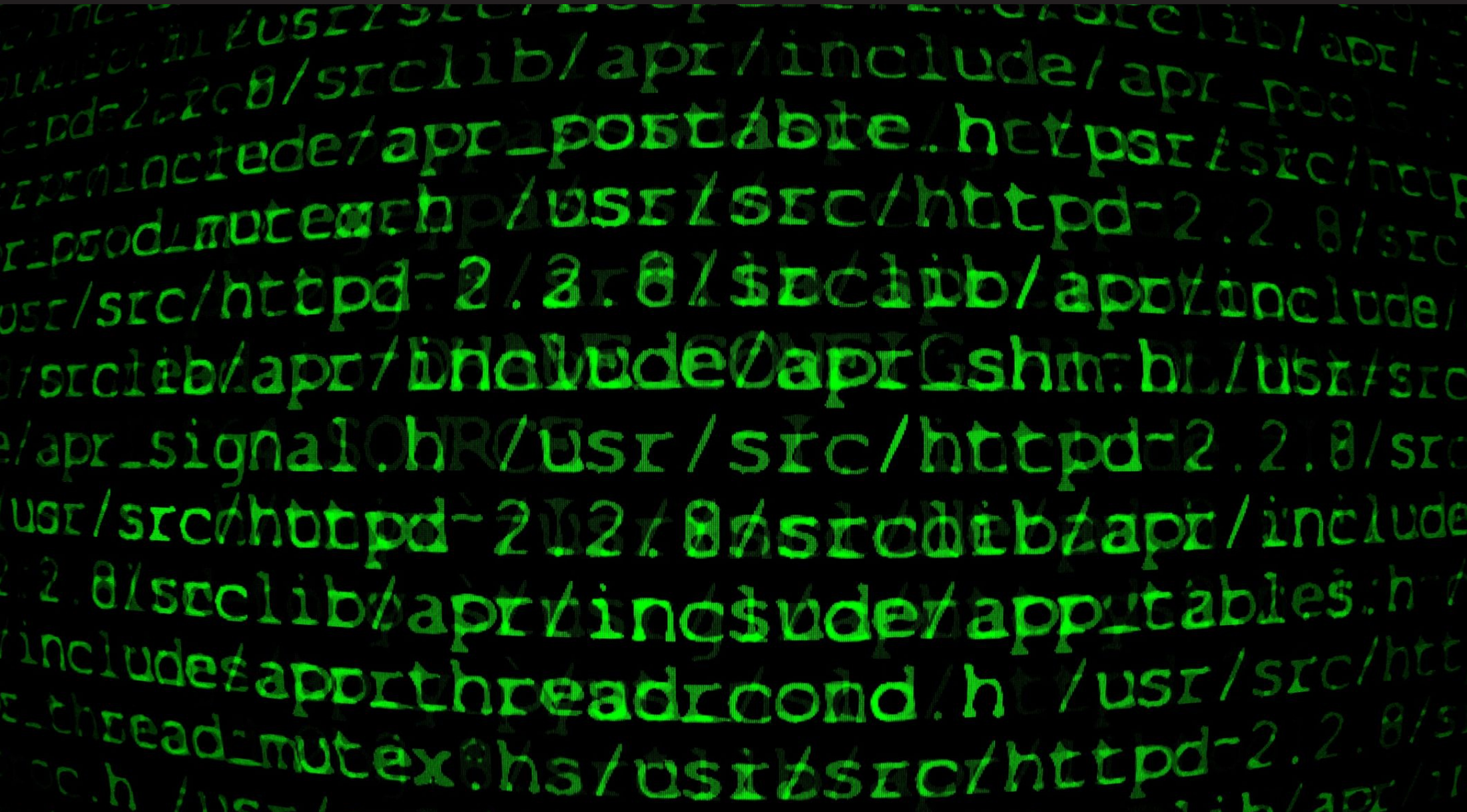
Ecodingt Hem Arineg Eologicalr Ecordd

Ndyr Idgwells & Andyk Irtlandt Urnera



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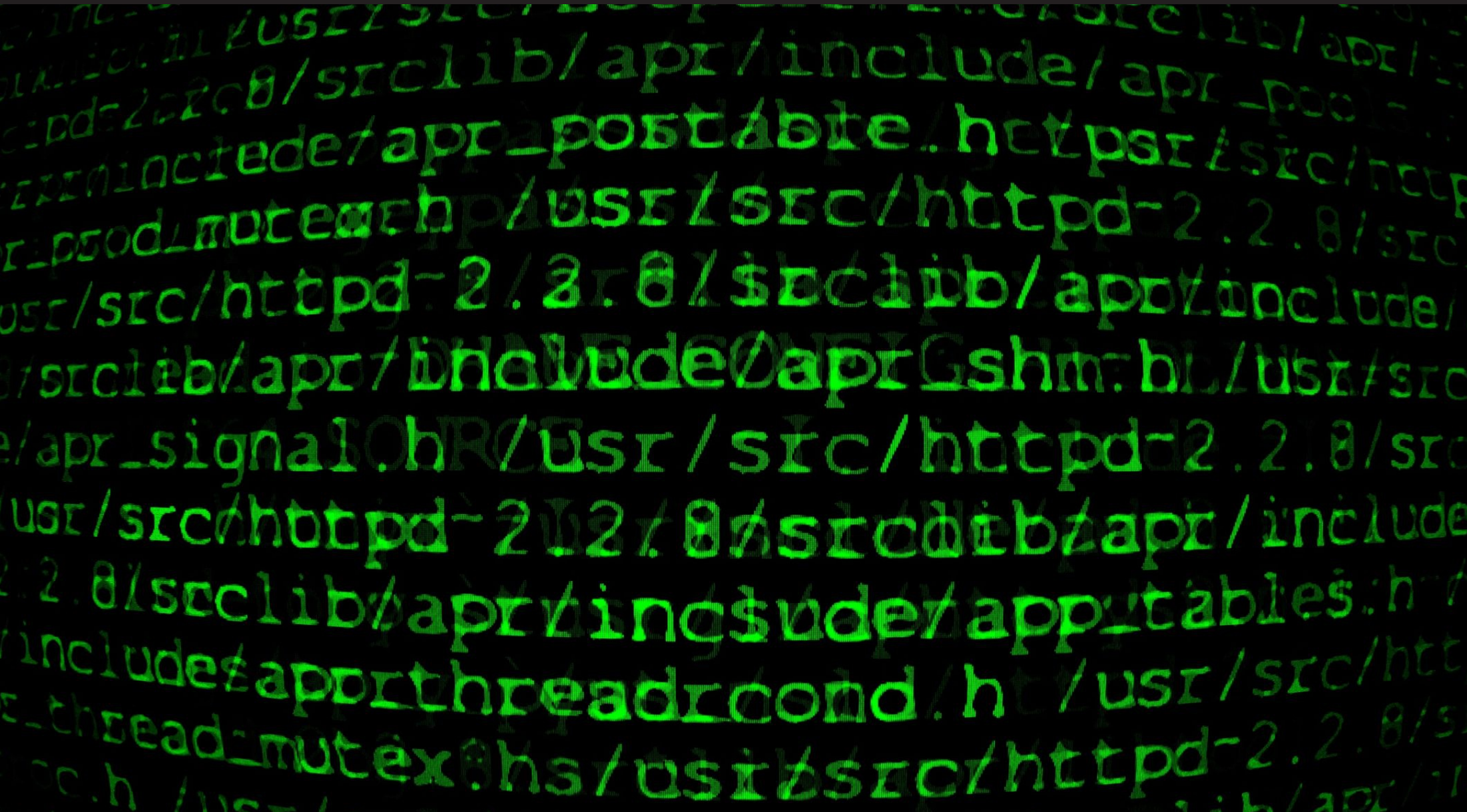
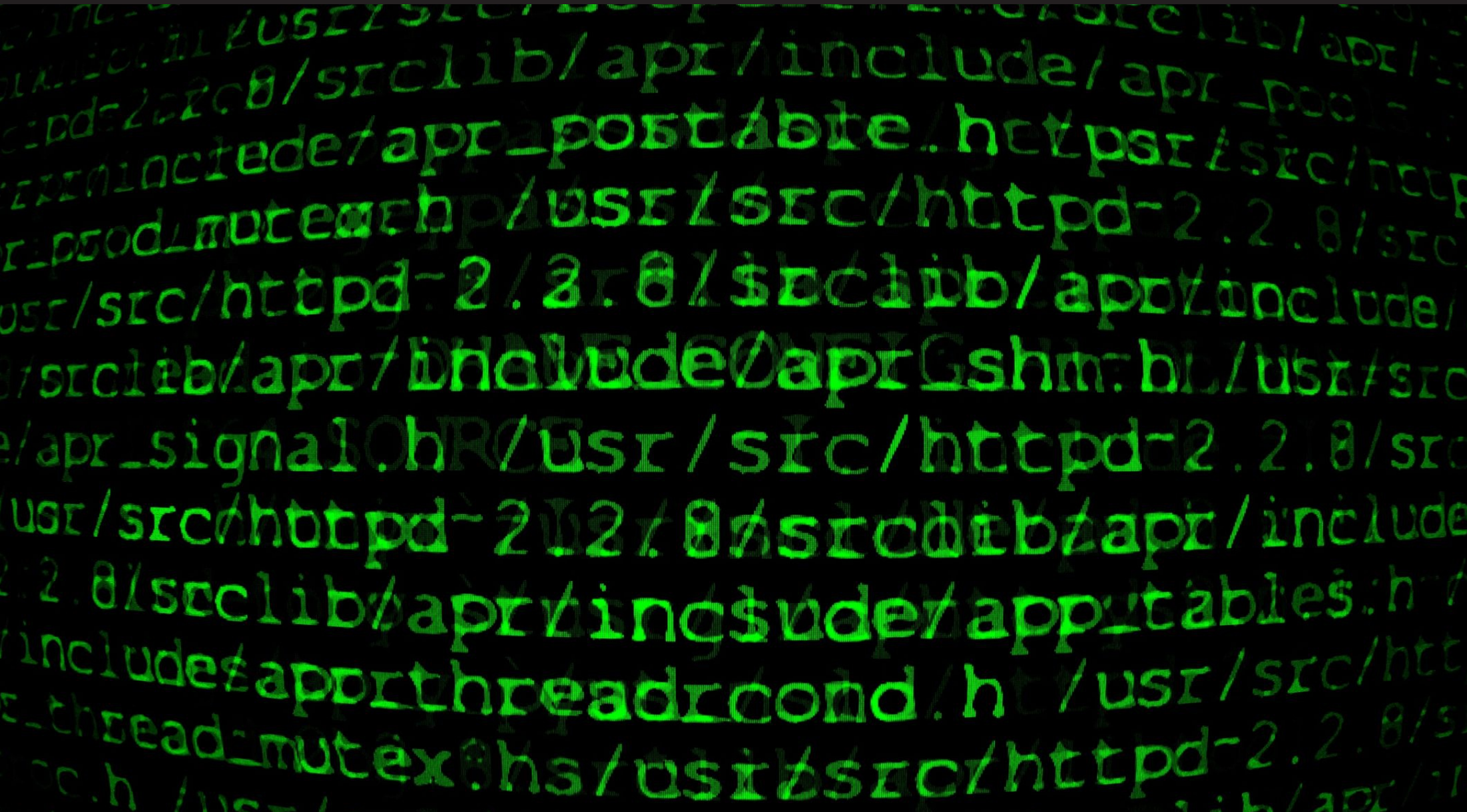
Ndyr Idgwells & Andyk Irtlandt Urnera



Εχοδινγτ Ηεμ

Αρινεγ Ε αλρ Εχορδδ

Νδψρ Ιδγωελλσ & Ανδψκ Ιρτλανδτ Υρνερα

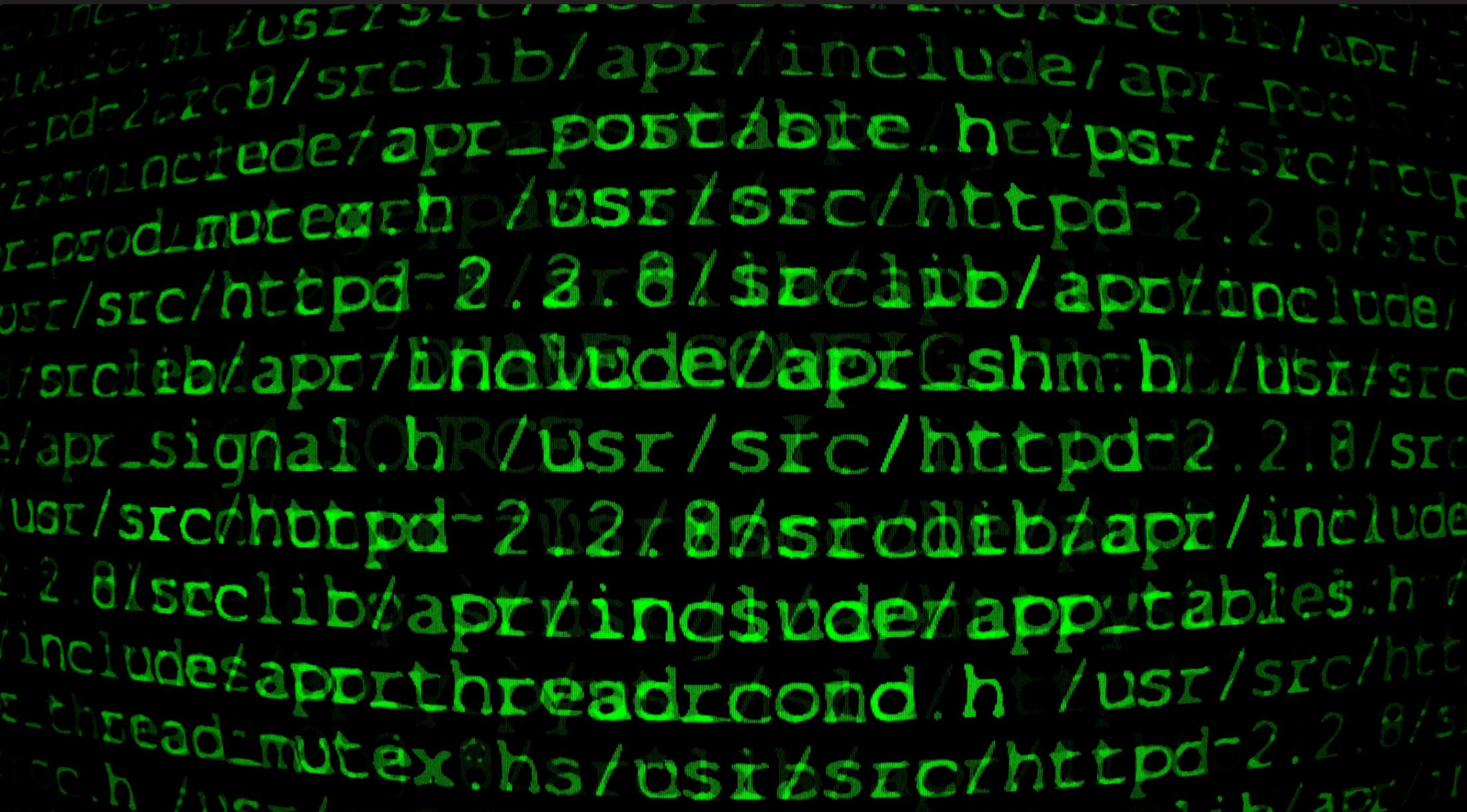


Decoding The Marine Geological Record

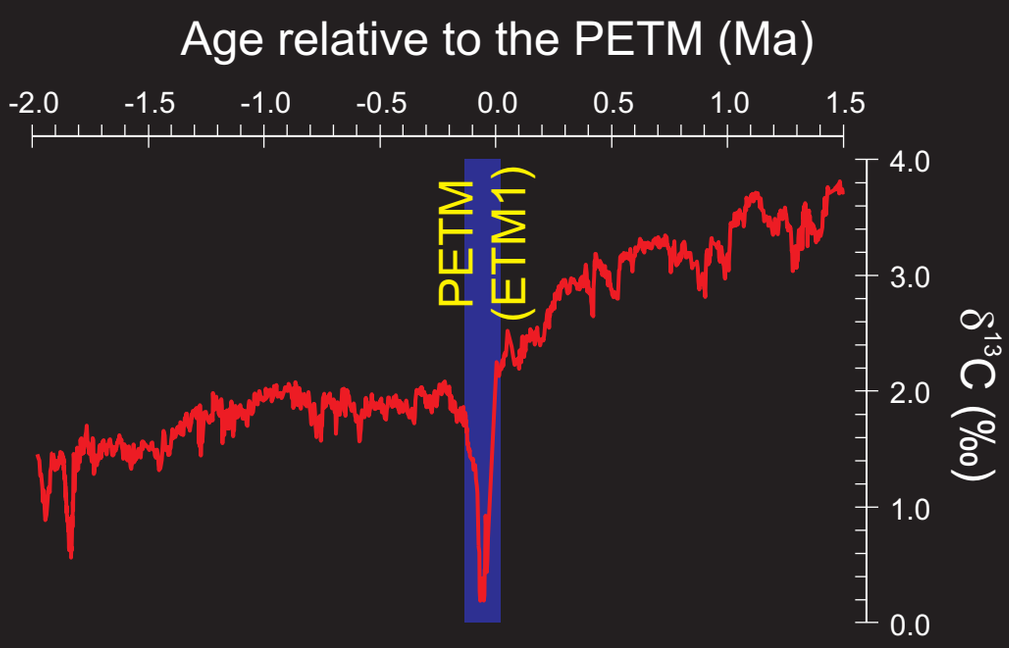
Andy Ridgwell & Sandy Kirtland Turner

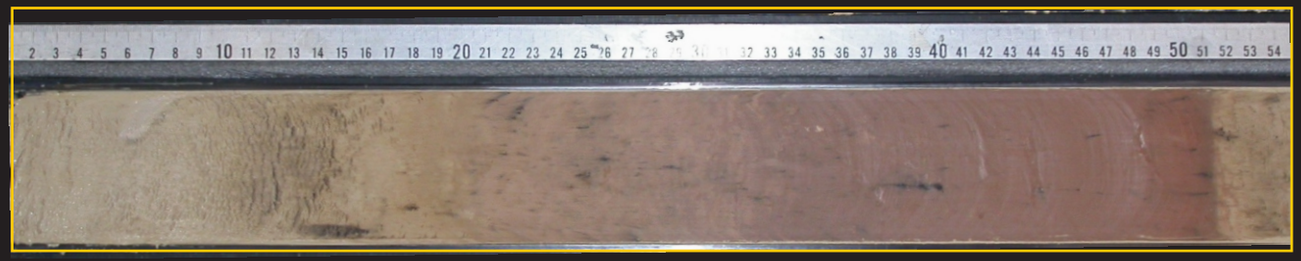
University of Bristol

The Royal Society
Celebrating 350 years

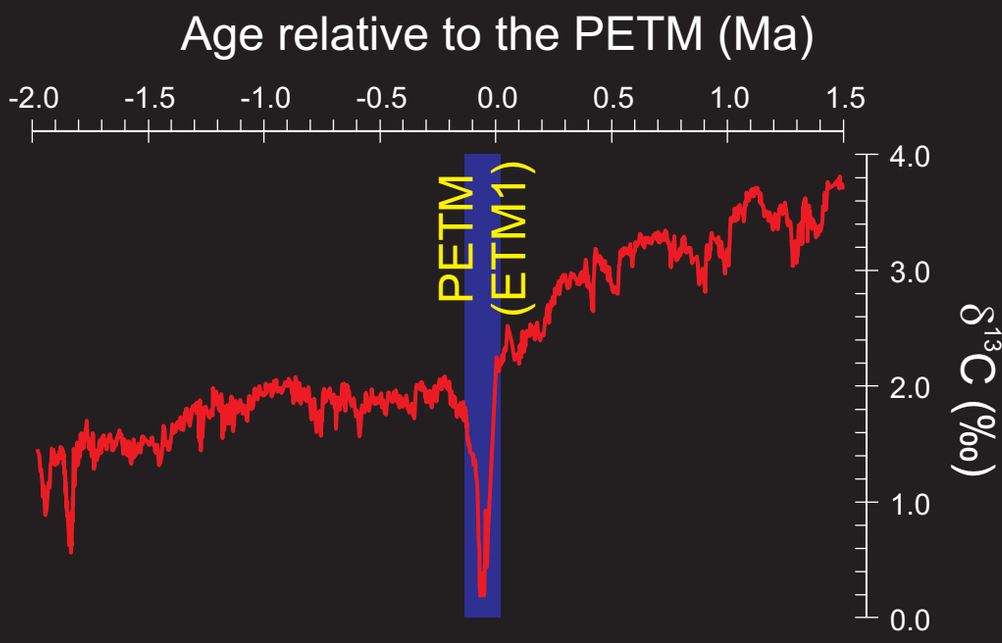


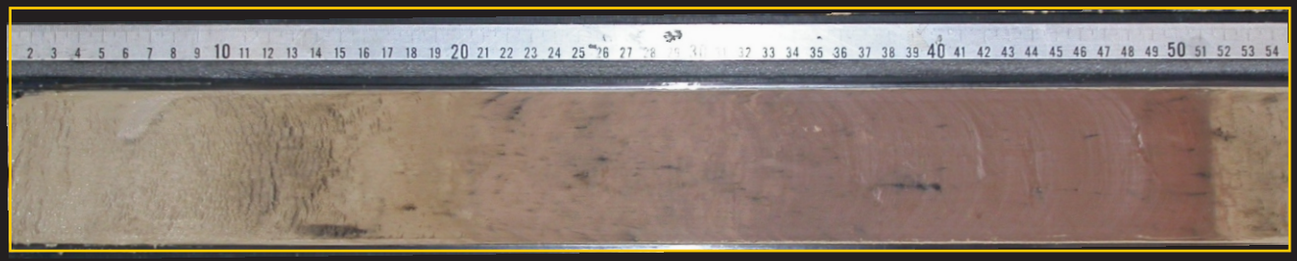
Decoding The Marine Geological Record



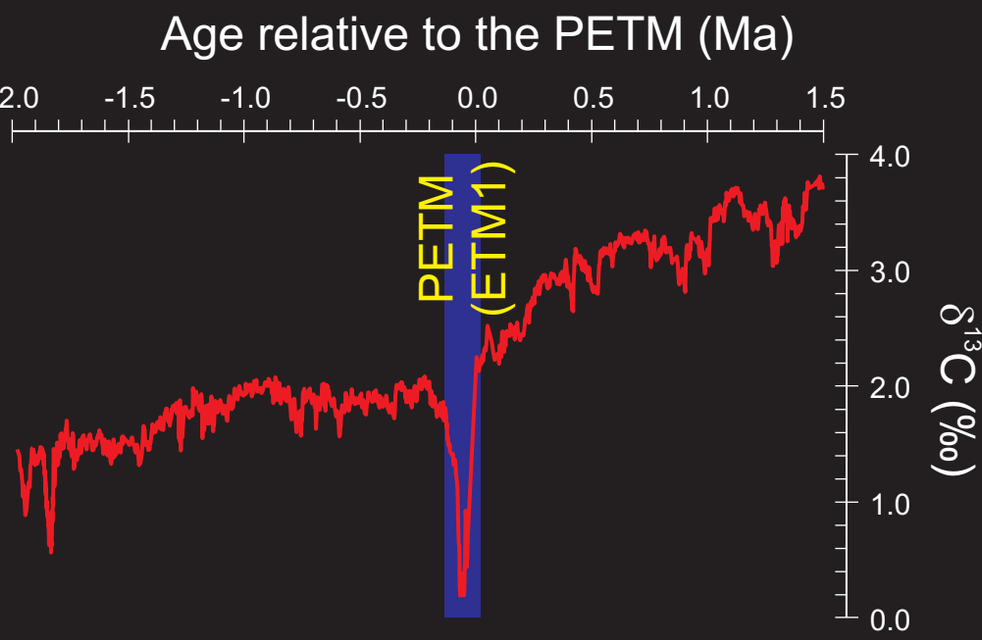


Decoding The Marine Geological Record

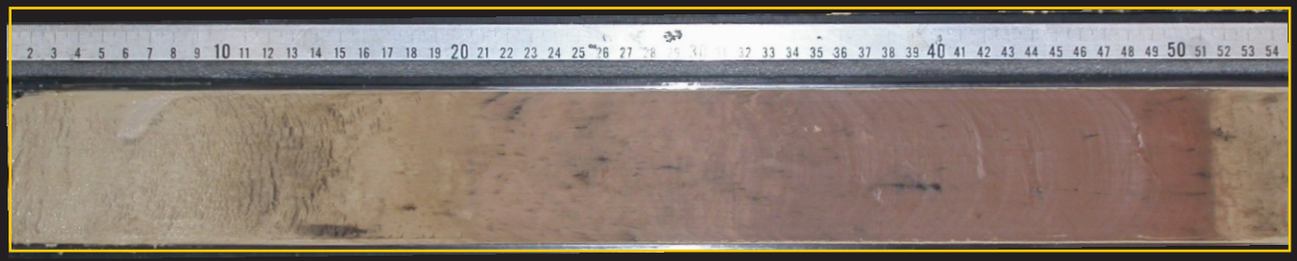




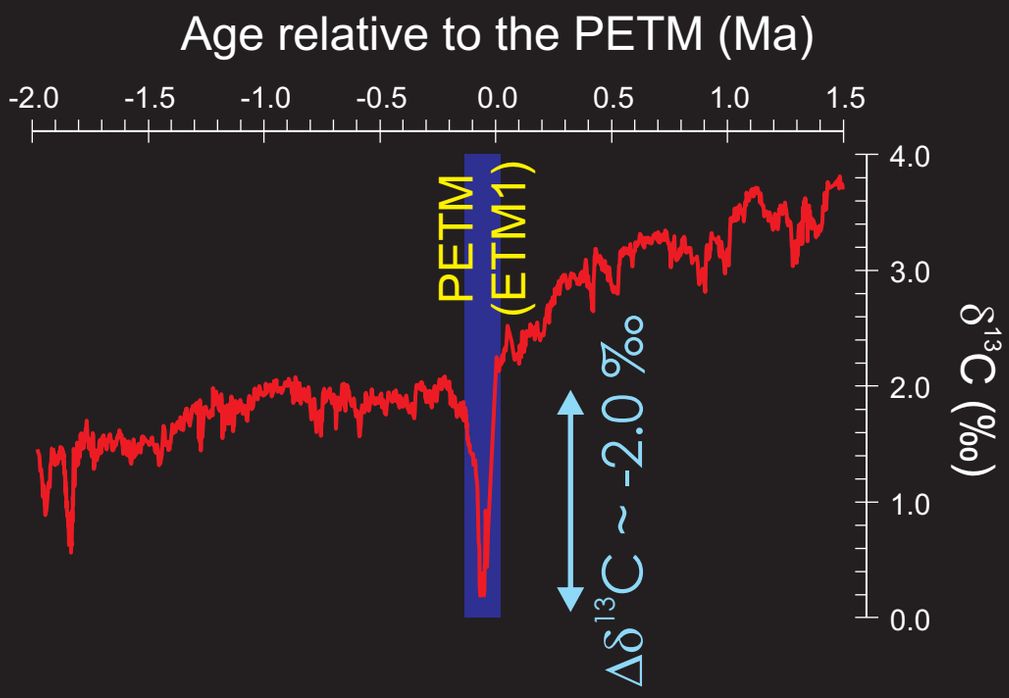
Decoding The Marine Geological Record



How much carbon?
(=> infer climate,
ecosystem sensitivity etc.)



Decoding The Marine Geological Record

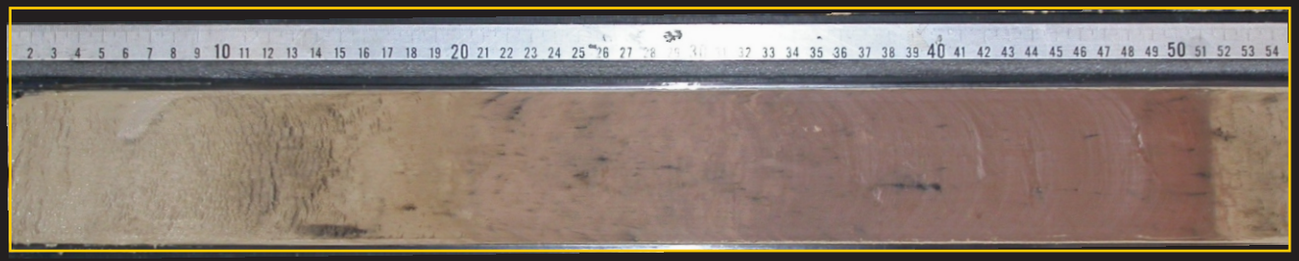


By simple mass balance, the size of an isotopic excursion is:

$\Delta\delta^{13}C \sim \delta^{13}C_{new} \times \Delta M_{new} / (M_{old} + \Delta M_{new})$

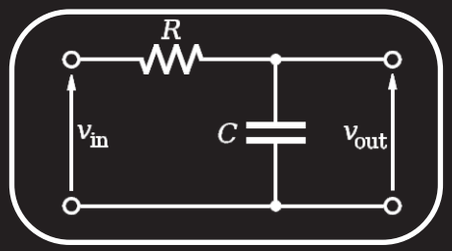
where ΔM_{new} is the mass added, $\delta^{13}C_{new}$ is its isotopic signature, and M_{old} is the original total mass of 'exchangeable' carbon. Or:

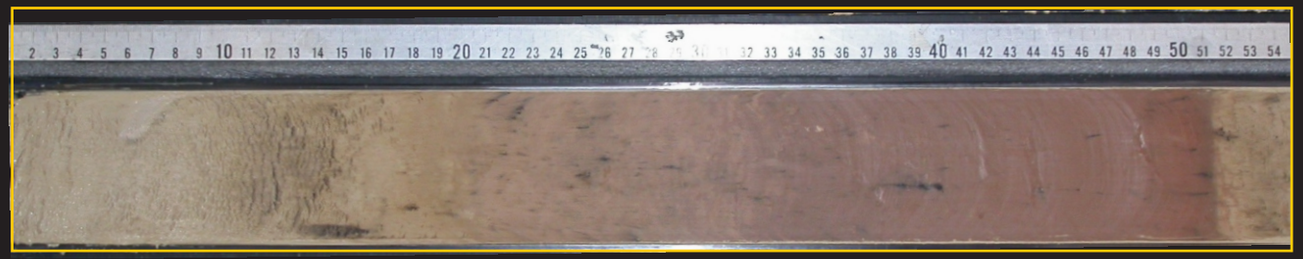
$\Delta M_{new} \sim \Delta\delta^{13}C \times M_{old} / (\delta^{13}C_{old} + \Delta\delta^{13}C - \delta^{13}C_{new})$

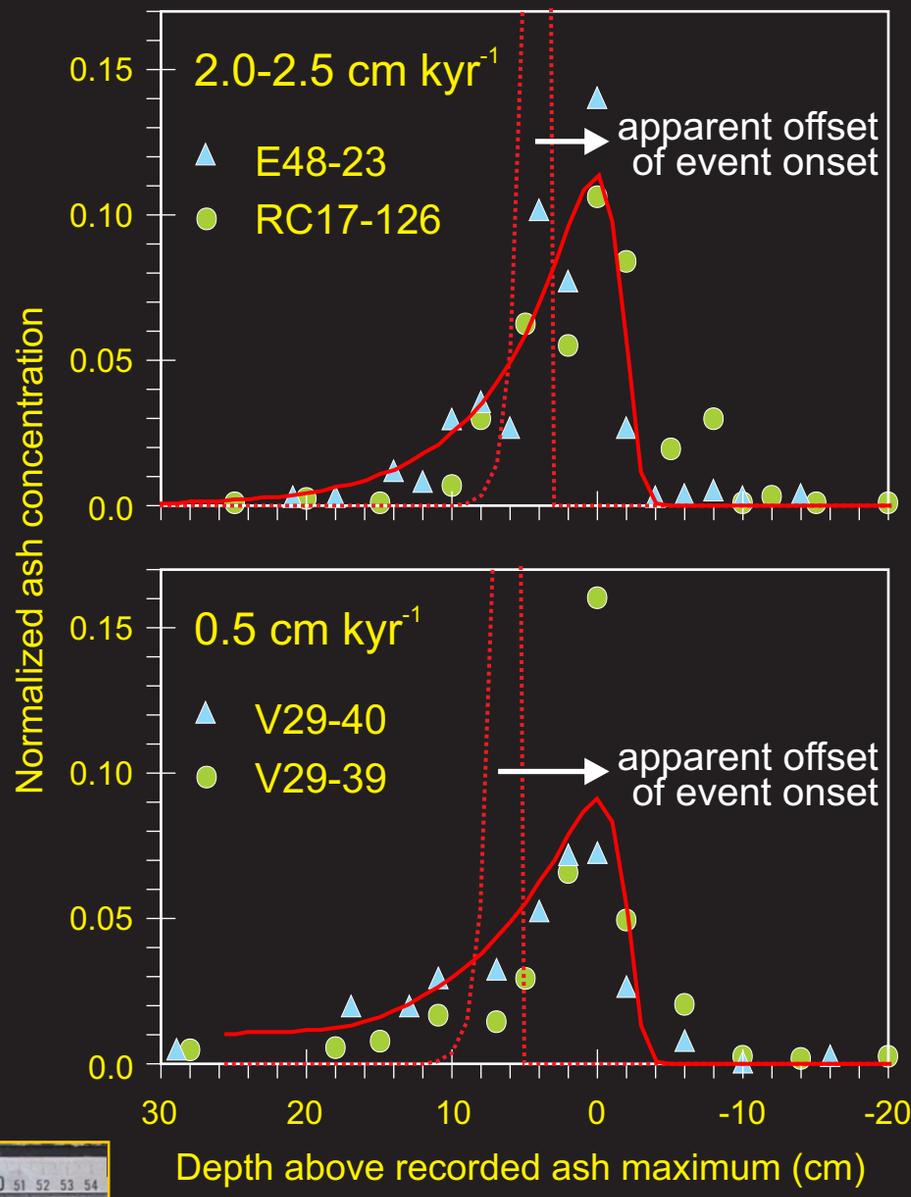


Decoding The Marine Geological Record

mixing
(bioturbation)

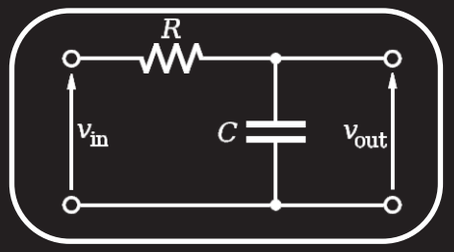




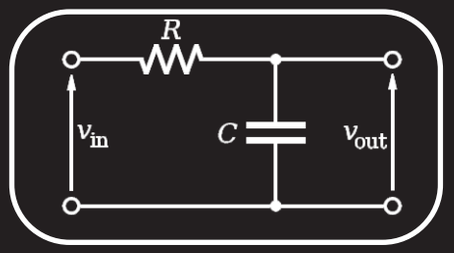


Decoding The Marine Geological Record

dissolution
(peservation)

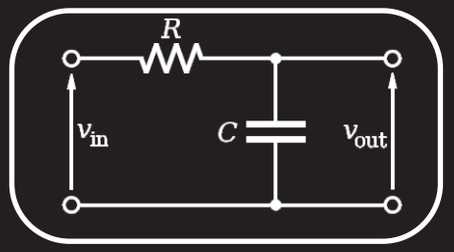


mixing
(bioturbation)

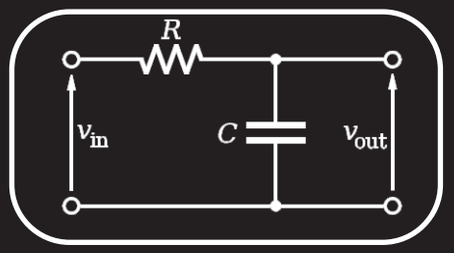


Decoding The Marine Geological Record

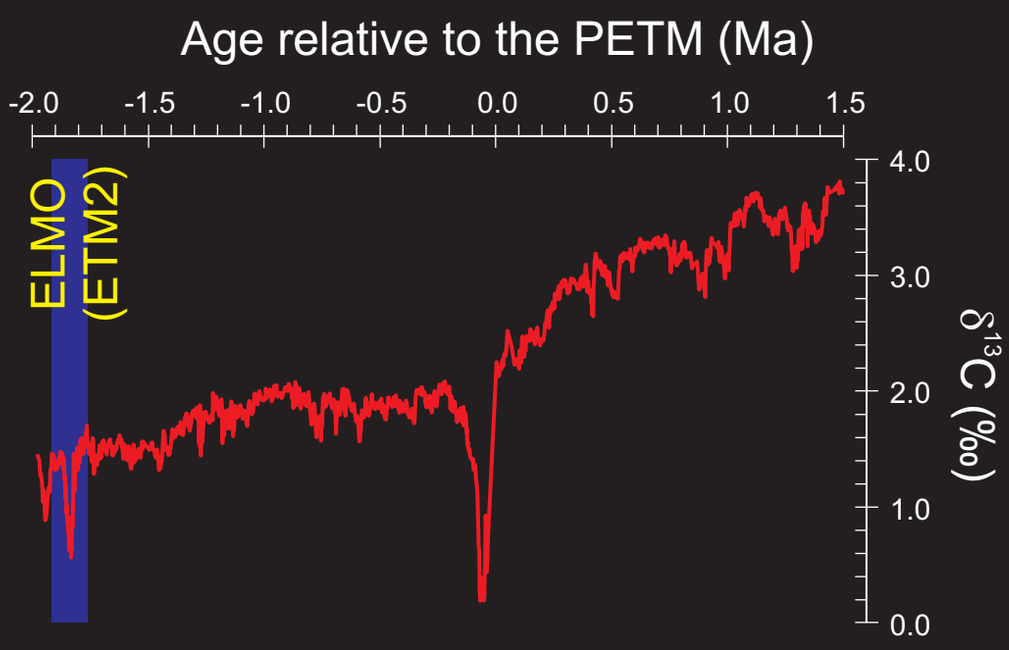
dissolution
(peservation)



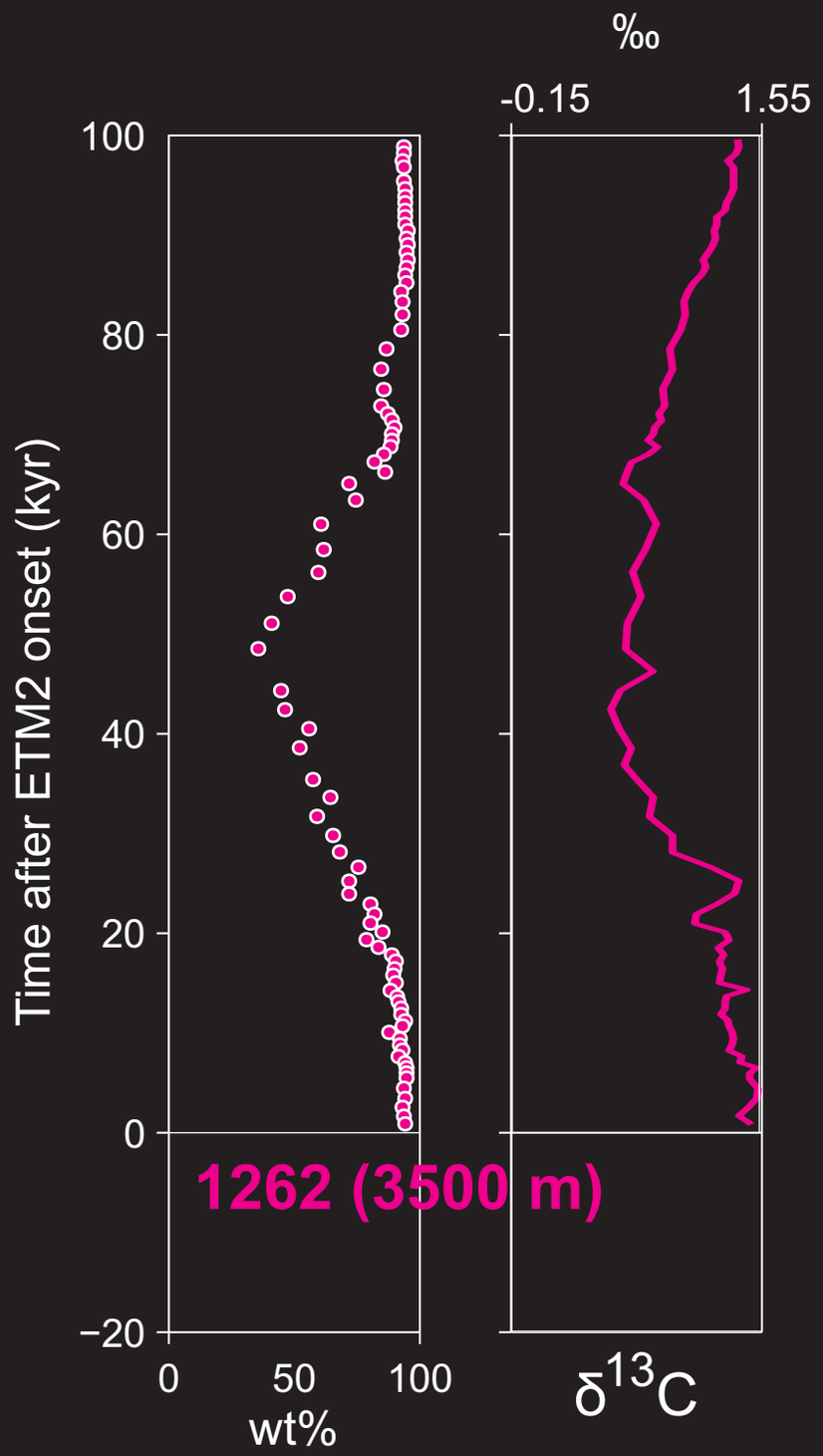
mixing
(bioturbation)

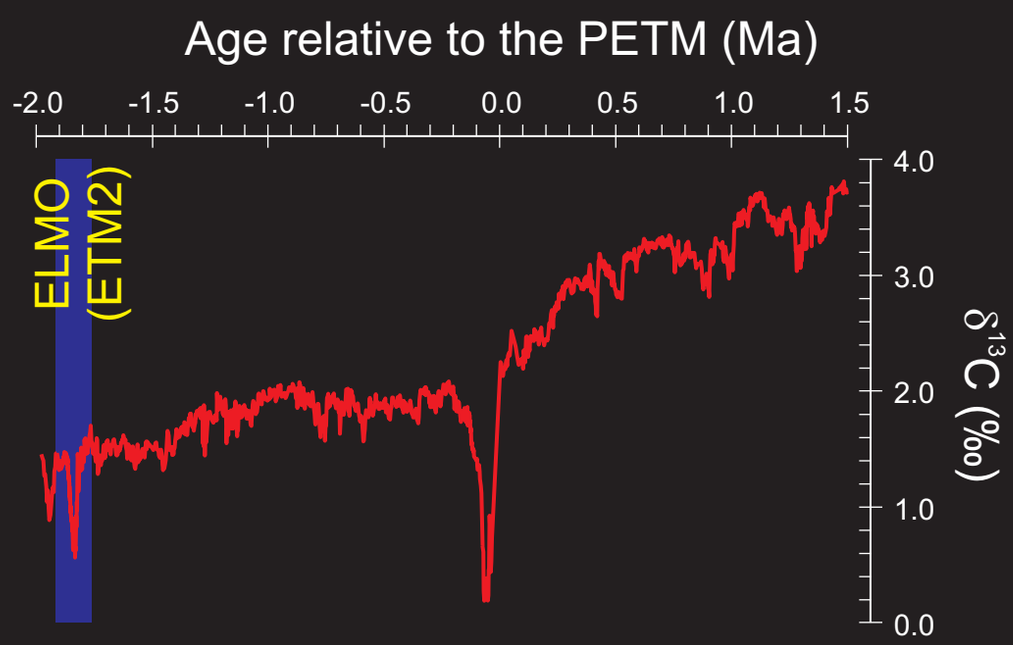


Decoding The Marine Geological Record



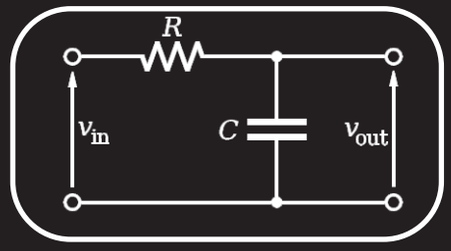
Decoding The Marine Geological Record



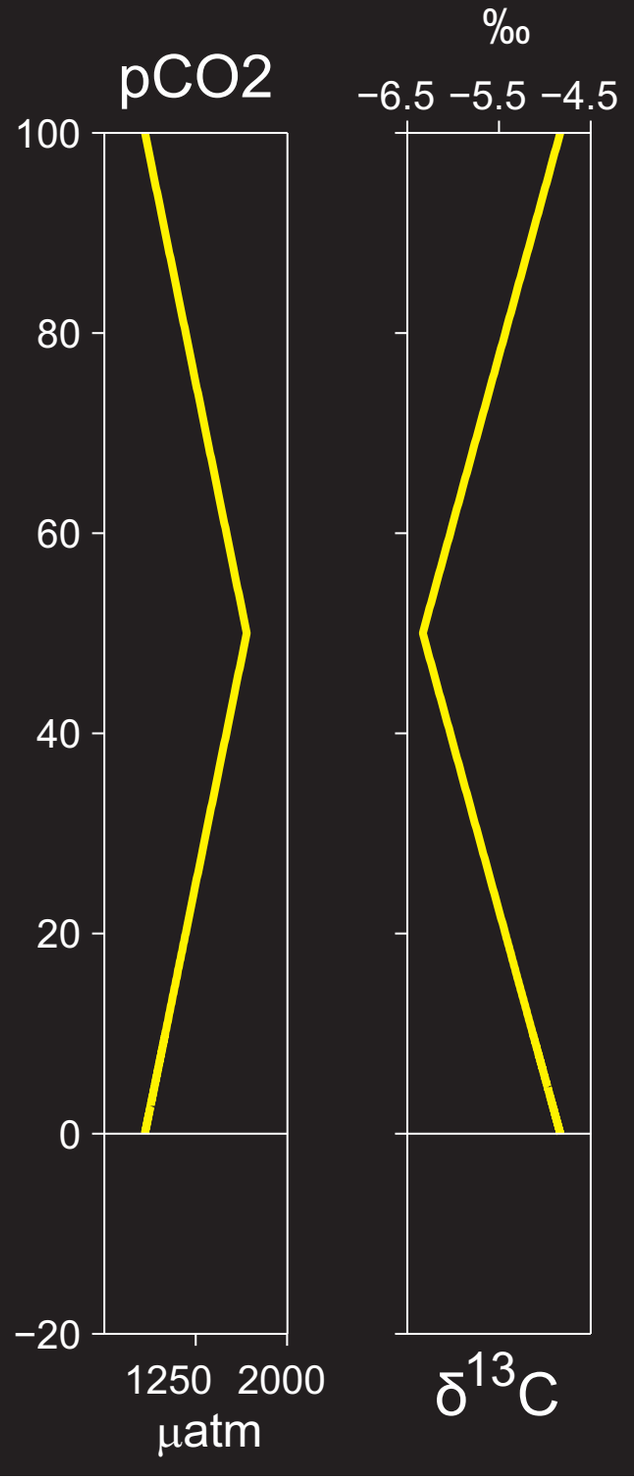


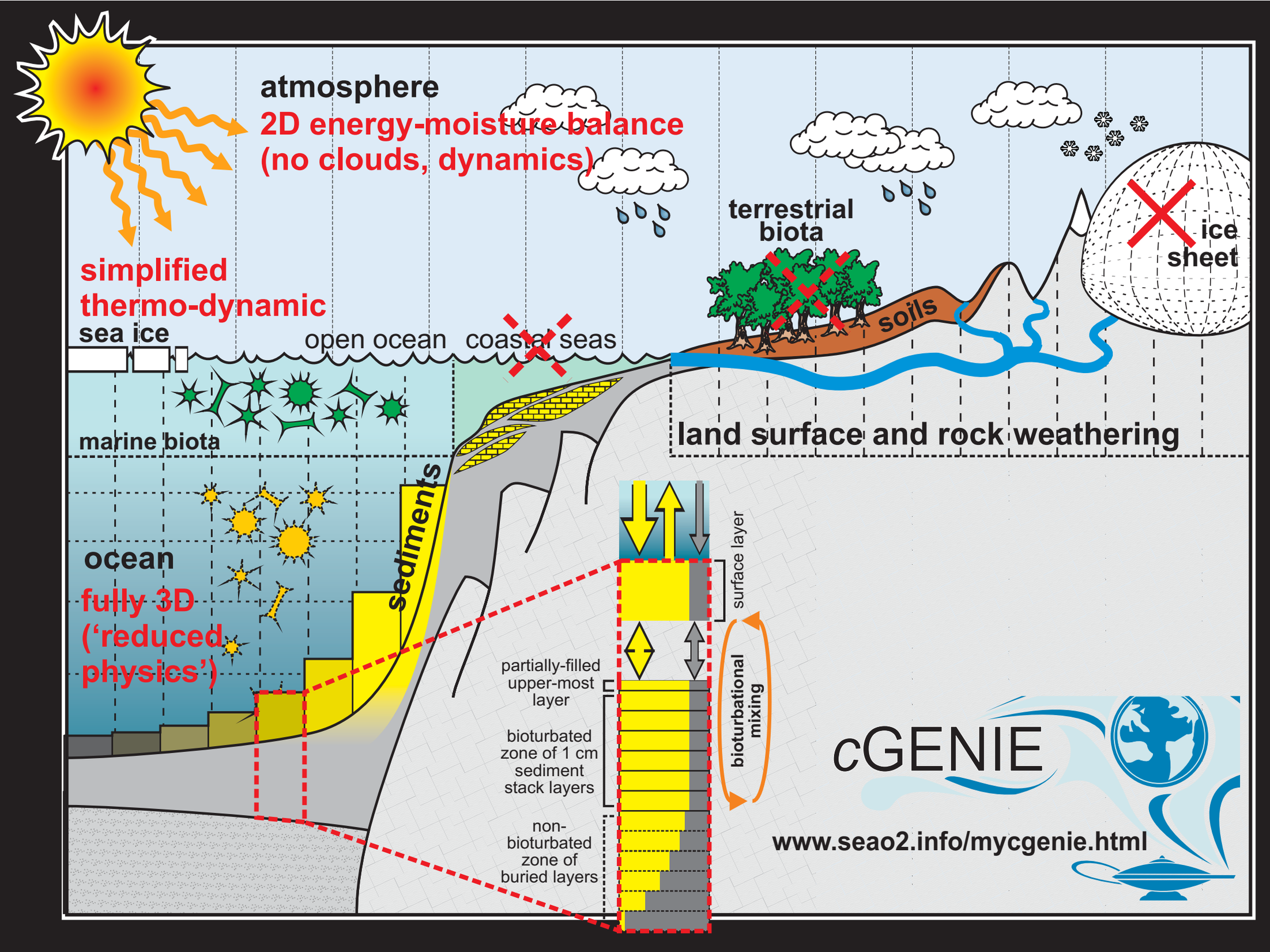
Decoding The Marine Geological Record

?

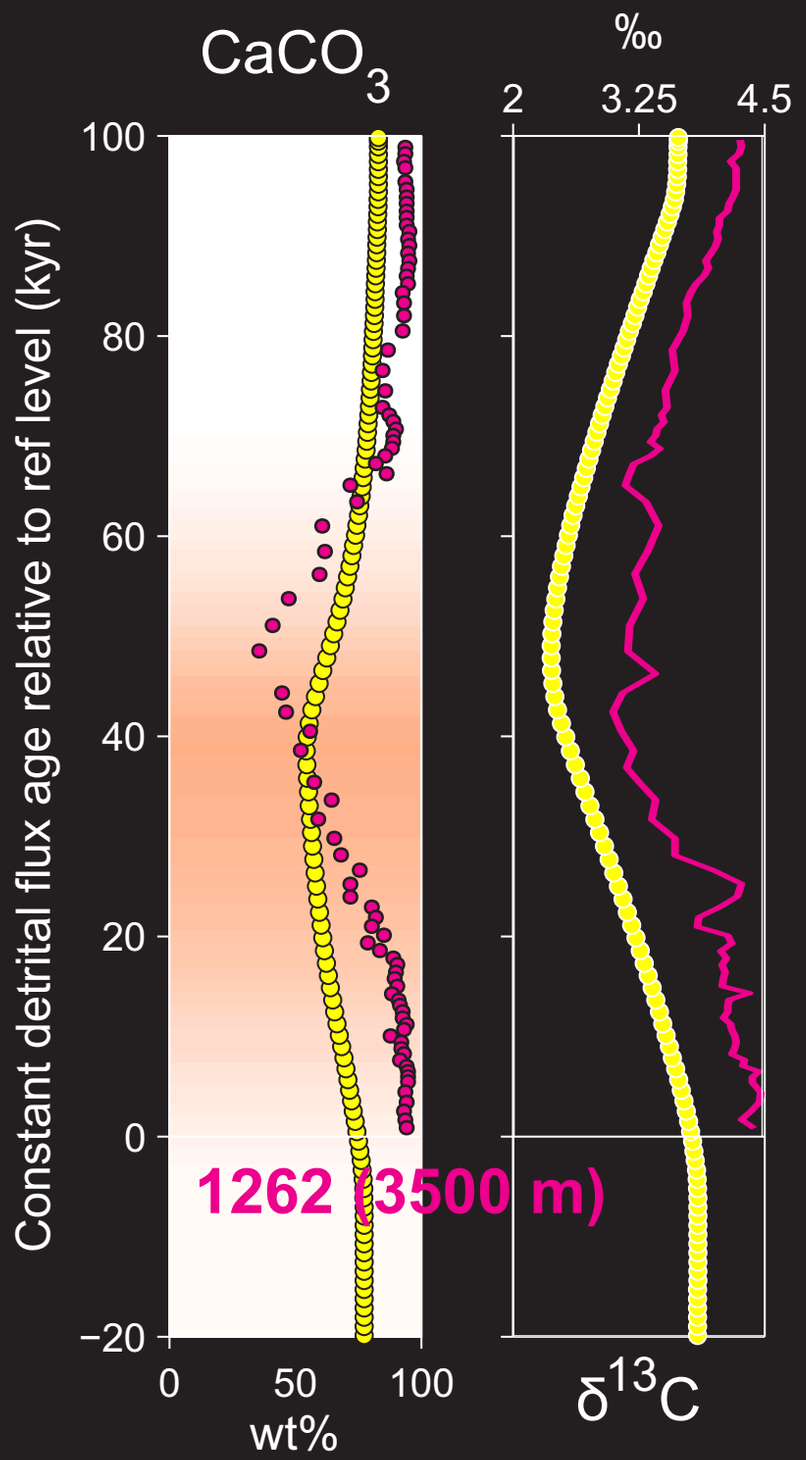


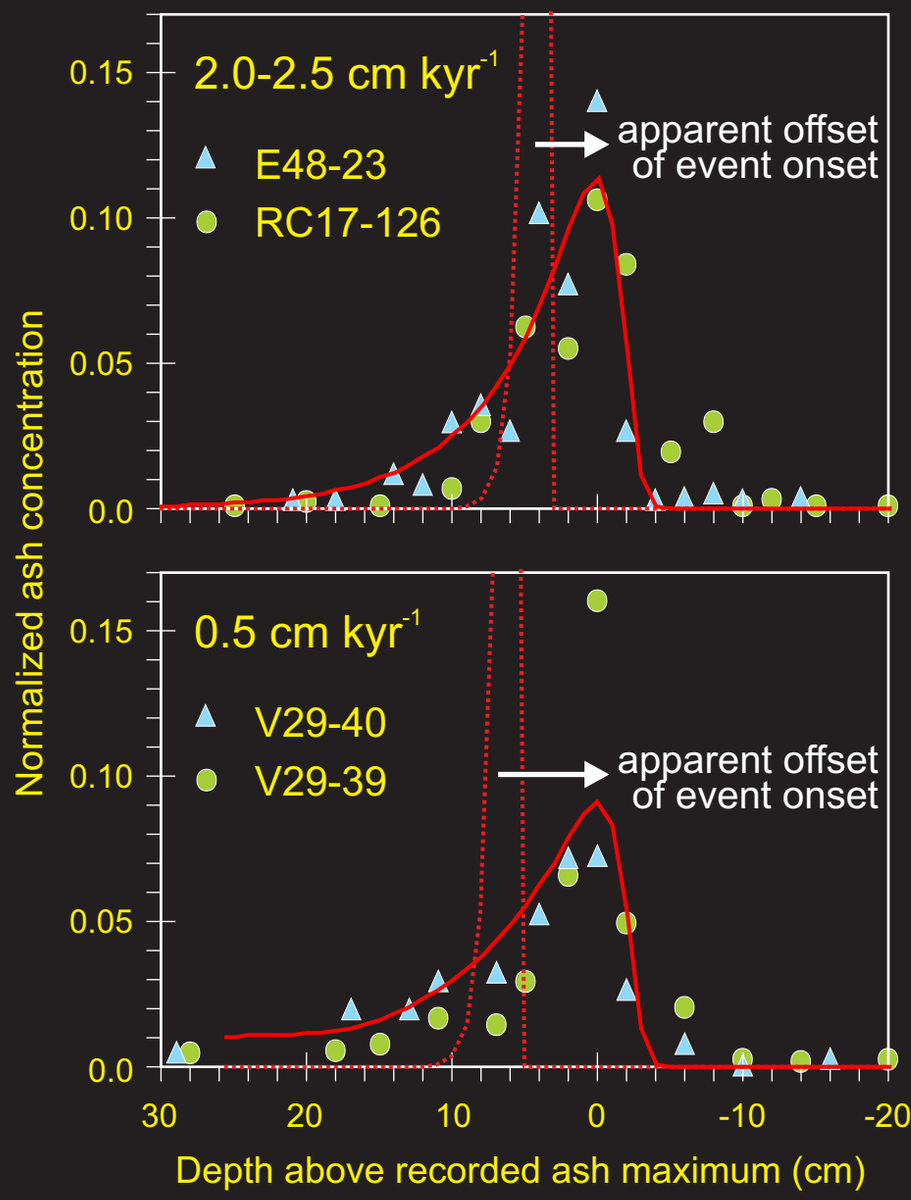
('traditional', forward-modelling approach)



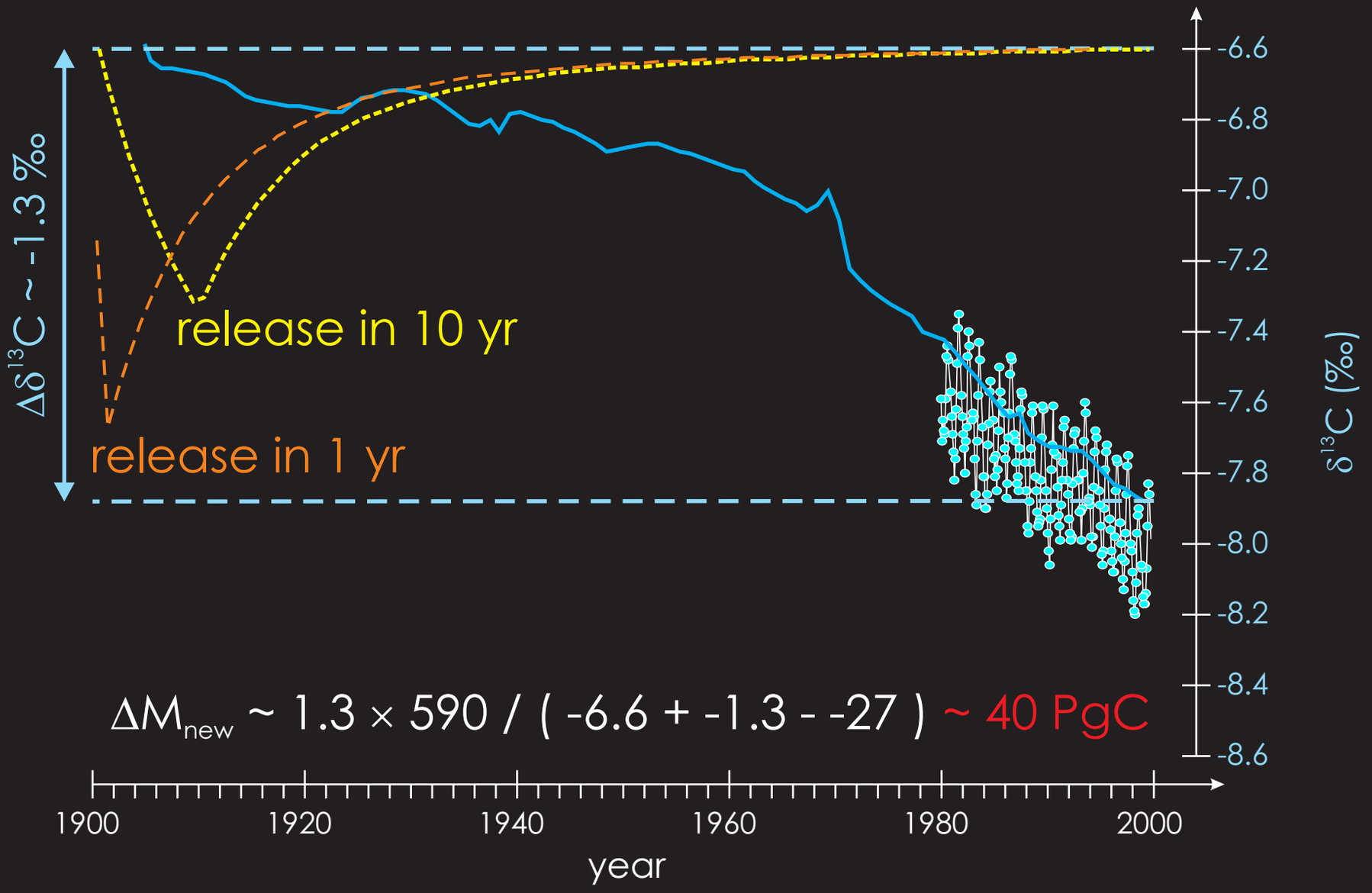

atmosphere
2D energy-moisture balance
(no clouds, dynamics)
simplified
thermo-dynamic
sea ice
open ocean
coastal seas
terrestrial
biota
soils
ice
sheet
land surface and rock weathering
marine biota
sediments
ocean
fully 3D
('reduced
physics')
surface layer
partially-filled
upper-most
layer
bioturbated
zone of 1 cm
sediment
stack layers
non-
bioturbated
zone of
buried layers
bioturbational
mixing
cGENIE
www.seao2.info/mycgenie.html

Decoding The Marine Geological Record



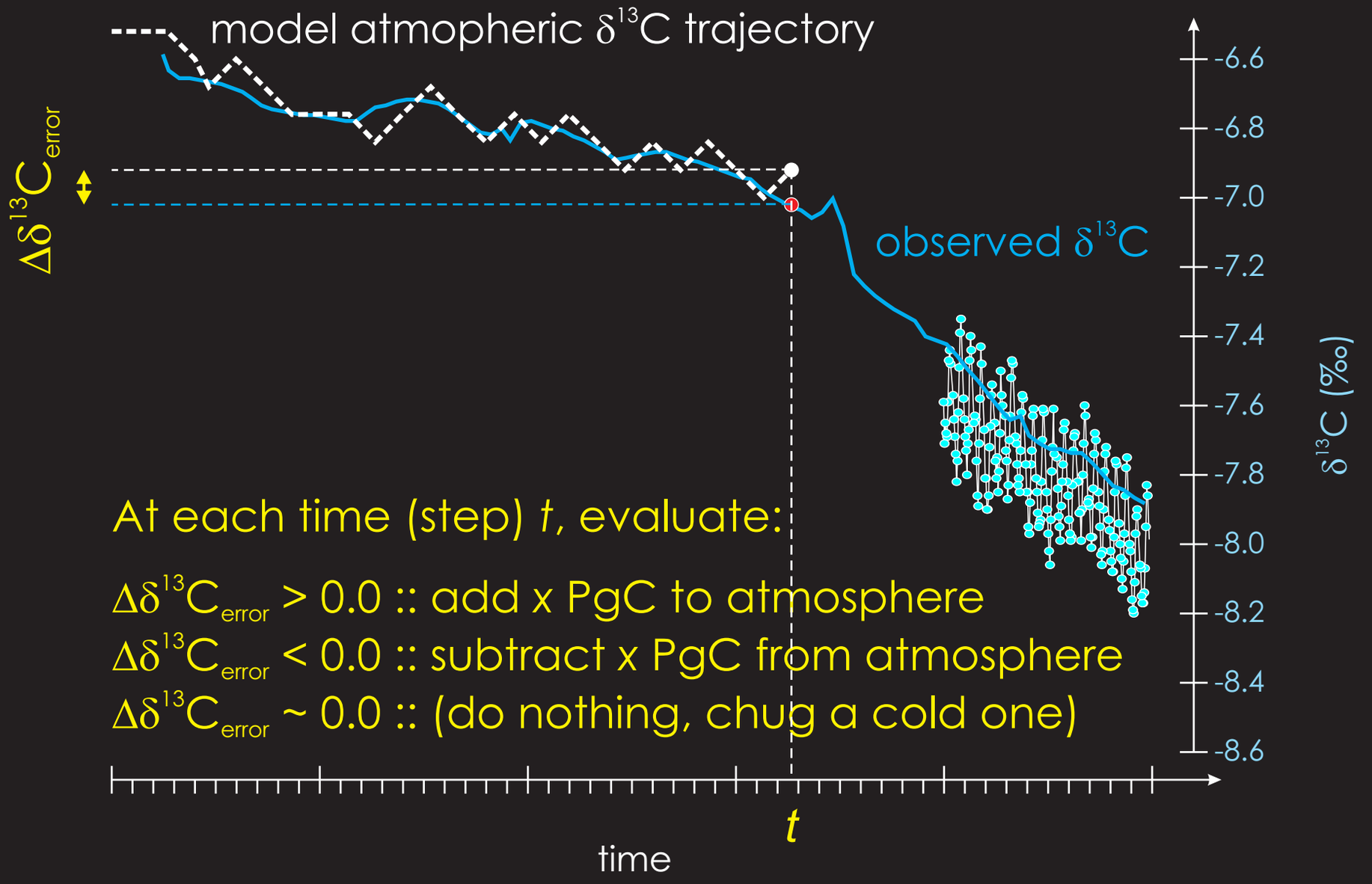


'Inverting' Isotopic Records

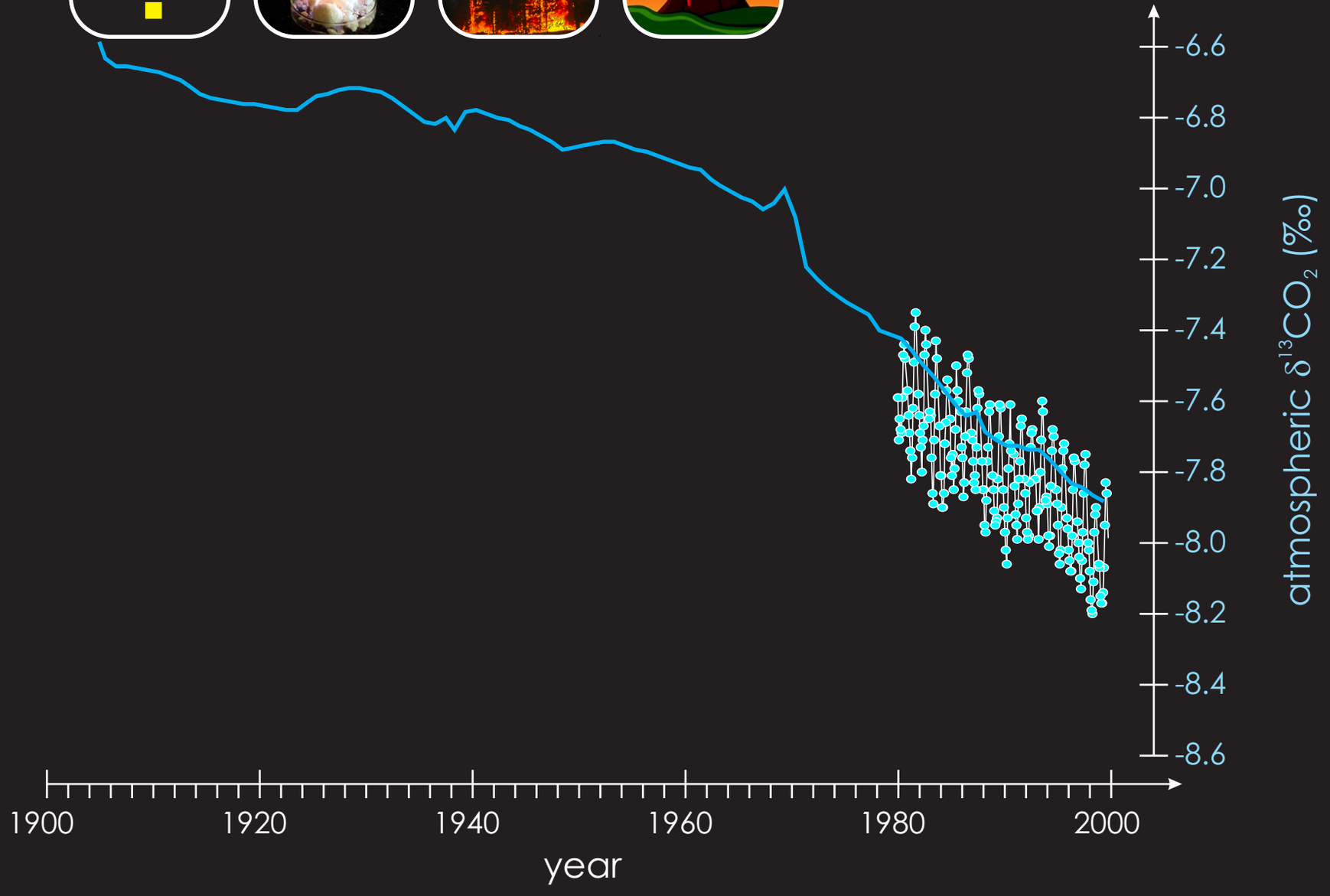


$\Delta M_{new} \sim 1.3 \times 590 / (-6.6 + -1.3 - -27) \sim 40$ PgC

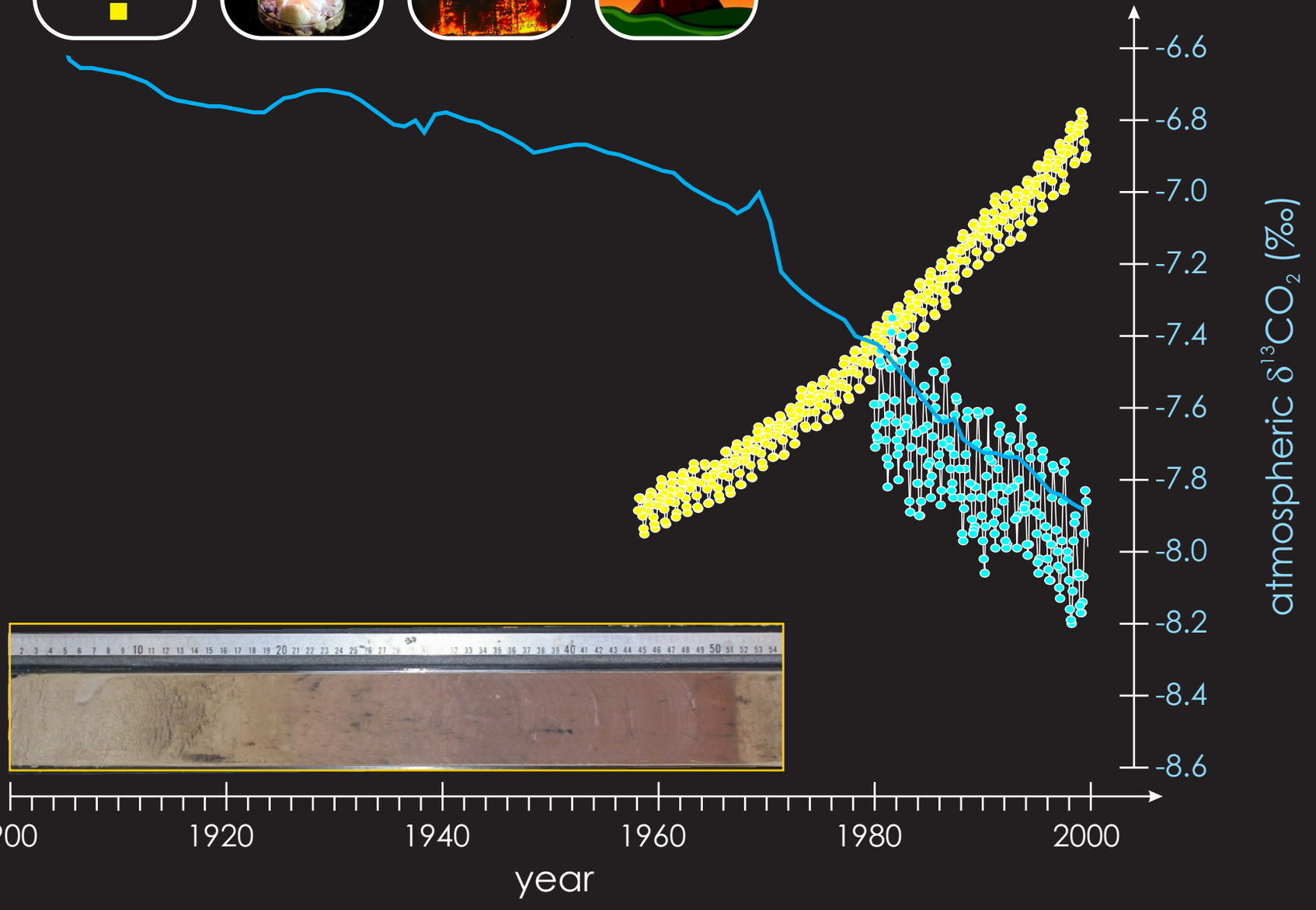
'Inverting' Isotopic Records



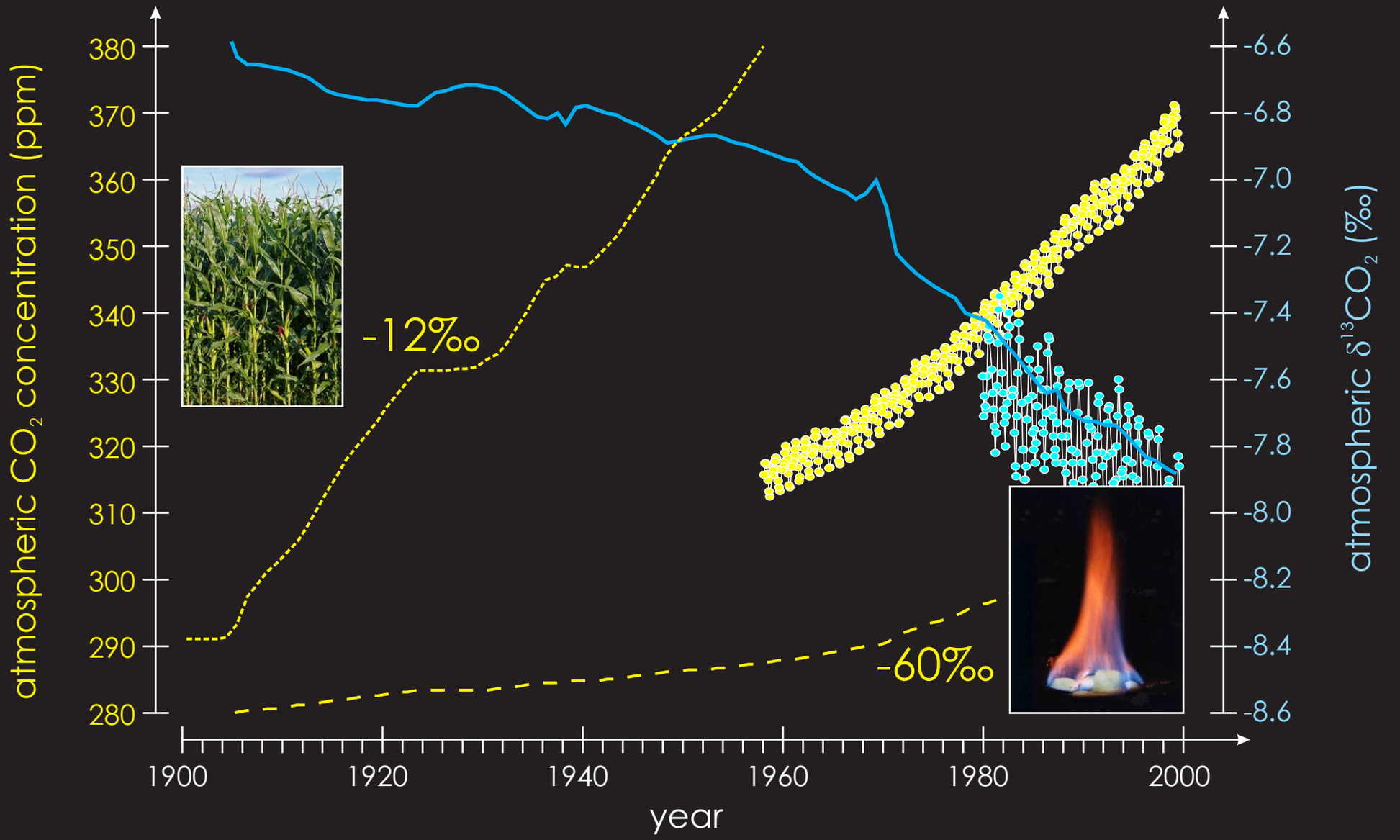
‘Inverting’ Isotopic Records



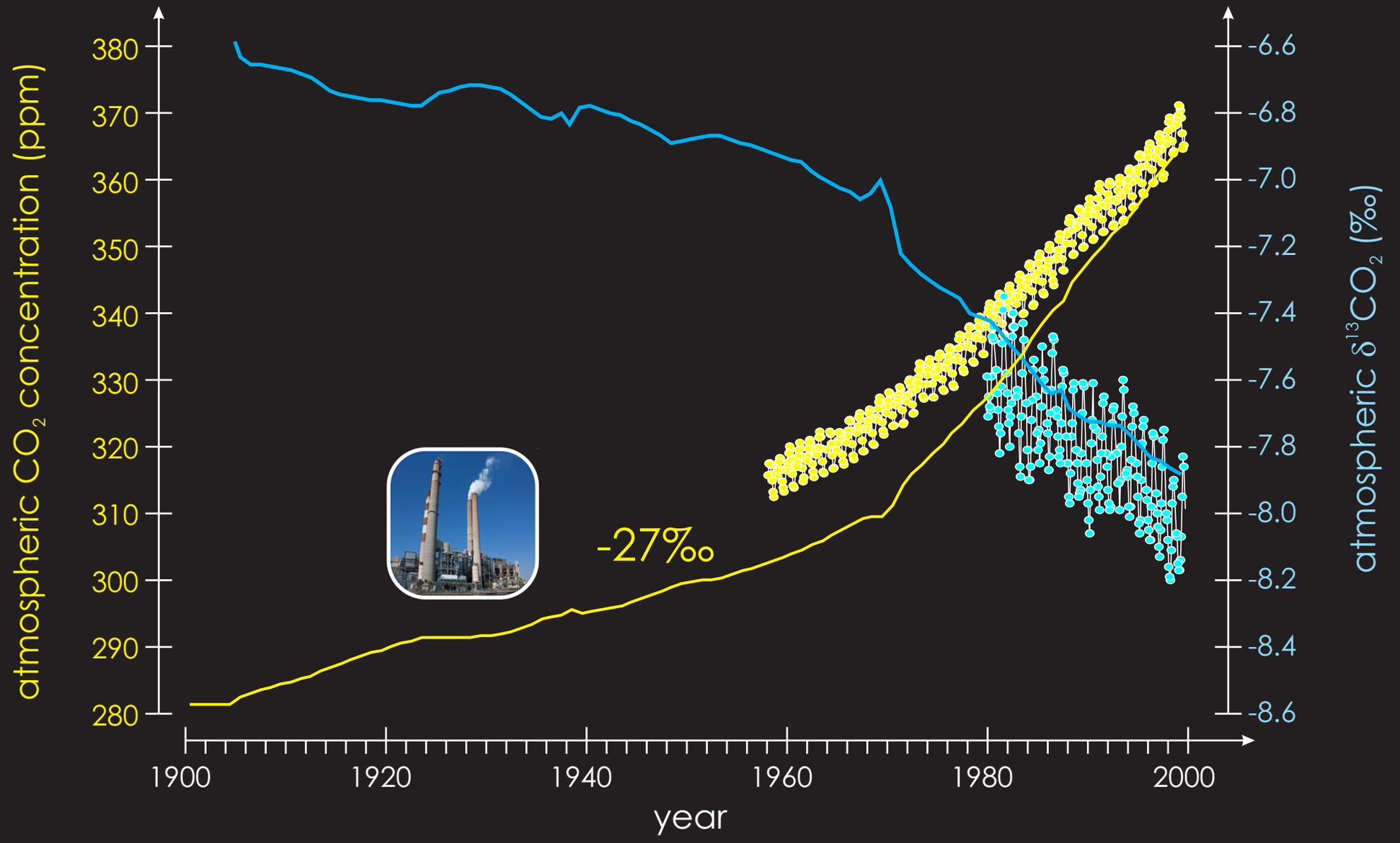
'Inverting' Isotopic Records

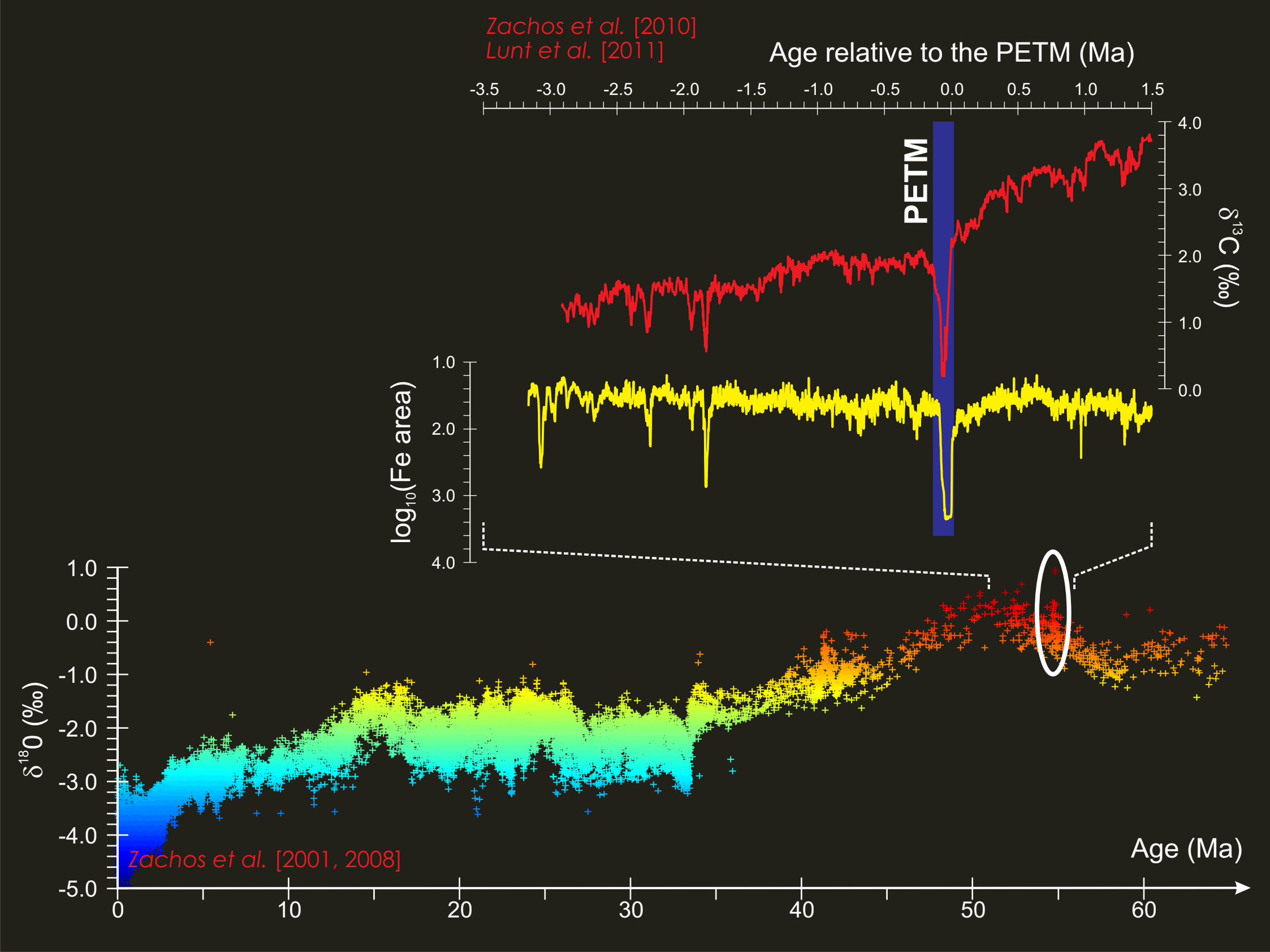


‘Inverting’ Isotopic Records



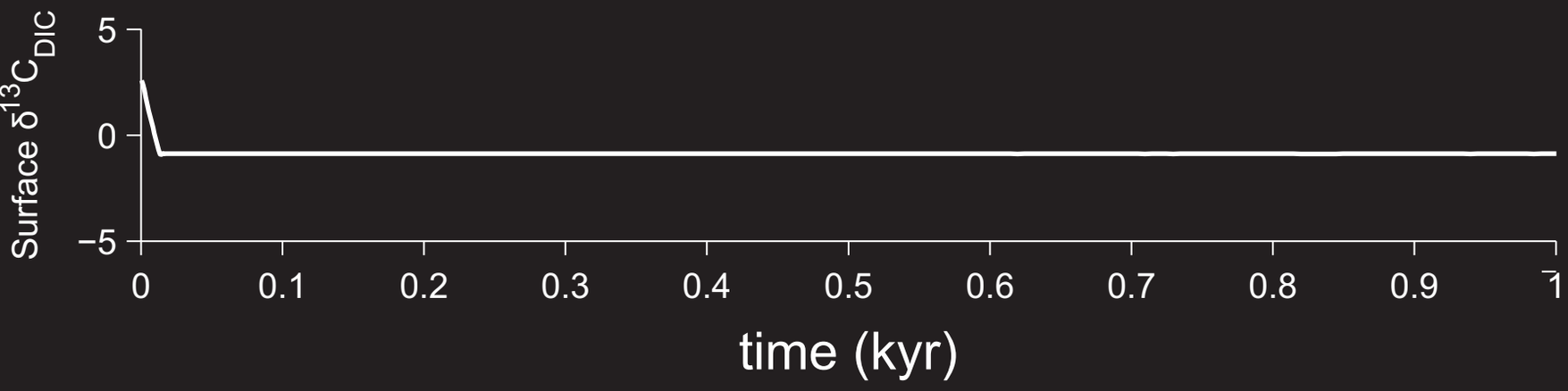
‘Inverting’ Isotopic Records




Zachos et al. [2010]
Lunt et al. [2011]
Age relative to the PETM (Ma)
-3.5
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
PETM
4.0
3.0
2.0
1.0
0.0
δ13C (‰)
log10(Fe area)
1.0
2.0
3.0
4.0
δ18O (‰)
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
Zachos et al. [2001, 2008]
Age (Ma)
0
10
20
30
40
50
60

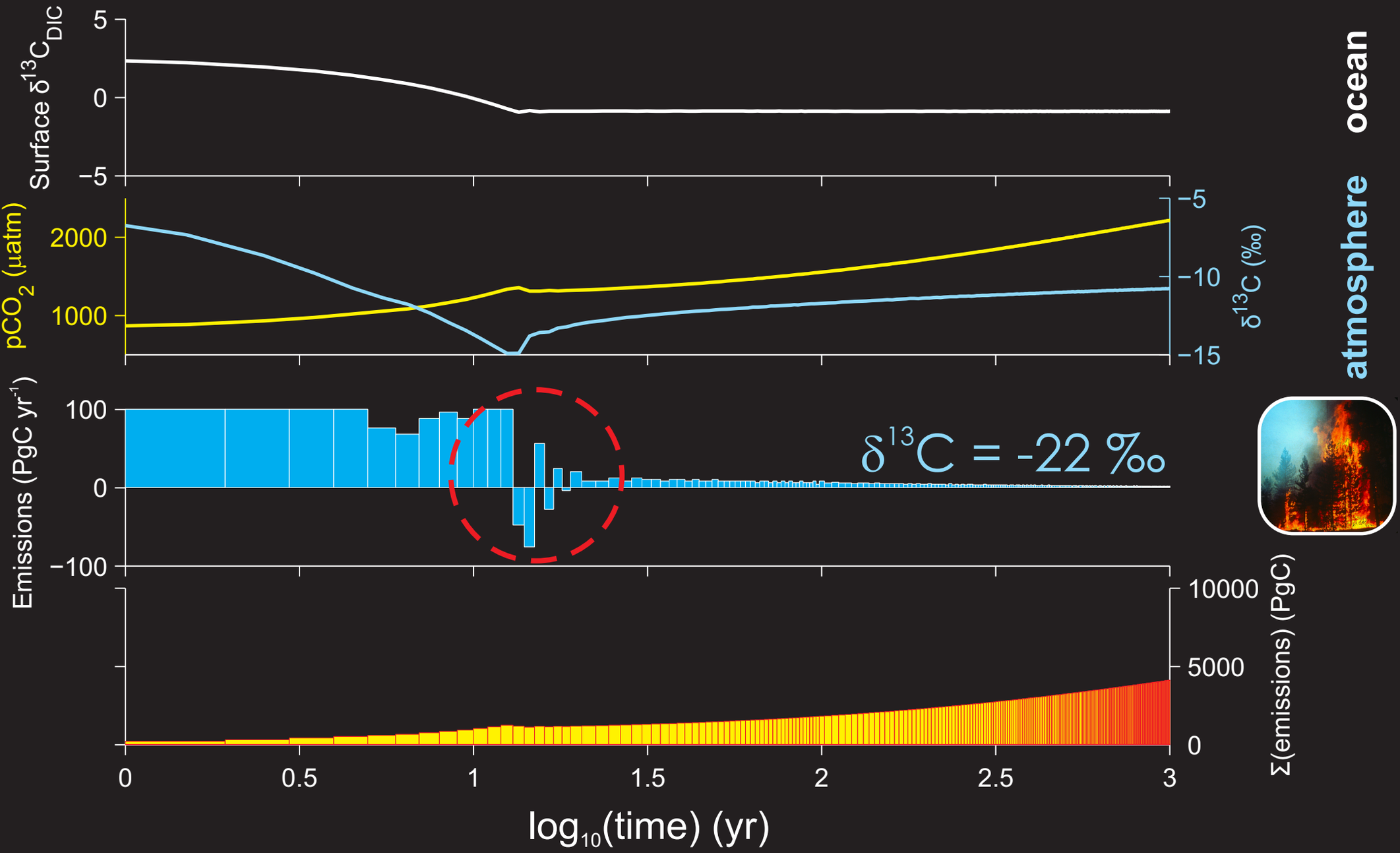
'Inverting' Isotopic Records

Wright and Schaller [2013]
(doi/10.1073/pnas.1309188110)

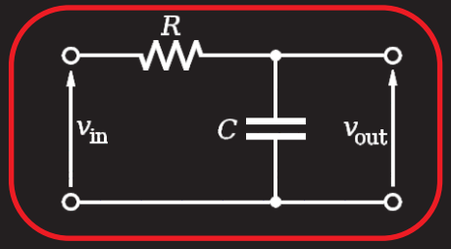


'Inverting' Isotopic Records

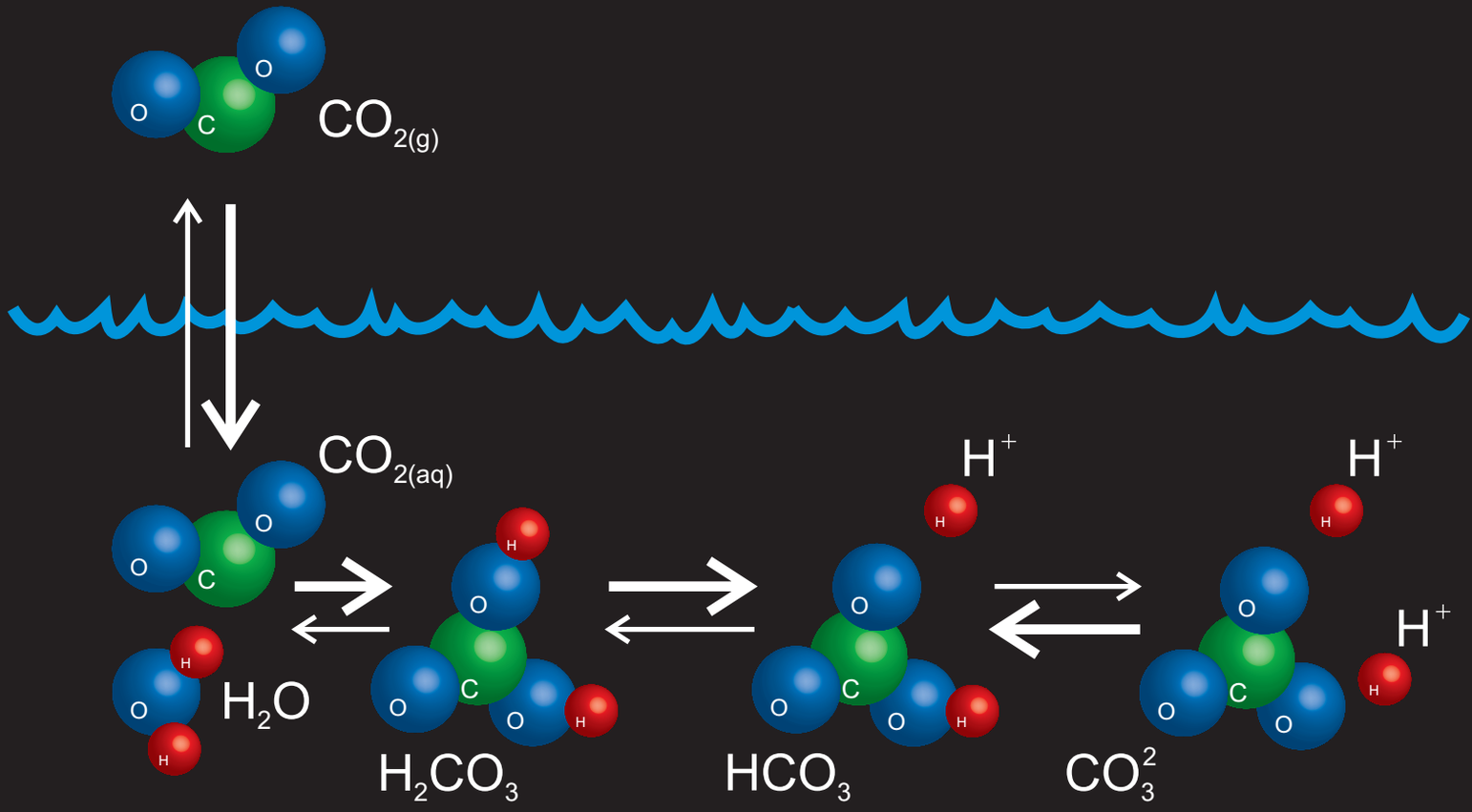
Zeebe et al. [2014]
(doi/10.1073/pnas.1321177111)



Decoding The Marine Geological Record



surface ocean
$\delta^{13}C$ record



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Zeebe et al. [2014]
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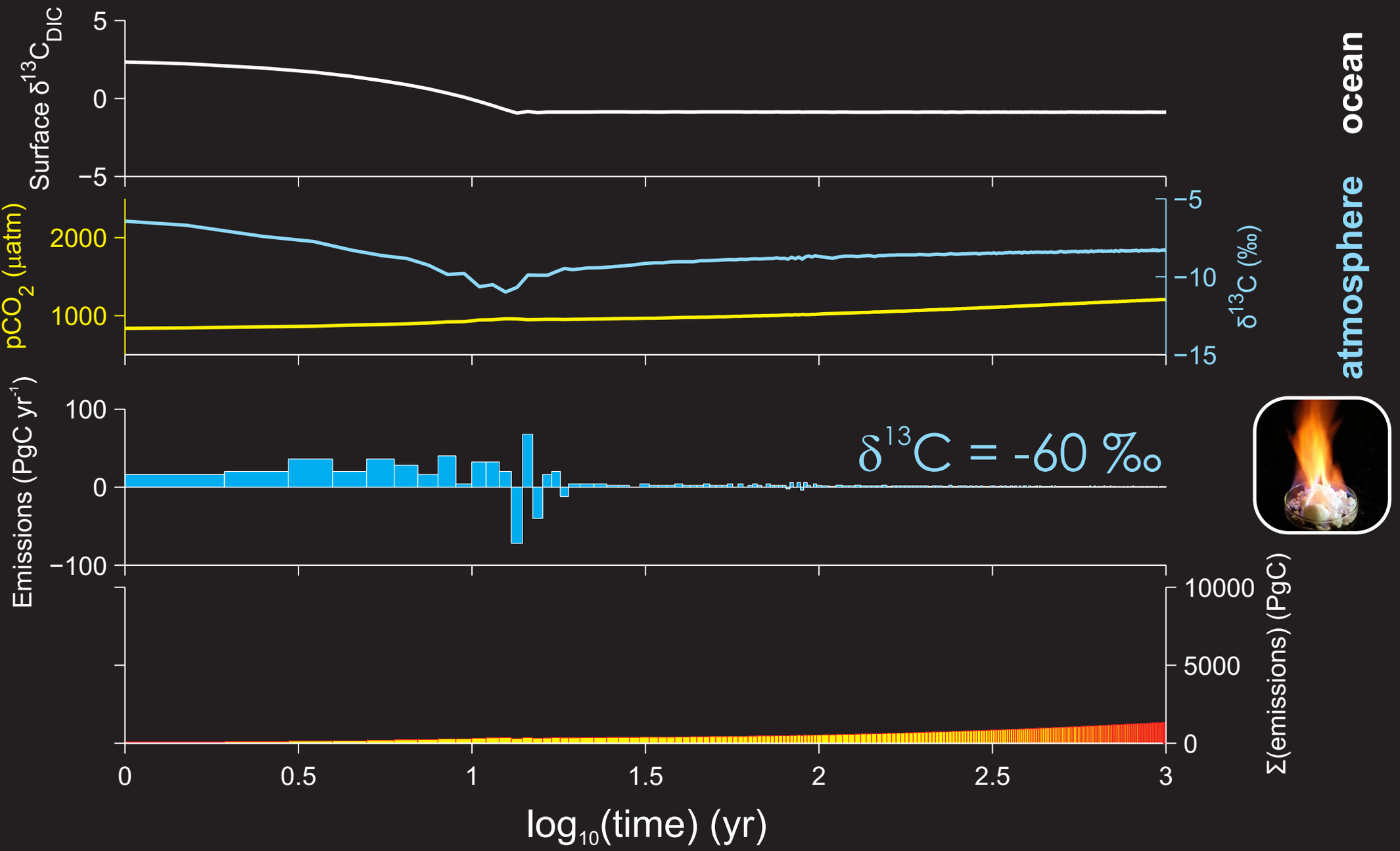
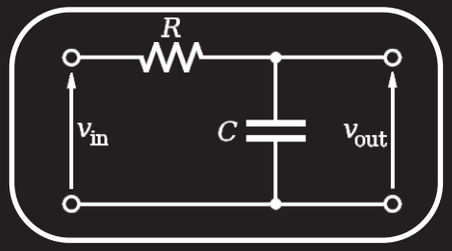
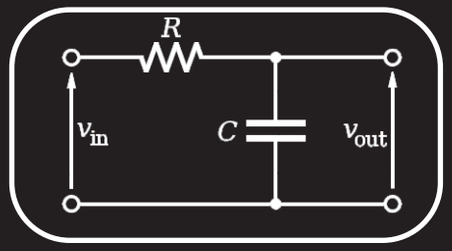


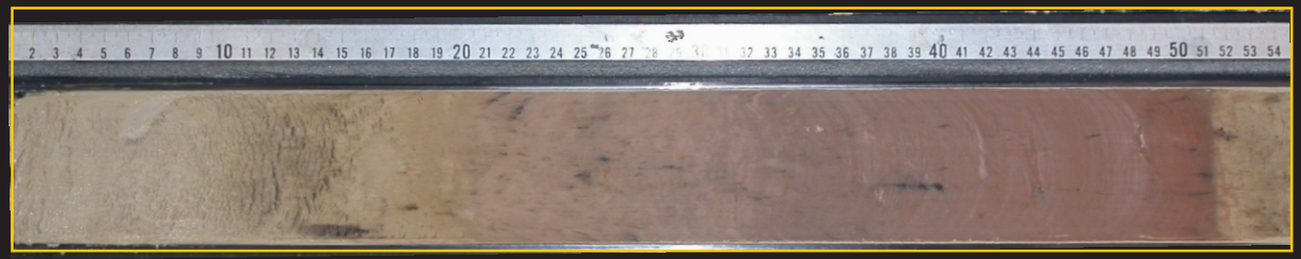
Decoding The Marine Geological Record

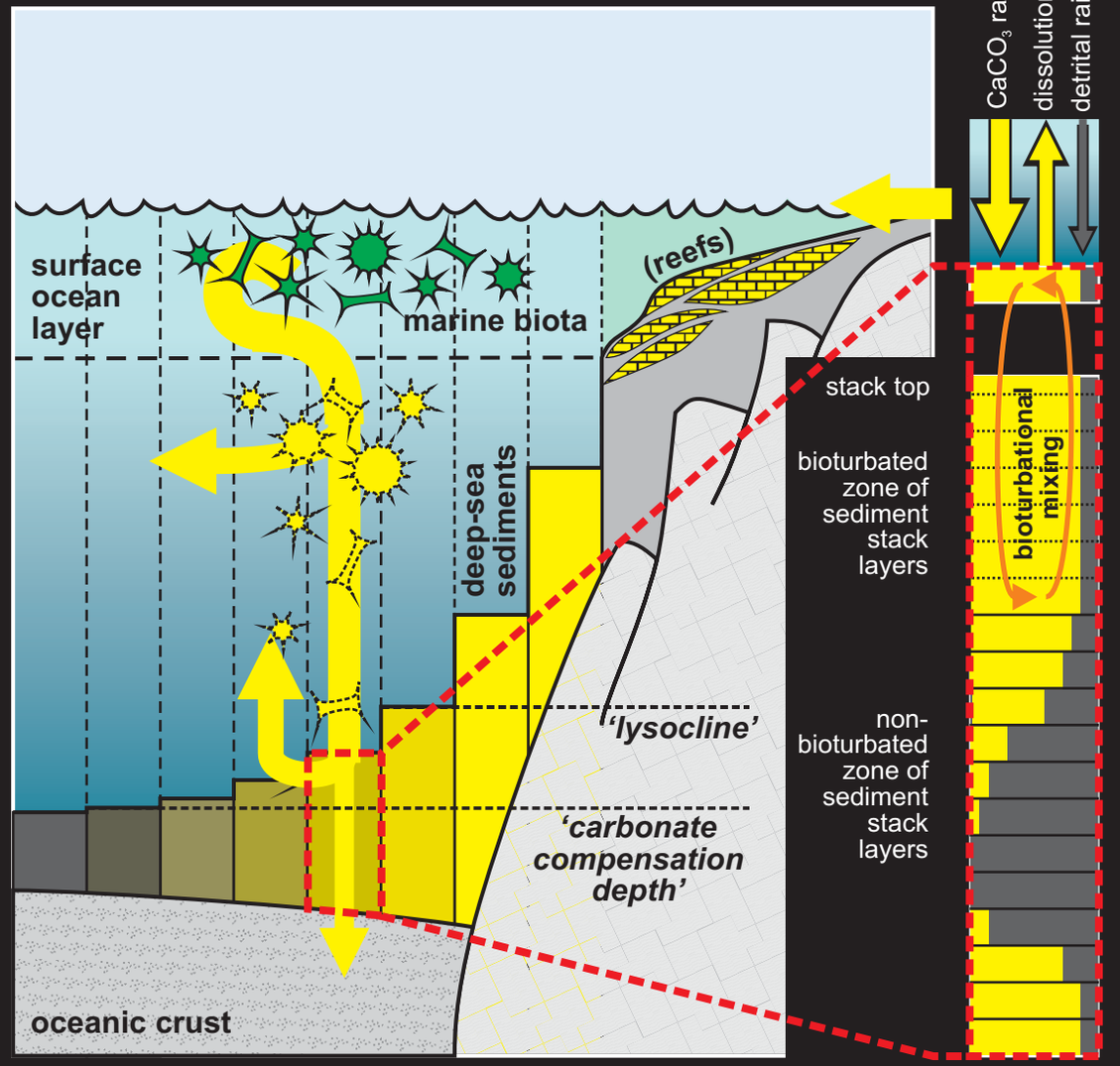
dissolution
(peservation)

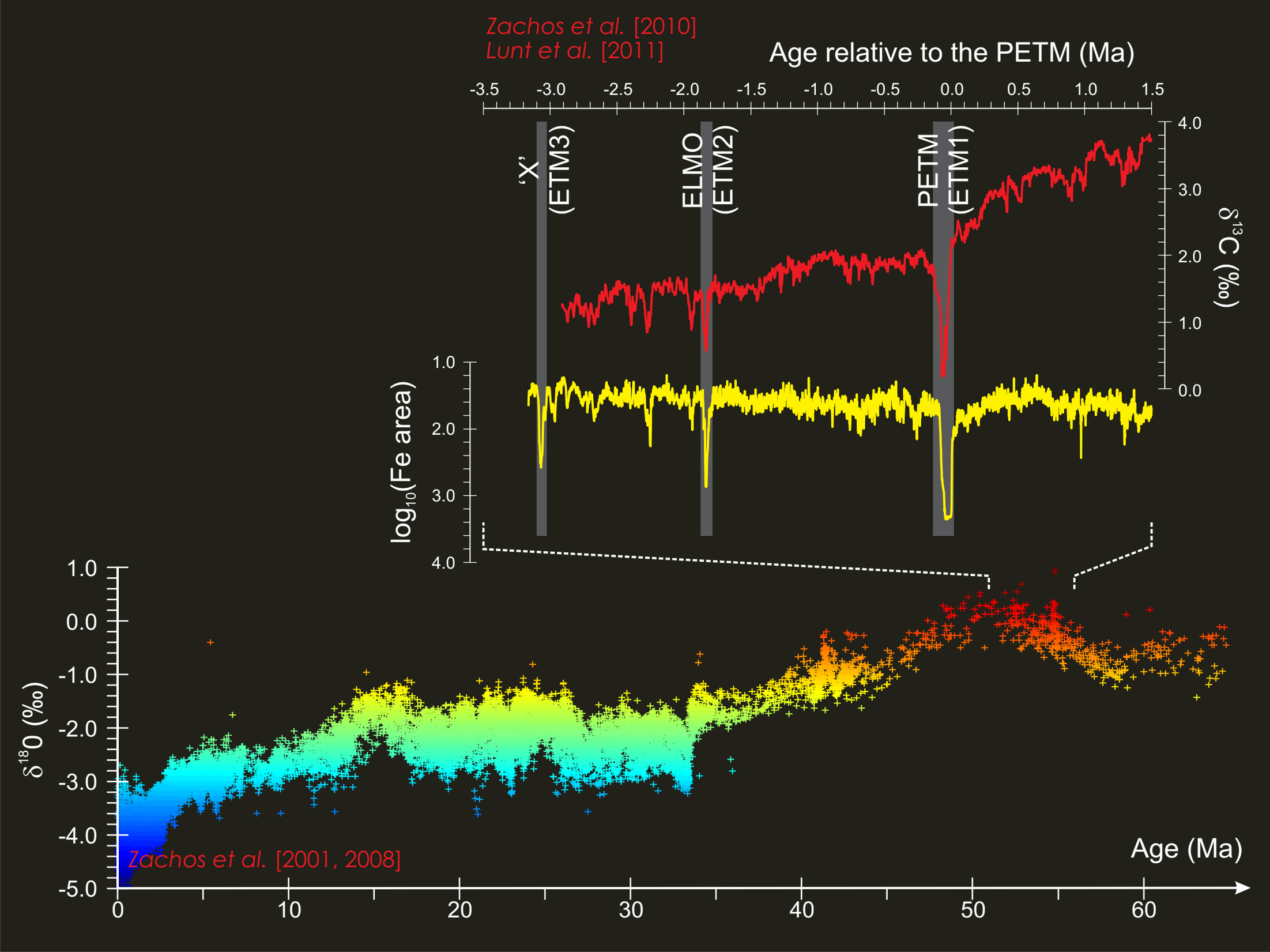


mixing
(bioturbation)








Zachos et al. [2010]
Lunt et al. [2011]
Age relative to the PETM (Ma)
-3.5
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
'X'
(ETM3)
ELMO
(ETM2)
PETM
(ETM1)
4.0
3.0
2.0
1.0
0.0
δ13C (‰)
log10(Fe area)
1.0
2.0
3.0
4.0
δ18O (‰)
1.0
0.0
-1.0
-2.0
-3.0
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Zachos et al. [2001, 2008]
Age (Ma)
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20
30
40
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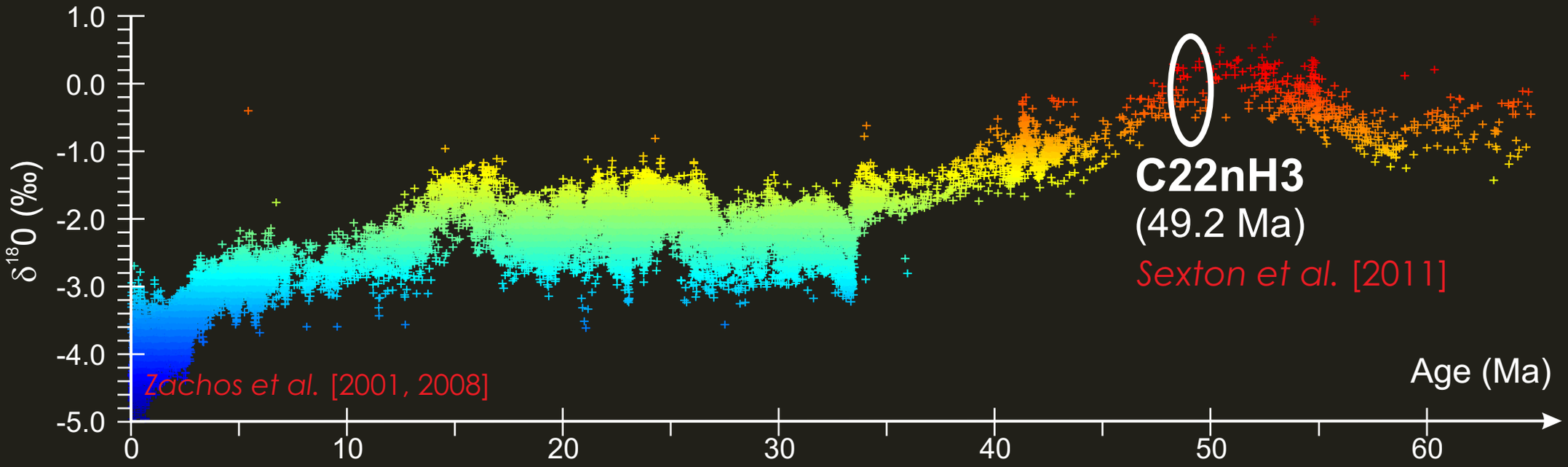
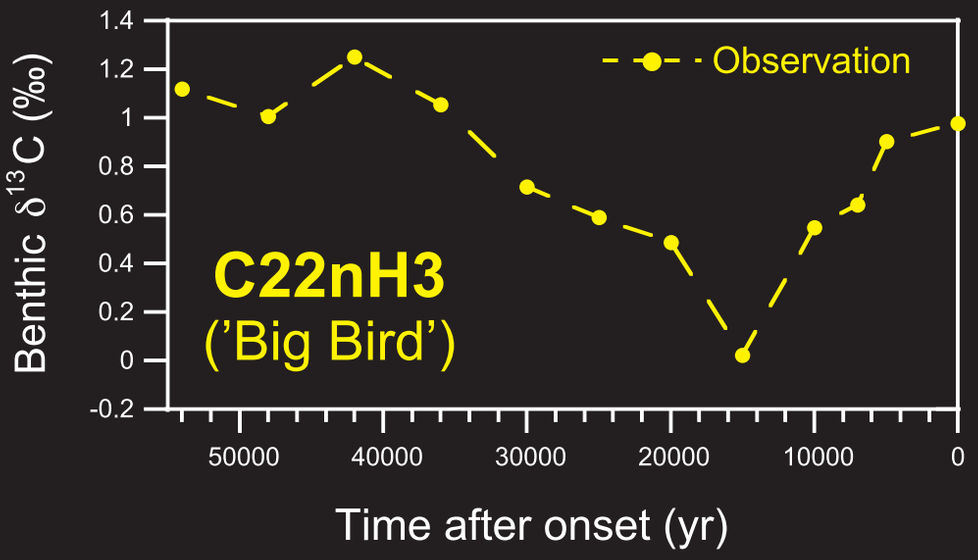
60

Decoding The Marine Geological Record

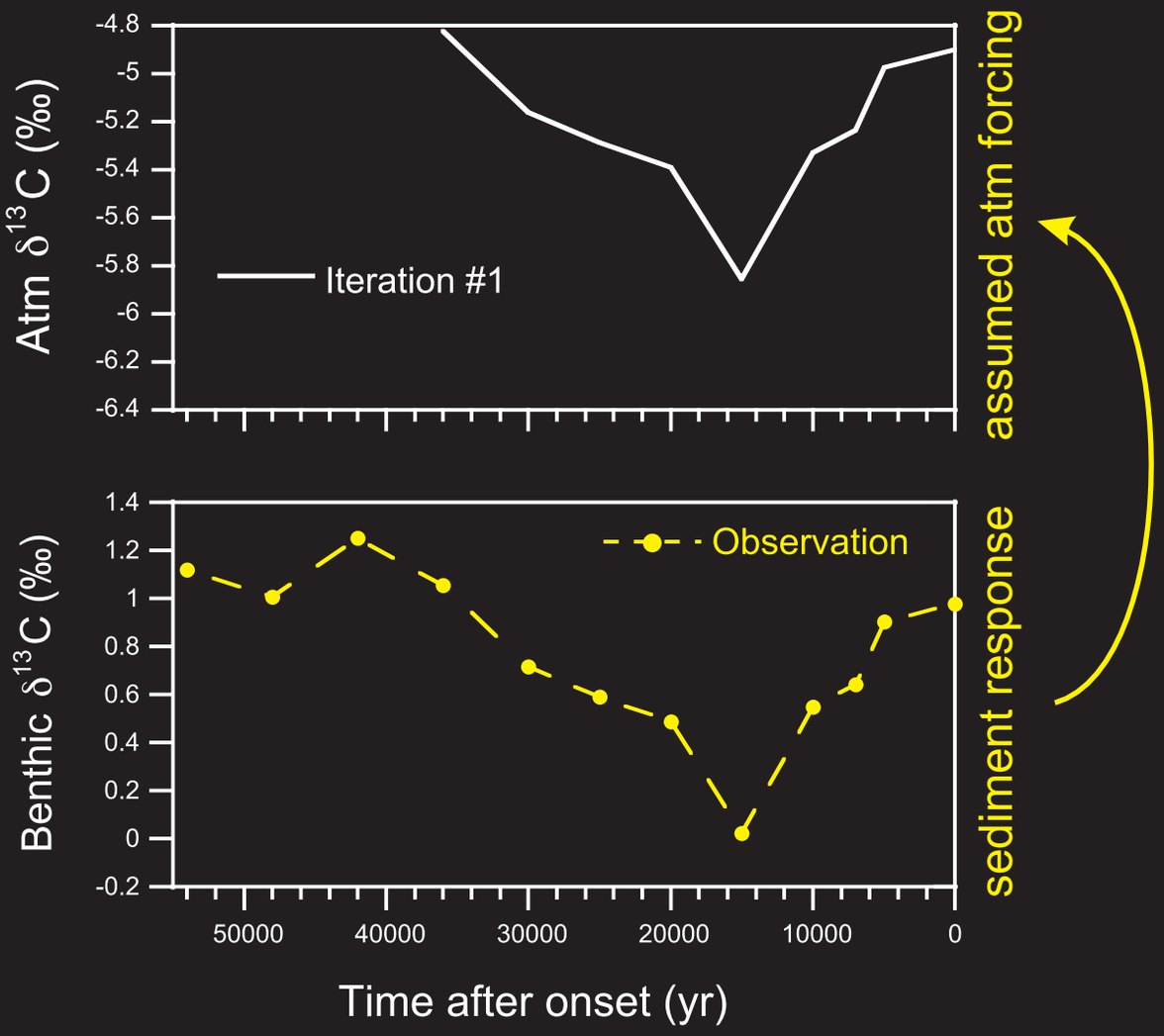


Decoding The Marine Geological Record



Kirtland-Turner and Ridgwell [2013]

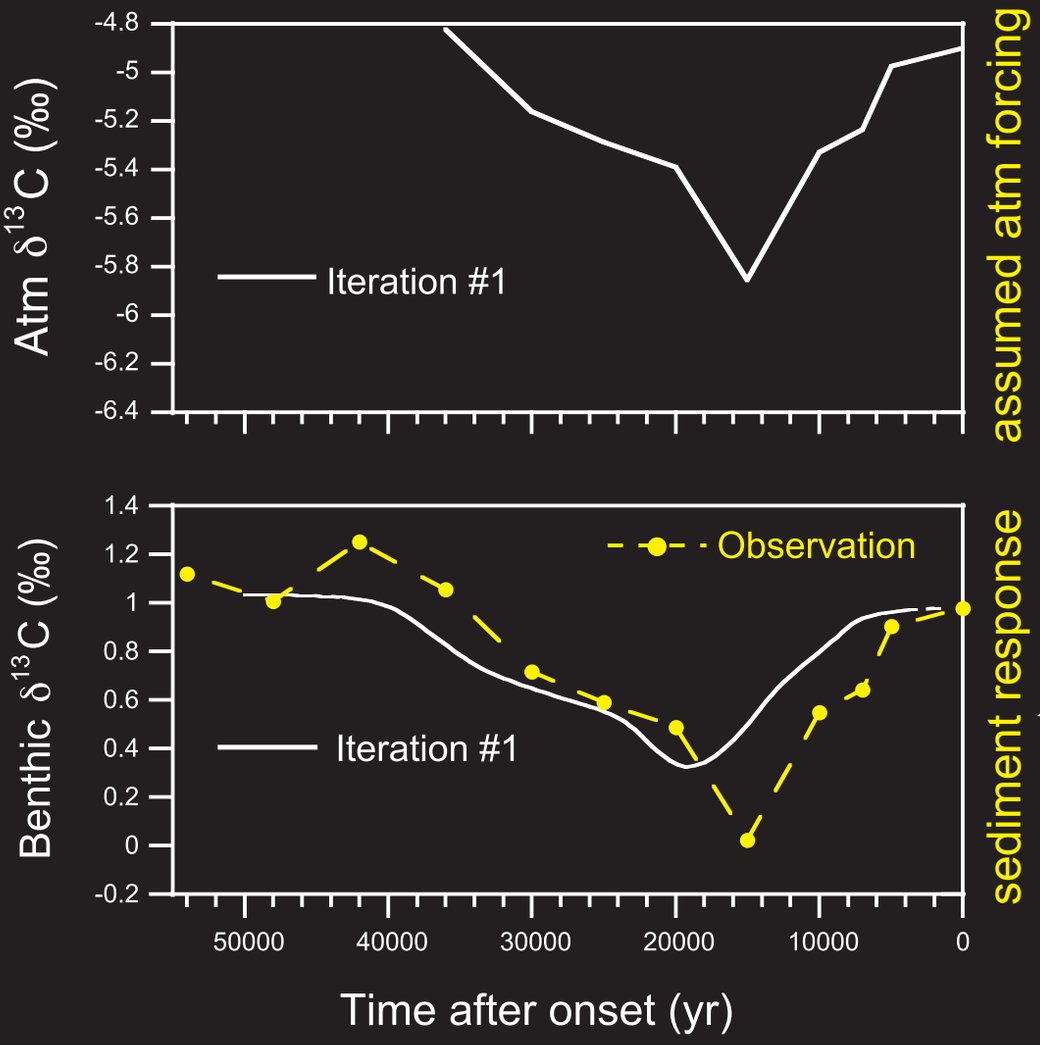
Decoding The Marine Geological Record



Initial guess:
observed δ^{13}C record
==
the atmospheric forcing

Kirtland-Turner and Ridgwell [2013]

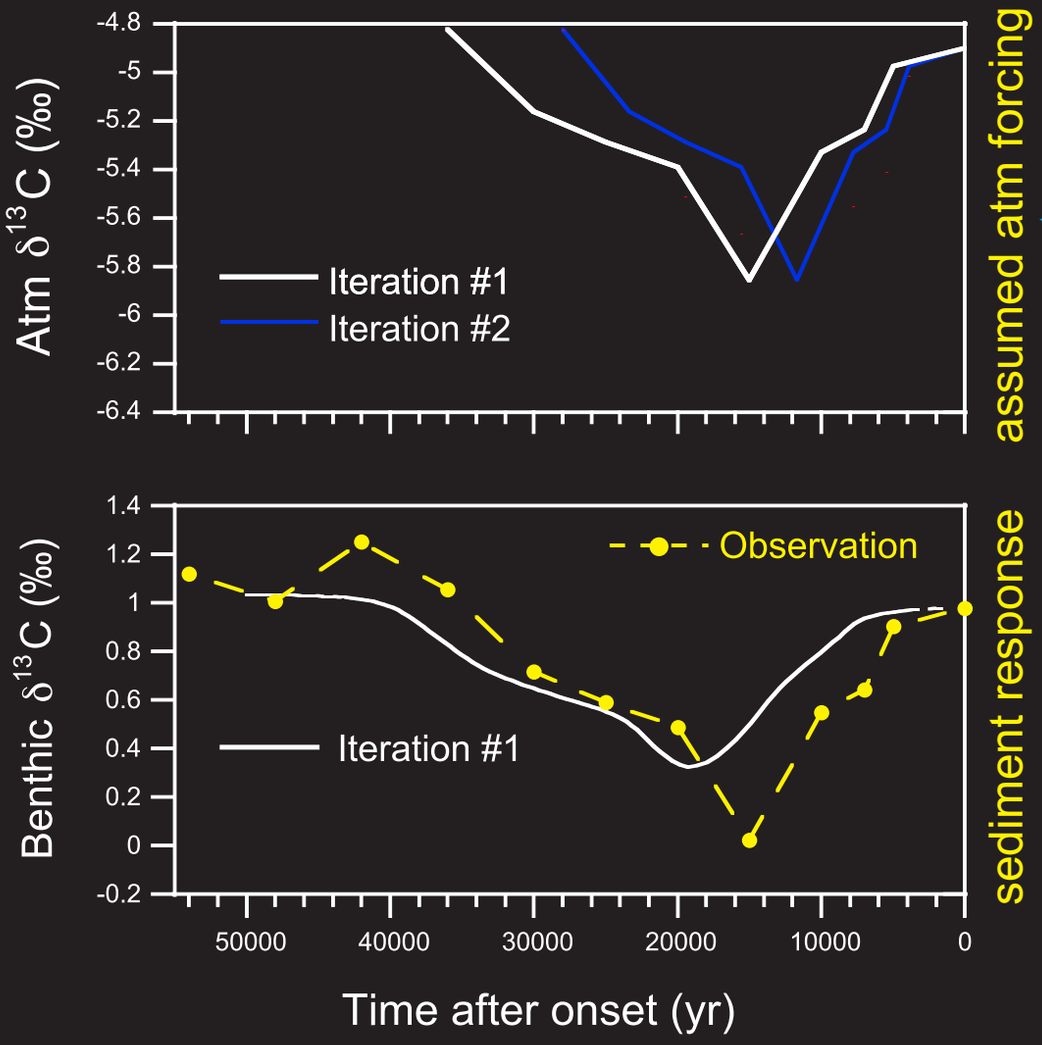
Decoding The Marine Geological Record



Step #1
Invert 'guesstimated' atmospheric δ^{13}C record and calculate sediment expression

Kirtland-Turner and Ridgwell [2013]

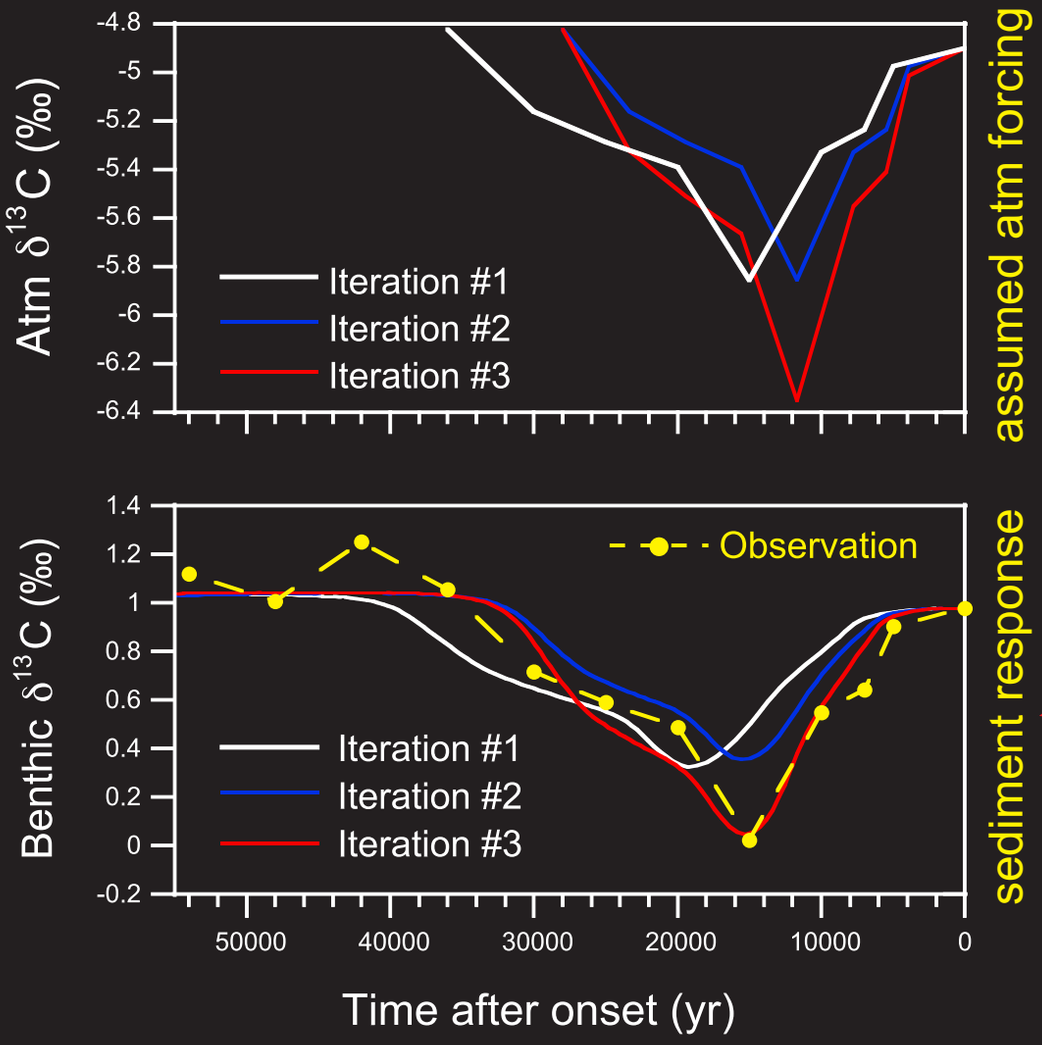
Decoding The Marine Geological Record



Adjust atmospheric record:
Correct for distortion in time

Kirtland-Turner and Ridgwell [2013]

Decoding The Marine Geological Record



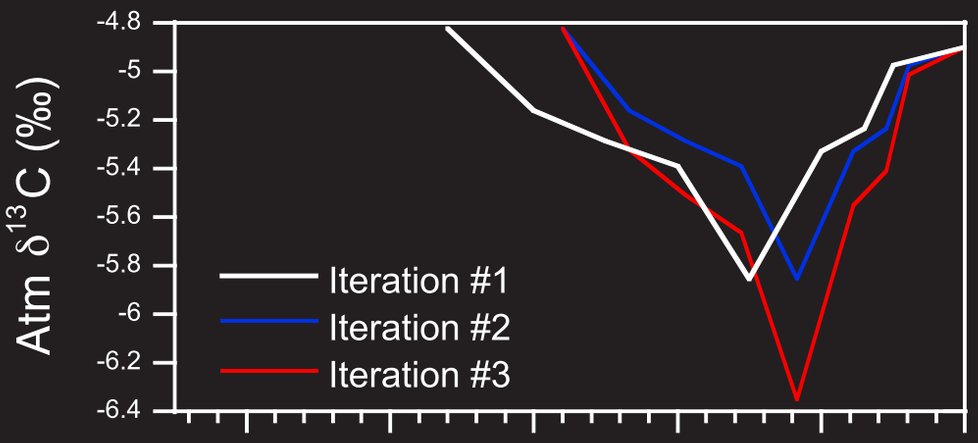
Step #2:
Invert adjusted atmospheric δ^{13}C record; then adjust forcing magnitude;

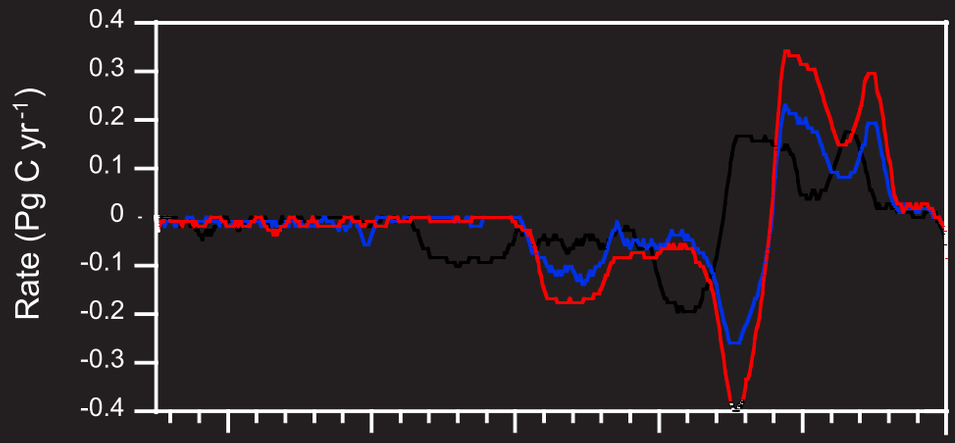
Step #3:
Invert the now twice-adjusted atmospheric δ^{13}C record

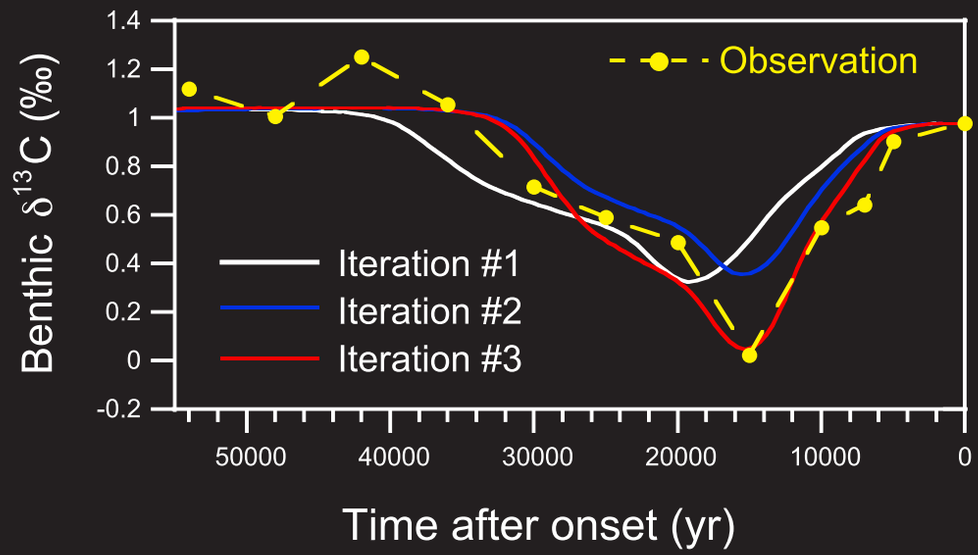
Kirtland-Turner and Ridgwell [2013]

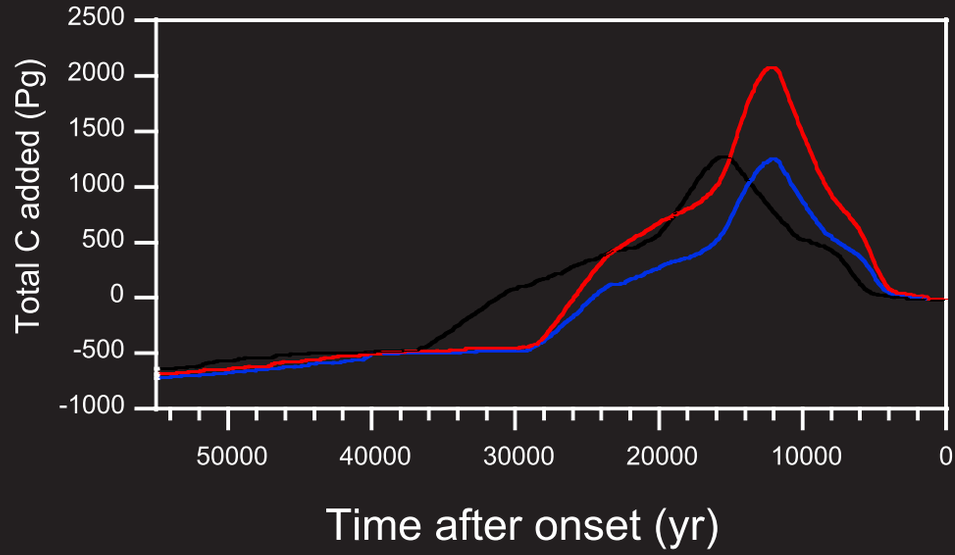
Decoding The Marine Geological Record

Recover rates of CO_2 emissions



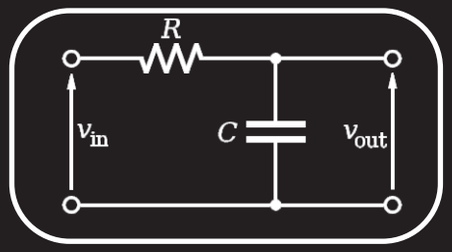




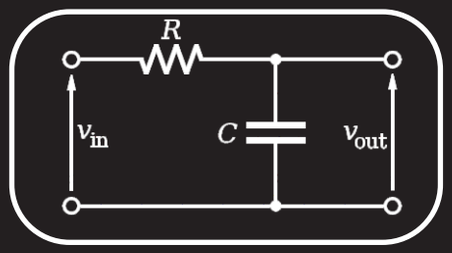


Decoding The Marine Geological Record

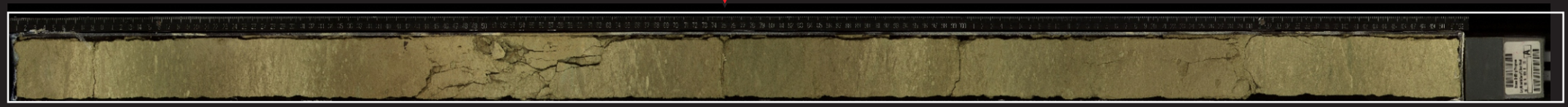
dissolution
(peservation)



mixing
(bioturbation)



C22nH3
('Big Bird')



Kirtland-Turner and Ridgwell [2013]

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