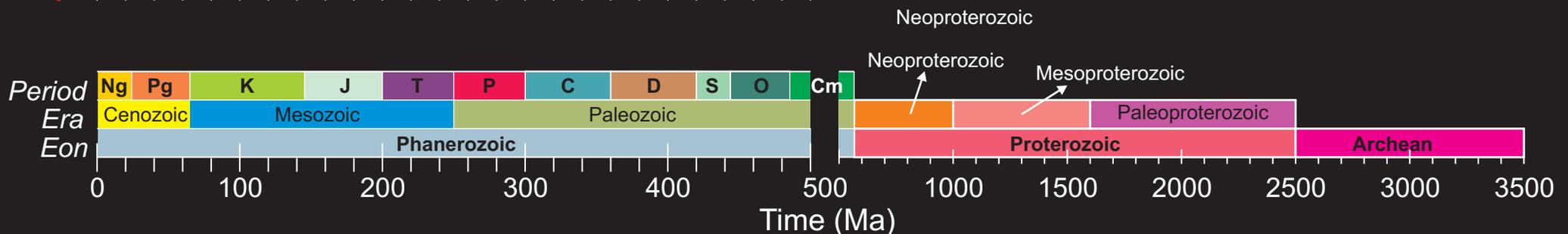
In the Eocene hyperthermal RDOC hypothesis, difficulties include envisioning a sufficiently stratified deep ocean (even when ignoring the lack of any evidence for widespread anoxia) that could partition RDOC away from the upper ocean and destruction by oxidation/photo-degradation.



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.

Major changes in plankton assemblage

Martin [1995]

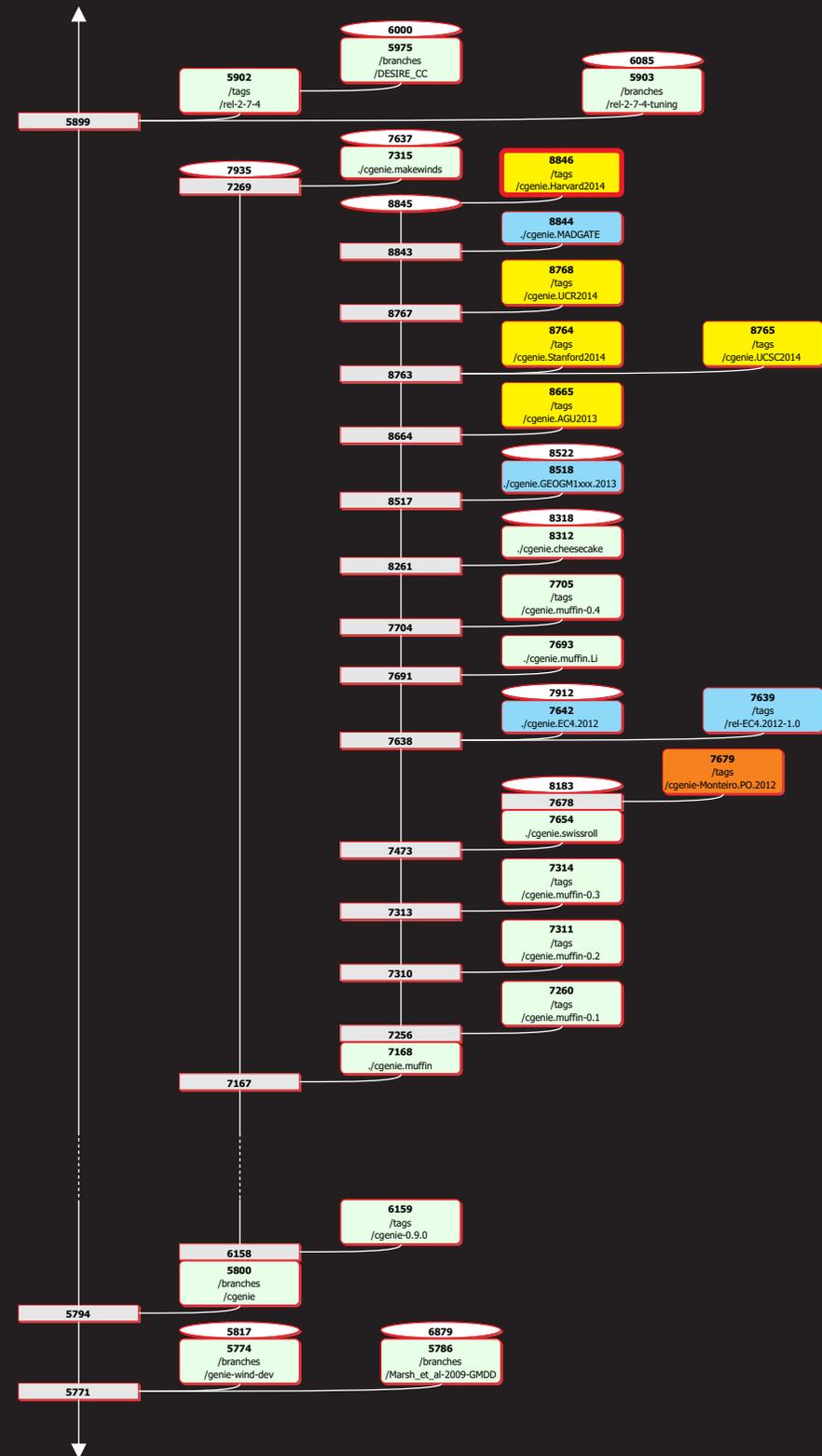


models . . .

```
! calculate carbonate alkalinity
loc_ALK_DIC = dum_ALK &
& - loc_H4BO4 - loc_OH - loc_HPO4 - 2.0*loc_PO4 - loc_H3SiO4 - loc_NH3 - loc_HS &
& + loc_H + loc_HSO4 + loc_HF + loc_H3PO4
! estimate the partitioning between the aqueous carbonate species
loc_zed = ( &
& (4.0*loc_ALK_DIC + dum_DIC*dum_carbconst(icc_k) -
loc_ALK_DIC*dum_carbconst(icc_k))**2 + &
& 4.0*(dum_carbconst(icc_k) - 4.0)*loc_ALK_DIC**2 &
& )**0.5      loc_conc_HCO3 = (dum_DIC*dum_carbconst(icc_k) -
loc_zed)/(dum_carbconst(icc_k) - 4.0)
loc_conc_CO3 = &
& ( &
& loc_ALK_DIC*dum_carbconst(icc_k) - dum_DIC*dum_carbconst(icc_k) - &
& 4.0*loc_ALK_DIC + loc_zed &
& ) &
& /(2.0*(dum_carbconst(icc_k) - 4.0))
loc_conc_CO2 = dum_DIC - loc_ALK_DIC + &
& ( &
& loc_ALK_DIC*dum_carbconst(icc_k) - dum_DIC*dum_carbconst(icc_k) - &
& 4.0*loc_ALK_DIC + loc_zed &
& ) &
& /(2.0*(dum_carbconst(icc_k) - 4.0))
loc_H1 = dum_carbconst(icc_k1)*loc_conc_CO2/loc_conc_HCO3
loc_H2 = dum_carbconst(icc_k2)*loc_conc_HCO3/loc_conc_CO3
```




www.seao2.info/misc_harvard2014.html





cGENIE ClimaTea 2014 version: README

Andy Ridgwell

April 23, 2014

- To get an exact (read-only) copy of the ('mu□n' development branch)cGENIE source code used for the ClimaTea presentation – in linux, (ideally from your home directory) type:

```
svn co https://svn.ggy.bris.ac.uk/subversion/genie/tags/cgenie.Harvard2014
```

```
--username=genie-user cgenie.muffin
```

NOTE: All this must be typed continuously on ONE LINE, with a S P A C E before '--username', and before 'cgenie'. You will be asked for a password – it isg3n1e-user.
- You need to set a couple of environment variables – the compiler name, netCDF library name, and netCDF path. These are specified in the fileuser.mak (genie-main directory). If the cgenie code tree (cgenie.muffin) and output directory (cgenie output) are installed anywhere other than in your account HOME directory, paths specifying this will have to be edited in: user.mak anduser.sh (genie-main directory). Installing the model code under the default directory name (cgenie.mu□n) in your HOME directory is hence by far the simplest and avoids incurring additional/unnecessary pain (configuration complexity) ...
 You will also need to have installed or linked to an appropriate FORTRAN compiler and netCDF library (built with the same FORTRAN compiler). The GNU FORTRAN compiler (gfort) version 4.4.4 or later is recommended. The netCDF version needs to be 4.0 (more recent versions require a little work-around, not documented here ...).
- To test the code installation – change directory tocgenie.muffin/genie-main and type:

```
make testbiogem
```

This compiles a carbon cycle enabled configuration ofcGENIE and runs a short test, comparing the results against those of a pre-run experiment (also downloaded alongside the model source code). It serves to check that you have the software environment correctly configured. If you are unsuccessful here ... double-check the software and directory environment settings in user.mak (or user.sh) and for a netCDF error, check the value of theNETCDF DIRenvironment variable. (Refer to the User Manual for addition fault-finding tips.) If environment variables are changed: before re-trying the test, you will need to type:

```
make cleanall
```

That is is for the basic installation. To run the model it is a simple matter of calling the 'runmuffin.sh' shell script fromgenie-main and supplying a couple of parameter values, e.g.:

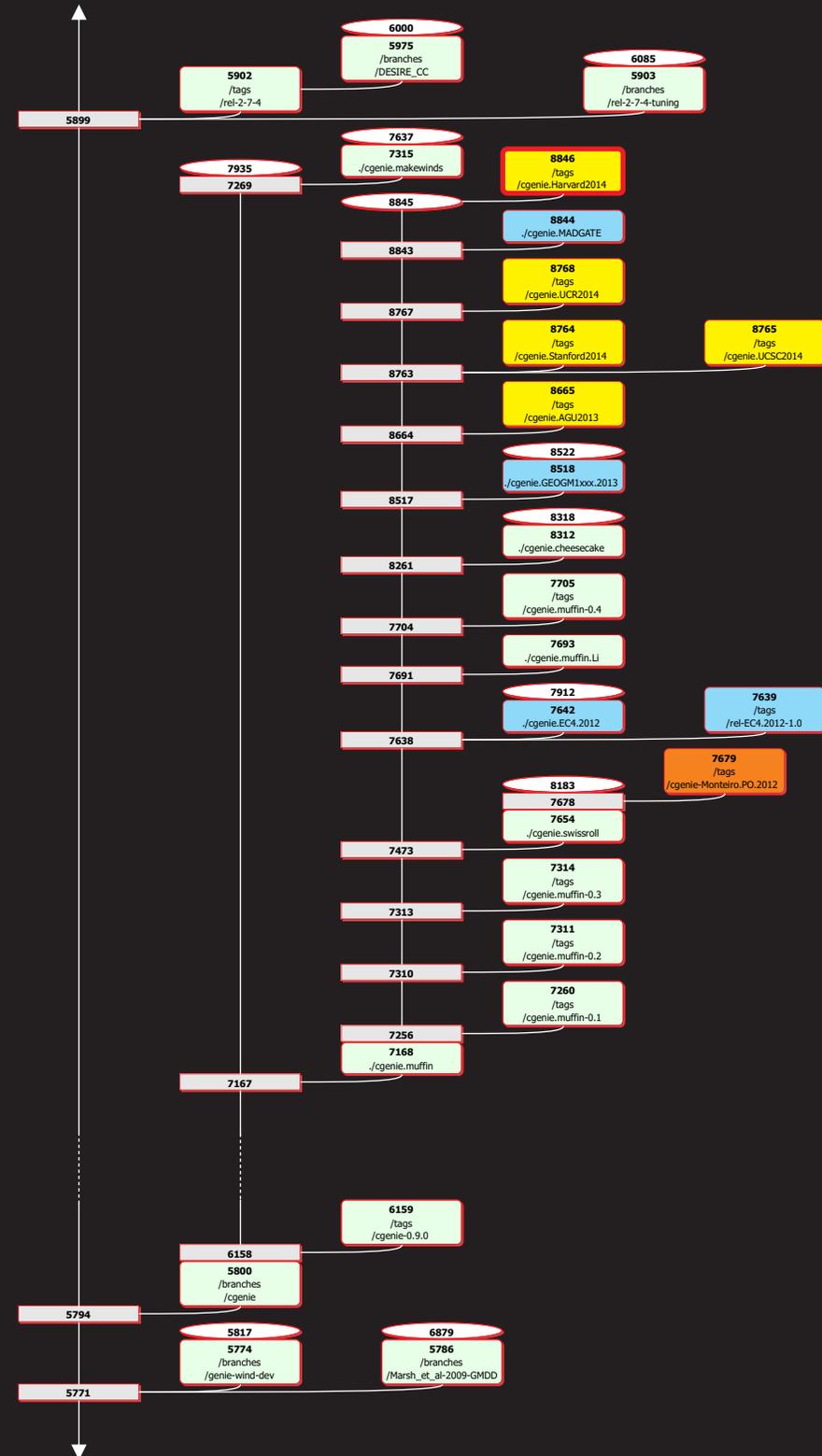
```
./runmuffin.sh cgenie.eb_go_gs_ac_bg.worjh2.ANTH / EXAMPLE.worjh2.Caoetal2009.SPIN 10000
```

Refer to thecGENIE User manualfor more information regarding installing, running, and analyzing model output, and cGENIE Examplesfor more information on this specific example.¹ Also read the cGENIE README

Highly recommended ... is in order to have a working appreciation of the structure of the model and output, plus the format of the model output and how to visualize it – to read through:

http://www.seao2.info/cgenie/labs/EC4.2013/GEOGM1110andM1404.2013-14.cGENIE_LAB.0000.pdf

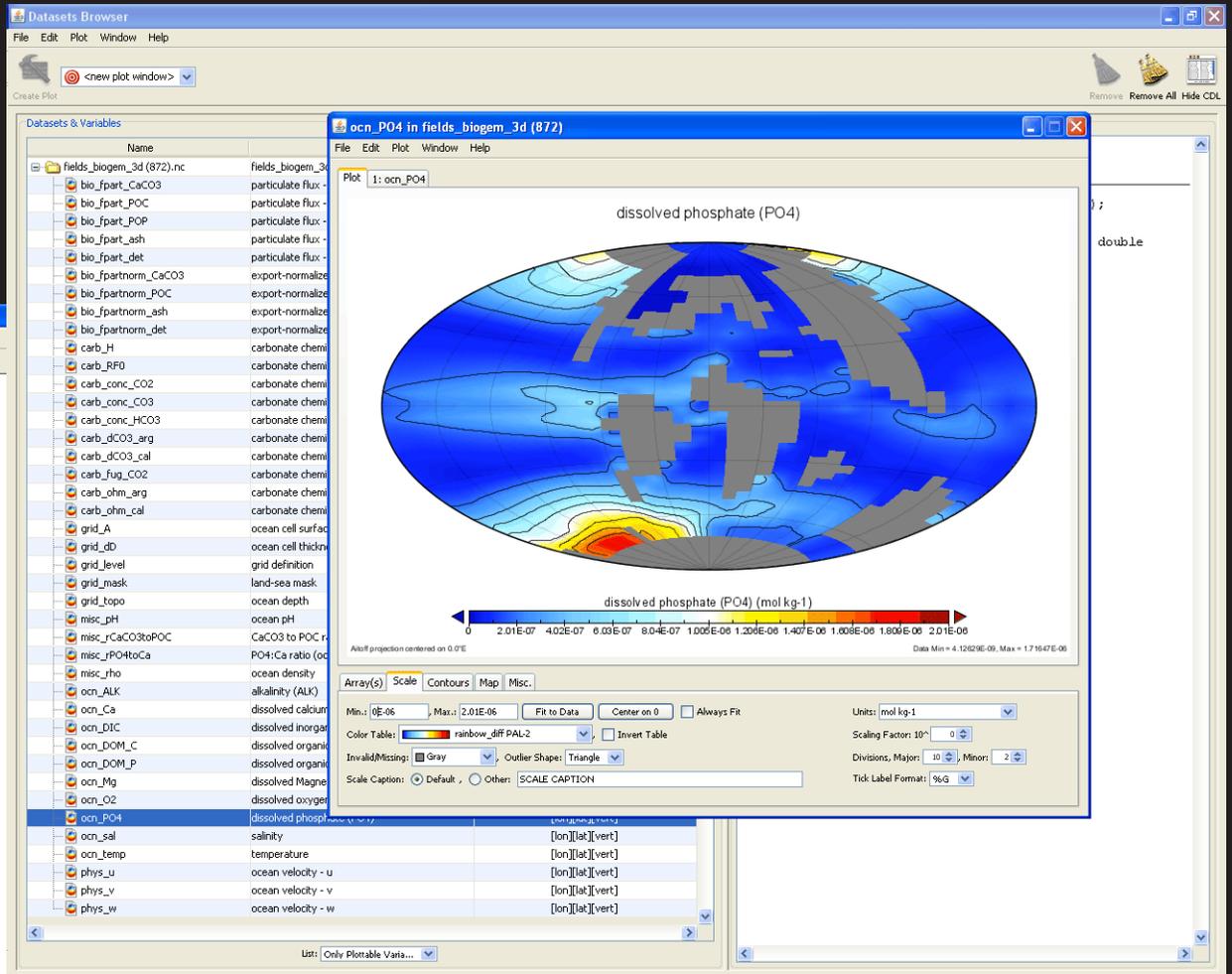
(which serves as a basic introduction to the model and how to use it).



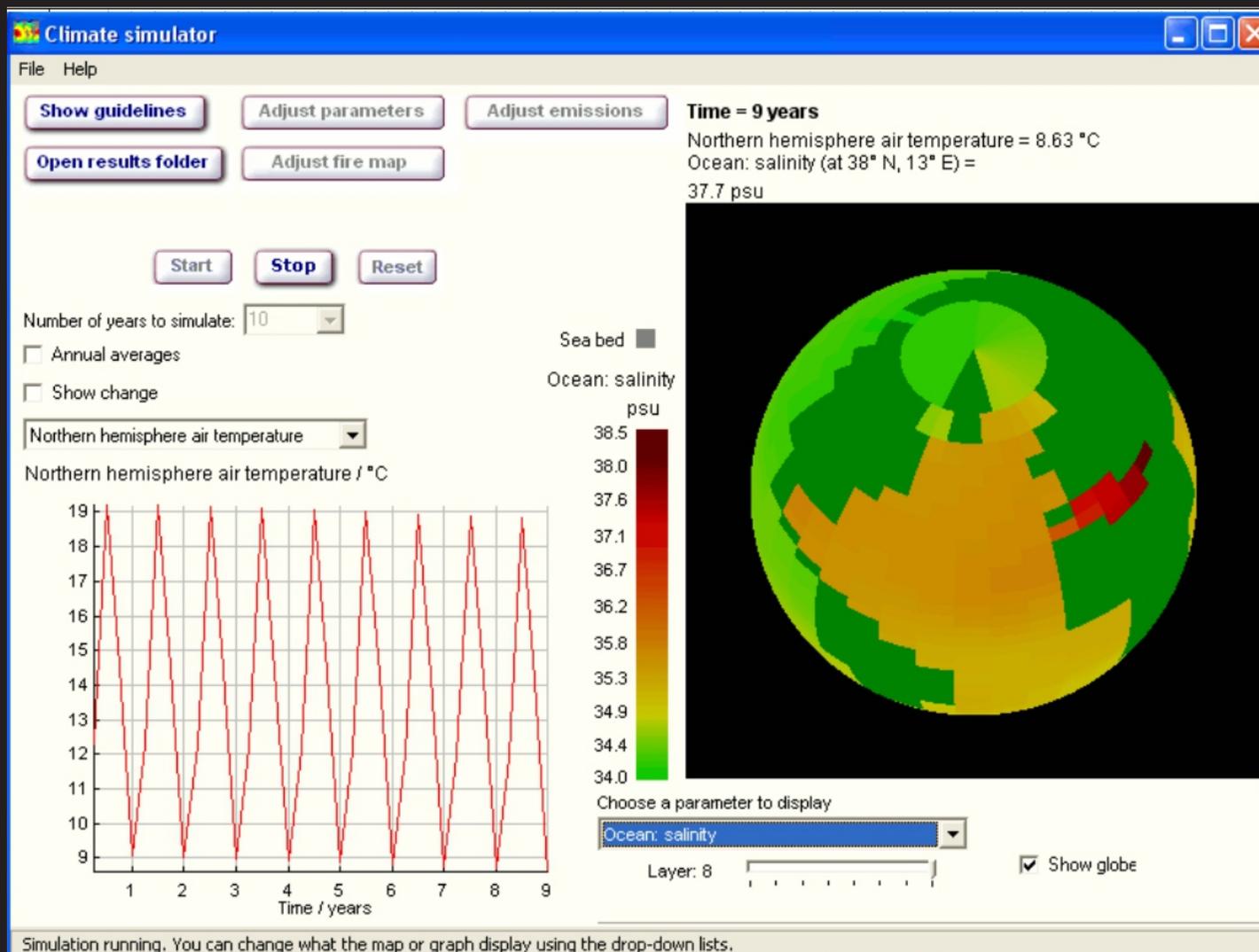
models . . .

```
1.almond.ggy.bris.ac.uk - mushroom@almond - SSH Secure Shell
File Edit View Window Help
Quick Connect Profiles
Filename for restart input : atchem
Filename for restart output : atchem
*****
Initialization of ATCHEM module complete
*****
Check for weightings from genie atm = 0.999999999999999
Check for weightings from genie ocn = 0.999999999999999
*****
Initialization complete, simulation starting
*****
do the looping.....

model year * pCO2(uatm) d13C02 * AMO(Sv) ice(%) <SST> <SSS> * <DIC>(uM) <ALK>(uM)
>>> SAVING BIOGEM TIME-SERIES @ year 0.50 285.160 -6.812 17.359 0.211 1.393 34.901 2242.457 2363.077
temp / min = 0.2713E+03 (19,36, 8) / max = 0.2774E+03 (27,20, 8)
sal / min = 0.3488E+02 ( 6,19, 8) / max = 0.3495E+02 (19,36, 8)
DIC / min = 0.2203E-02 (34,12, 8) / max = 0.2249E-02 ( 4,16, 7)
DIC_13C / min = 0.3334E+00 ( 4,16, 7) / max = 0.8799E+00 (35,12, 8)
DIC_14C / min = -0.1917E+00 ( 4,16, 7) / max = 0.1239E+01 (35,12, 8)
PO4 / min = 0.1968E-05 (36,19, 8) / max = 0.2203E-05 ( 4,16, 7)
O2 / min = 0.1641E-03 ( 4,16, 7) / max = 0.3379E-03 (34,11, 8)
ALK / min = 0.2363E-02 ( 4,16, 7) / max = 0.2365E-02 (21,22, 8)
DOM_C / min = -0.3186E-07 (17,25, 6) / max = 0.1155E-04 (31,20, 8)
DOM_C_13C / min = -0.1000E+20 ( 1,13, 1) / max = -0.2874E+02 (21,25, 4)
DOM_C_14C / min = -0.1000E+20 ( 1,13, 1) / max = -0.2505E+02 (21,25, 4)
DOM_P / min = -0.3006E-09 (17,25, 6) / max = 0.1090E-06 (31,20, 8)
Ca / min = 0.1025E-01 (25,21, 8) / max = 0.1025E-01 (19,36, 8)
CFC11 / min = 0.0000E+00 ( 1, 3, 2) / max = 0.0000E+00 ( 1, 3, 2)
CFC12 / min = 0.0000E+00 ( 1, 3, 2) / max = 0.0000E+00 ( 1, 3, 2)
Mg / min = 0.5281E-01 ( 8,33, 8) / max = 0.5283E-01 (19,36, 8)
>>> SAVING BIOGEM TIME-SLICE @ year 0.5000000000000000
temp / min = 0.2712E+03 (19,36, 8) / max = 0.2831E+03 (27,20, 8)
sal / min = 0.3483E+02 (25,21, 8) / max = 0.3516E+02 (19,36, 8)
DIC / min = 0.2168E-02 (31,19, 8) / max = 0.2258E-02 ( 4,16, 7)
DIC_13C / min = 0.2156E+00 ( 4,16, 7) / max = 0.1296E+01 (34,11, 8)
DIC_14C / min = -0.5418E+00 ( 4,16, 7) / max = 0.2424E+01 (34,11, 8)
PO4 / min = 0.1736E-05 ( 3,16, 8) / max = 0.2289E-05 ( 4,16, 7)
O2 / min = 0.1543E-03 ( 4,16, 7) / max = 0.3343E-03 (13,29, 8)
ALK / min = 0.2362E-02 (10,34, 8) / max = 0.2369E-02 (18,36, 8)
DOM_C / min = -0.1272E-06 (17,25, 6) / max = 0.1772E-04 (31,20, 8)
DOM_C_13C / min = -0.1000E+20 ( 1,12, 1) / max = 0.6187E+01 (27,16, 1)
DOM_C_14C / min = -0.1000E+20 ( 1,12, 1) / max = 0.3613E+02 (27,16, 1)
DOM_P / min = -0.1200E-08 (17,25, 6) / max = 0.1672E-06 (31,20, 8)
Ca / min = 0.1024E-01 (25,21, 8) / max = 0.1028E-01 (18,36, 8)
CFC11 / min = 0.0000E+00 ( 1, 3, 2) / max = 0.0000E+00 ( 1, 3, 2)
CFC12 / min = 0.0000E+00 ( 1, 3, 2) / max = 0.0000E+00 ( 1, 3, 2)
Mg / min = 0.5276E-01 (25,21, 8) / max = 0.5295E-01 (18,36, 8)
temp / min = 0.2712E+03 (19,36, 8) / max = 0.2857E+03 (31,20, 8)
sal / min = 0.3479E+02 (25,21, 8) / max = 0.3526E+02 (19,36, 8)
DIC / min = 0.2143E-02 (31,19, 8) / max = 0.2265E-02 ( 4,16, 7)
DIC_13C / min = 0.1340E+00 ( 4,16, 7) / max = 0.1540E+01 (22,25, 8)
DIC_14C / min = -0.8203E+00 ( 4,16, 7) / max = 0.3046E+01 (11,27, 8)
PO4 / min = 0.1575E-05 ( 3,16, 8) / max = 0.2352E-05 (26,29, 7)
O2 / min = 0.1463E-03 ( 4,16, 7) / max = 0.3331E-03 (13,30, 8)
ALK / min = 0.2360E-02 (25,21, 8) / max = 0.2371E-02 (18,36, 8)
Connected to almond.ggy.bris.ac.uk
SSH2 - aes128-cbc - hmac-md5 - none 178x61 NUM
```



models . . .



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