Carbonate Fluxes During Earth History

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An Analysis of the Ronov Database

- The database was built under the direction of Alexander Borisovitch Ronov (affectionately known as „Sambareesh“) at the Vernadski Institute of Geochemistry, Moscow
- Started in 1947, data on areas, volumes and masses of sediments were actively added and analysed until 1995
- Areg Migdisov and Alex Balukhovsky have been actively working since 1995 to preserve the original data

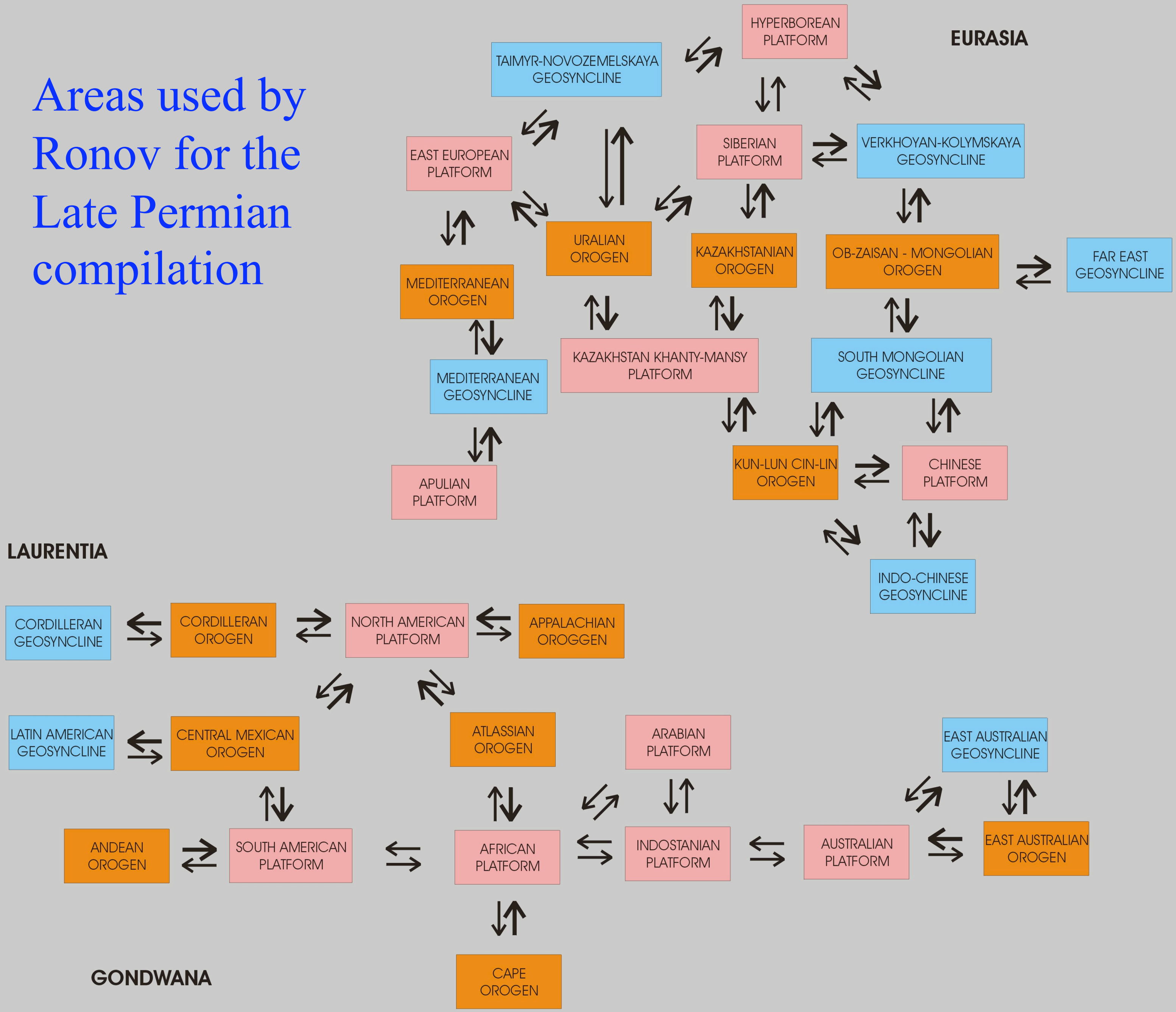
The database was produced by first constructing Lithologic-Paleogeographical maps of the continents. The original (unpublished) equal-area map for the Upper Cretaceous of North America is shown here.

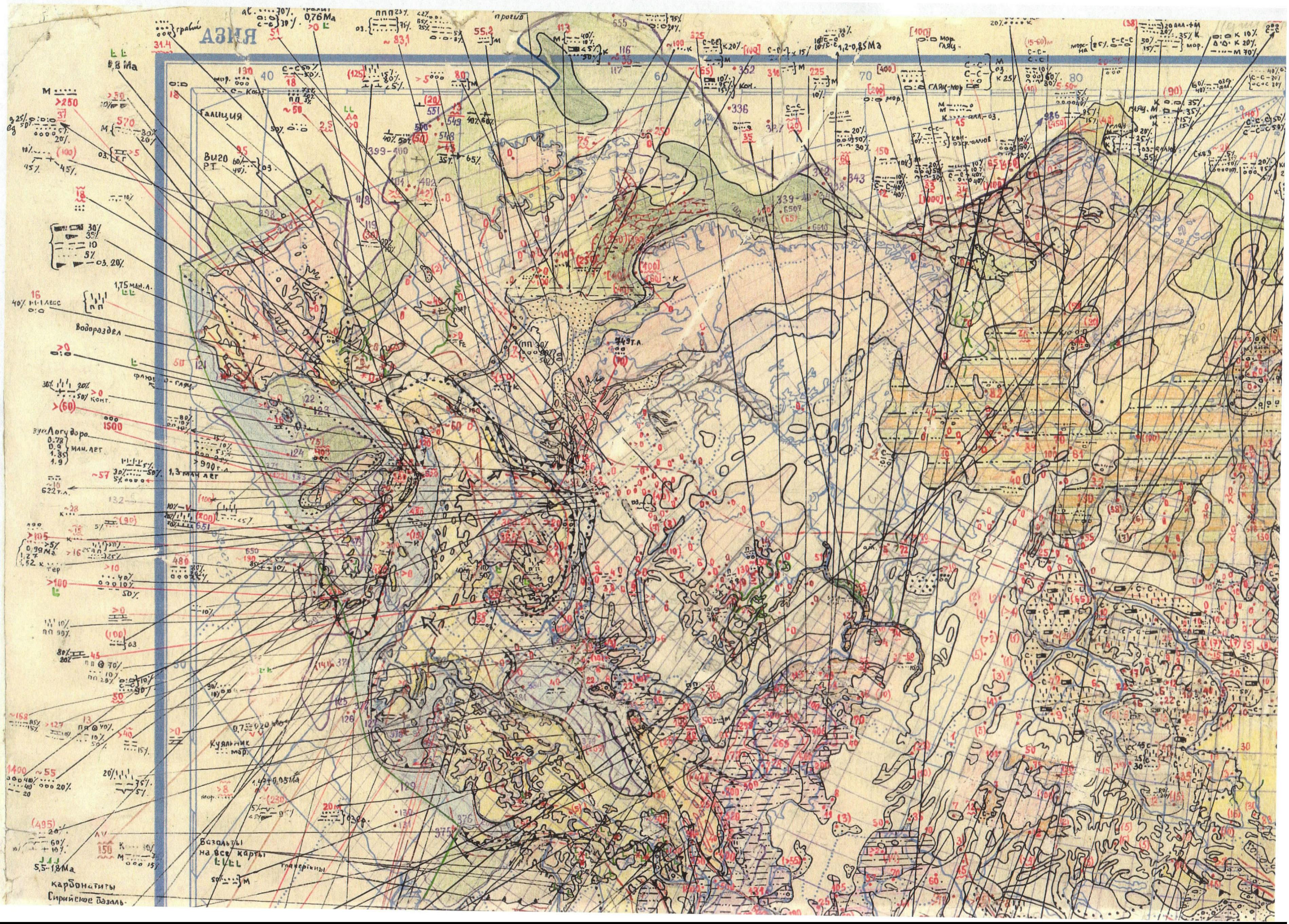
From the information on the map, the areas and thicknesses of each lithology were measured and the volume and mass calculated.

The compilation includes volumes of the following sediment types for each region:

Continental terrigenous sediment
Coal-bearing terrigenous sediment
Glacial sediment
Molasse
Marine sands
Marine shales
Marine terrigenous sediment
Flysch
Carbonate-terrigenous sediment (Marls)
Carbonates
Halite
Gypsum/Anhydrite
Siliceous sediment

Areas used by Ronov for the Late Permian compilation




АЗИЯ
Галиция
Водораздел
Базальты
на все карты
карбонатиты
Сирийские базаль-

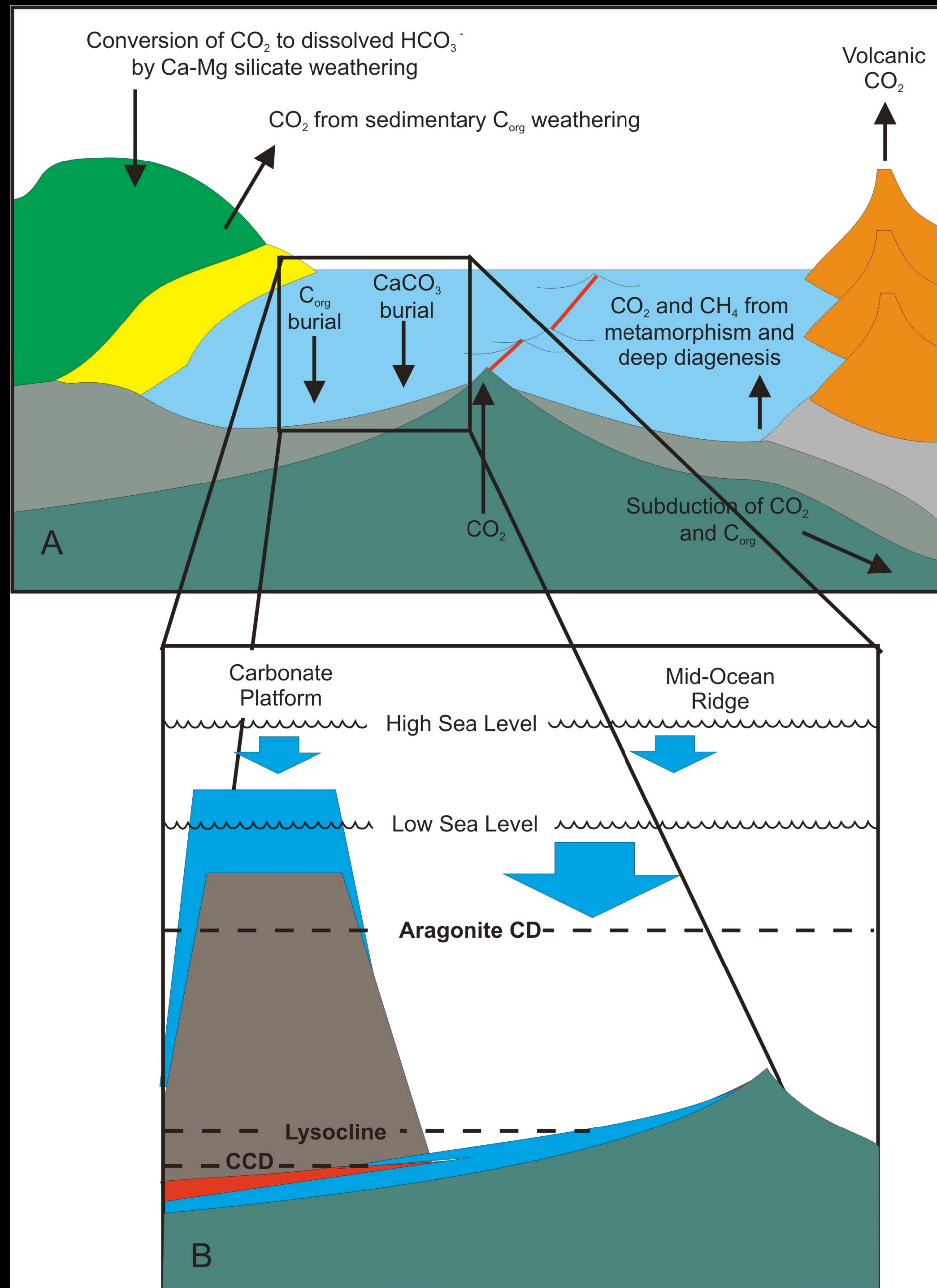
Detrital and dissolved loads of rivers are deposited in different ways

- The detrital load (sand, silt, clay, etc. settles is deposited in tvalleys, the coastal plain, and settles onto the sea floor
- The dissolved load can be stored in the ocean for short (carbonate) or long (salt) periods of time and its site of deposition is unrelated to where it originally entered the sea

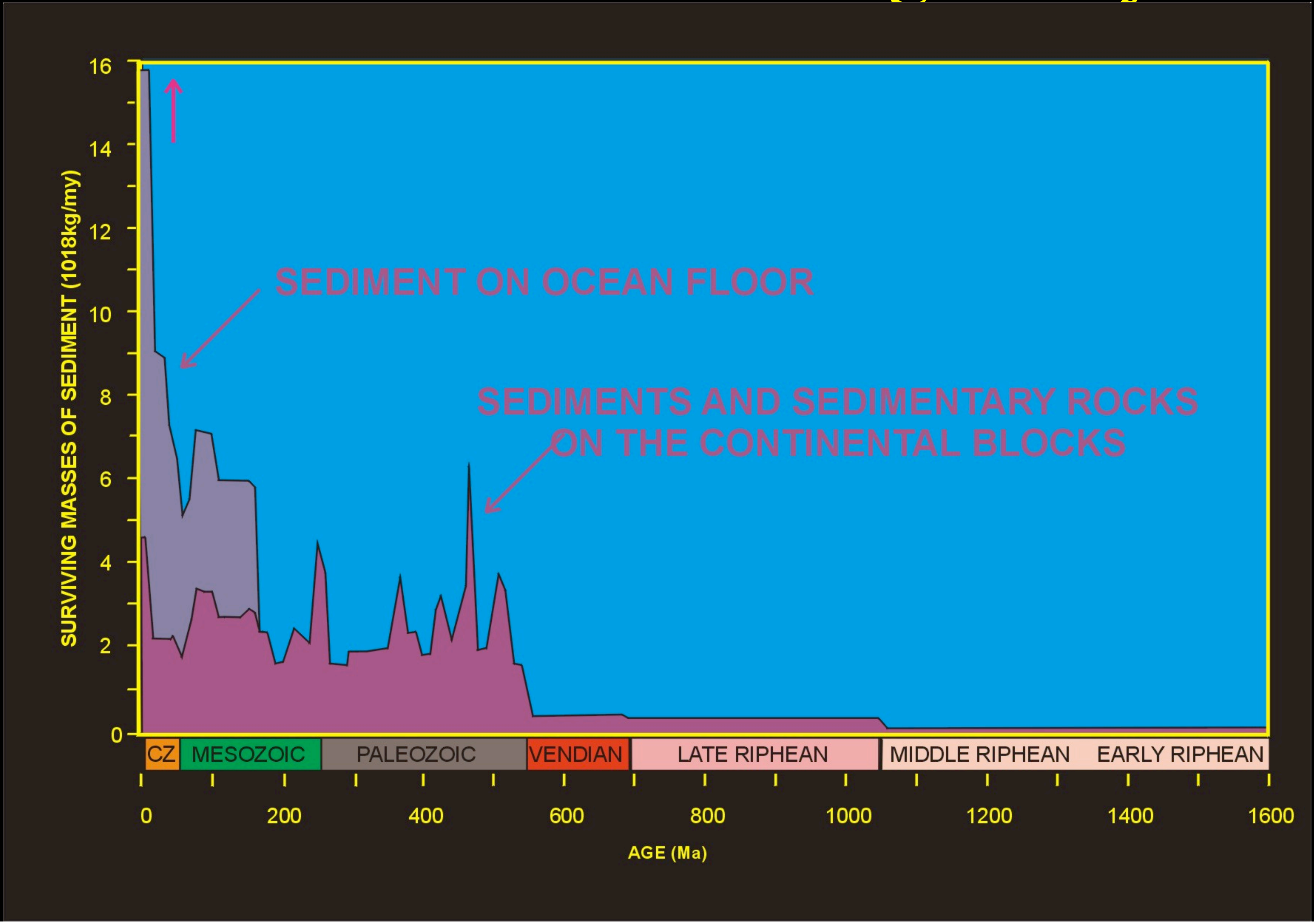
For the dissolved load - On the long term: what goes in must come out.

But . . .

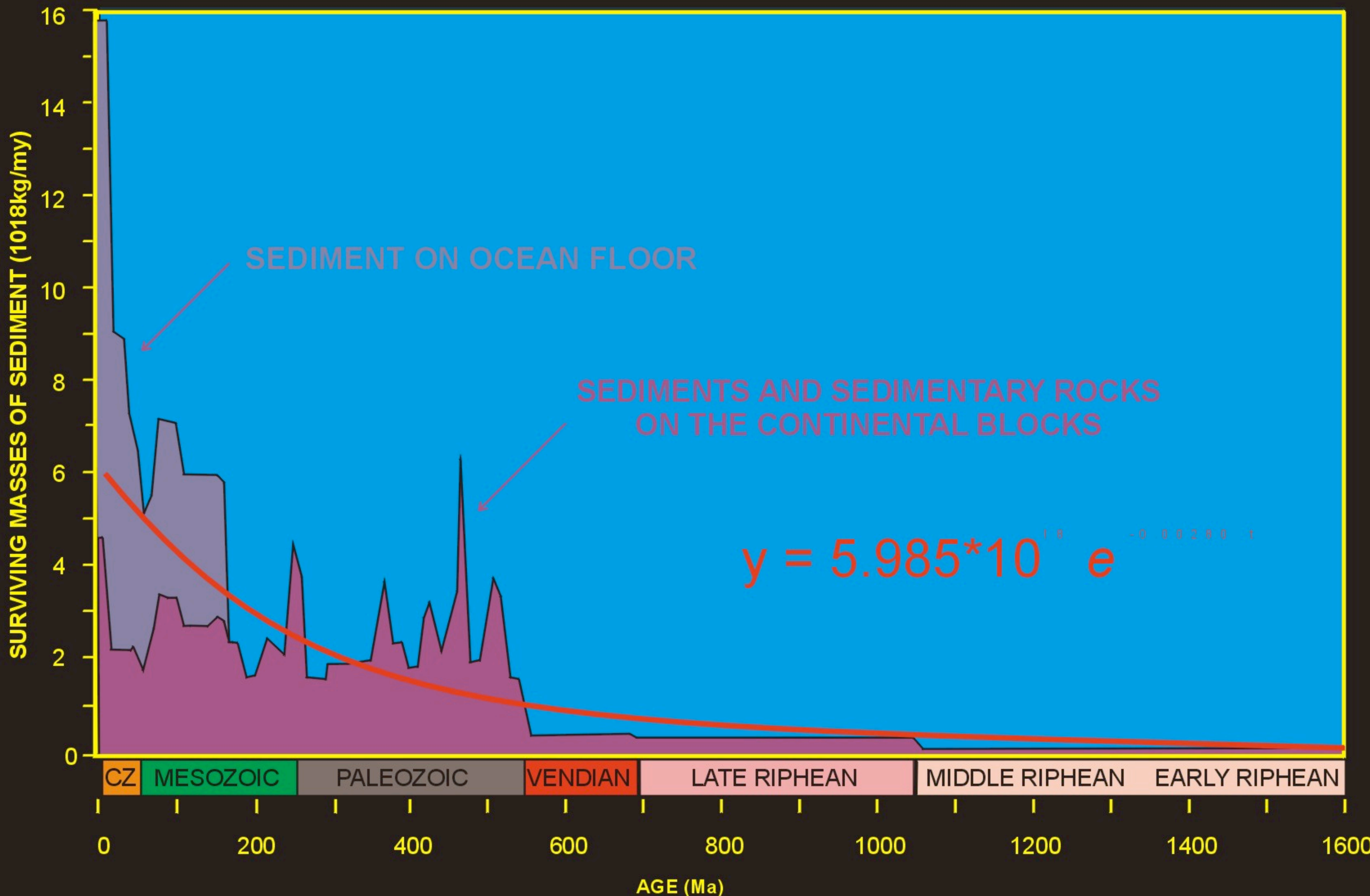
Over the past 100 my the calcareous nannoplankton have become an important part of the internal workings of the carbon cycle



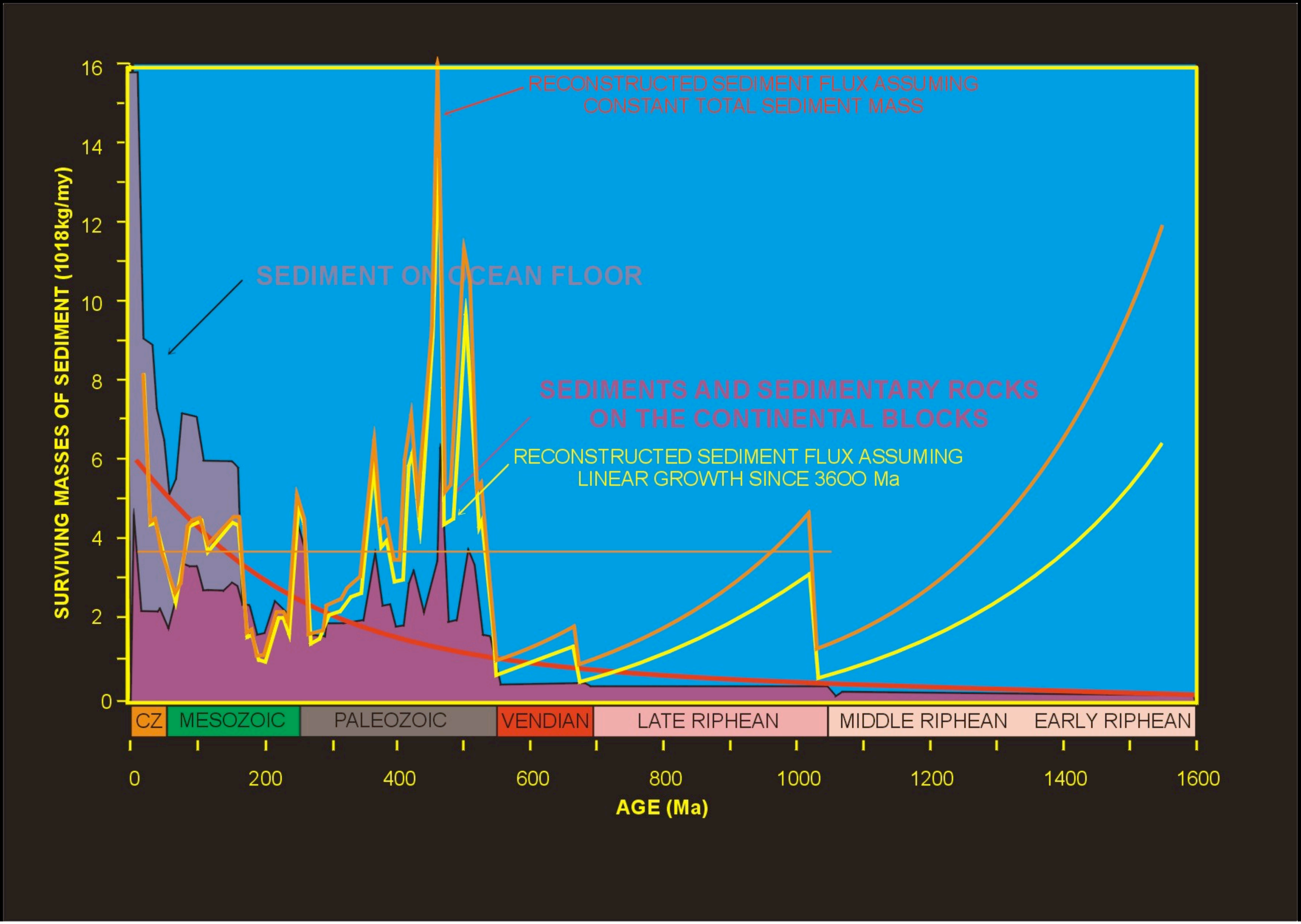
The Sediment Existing Today



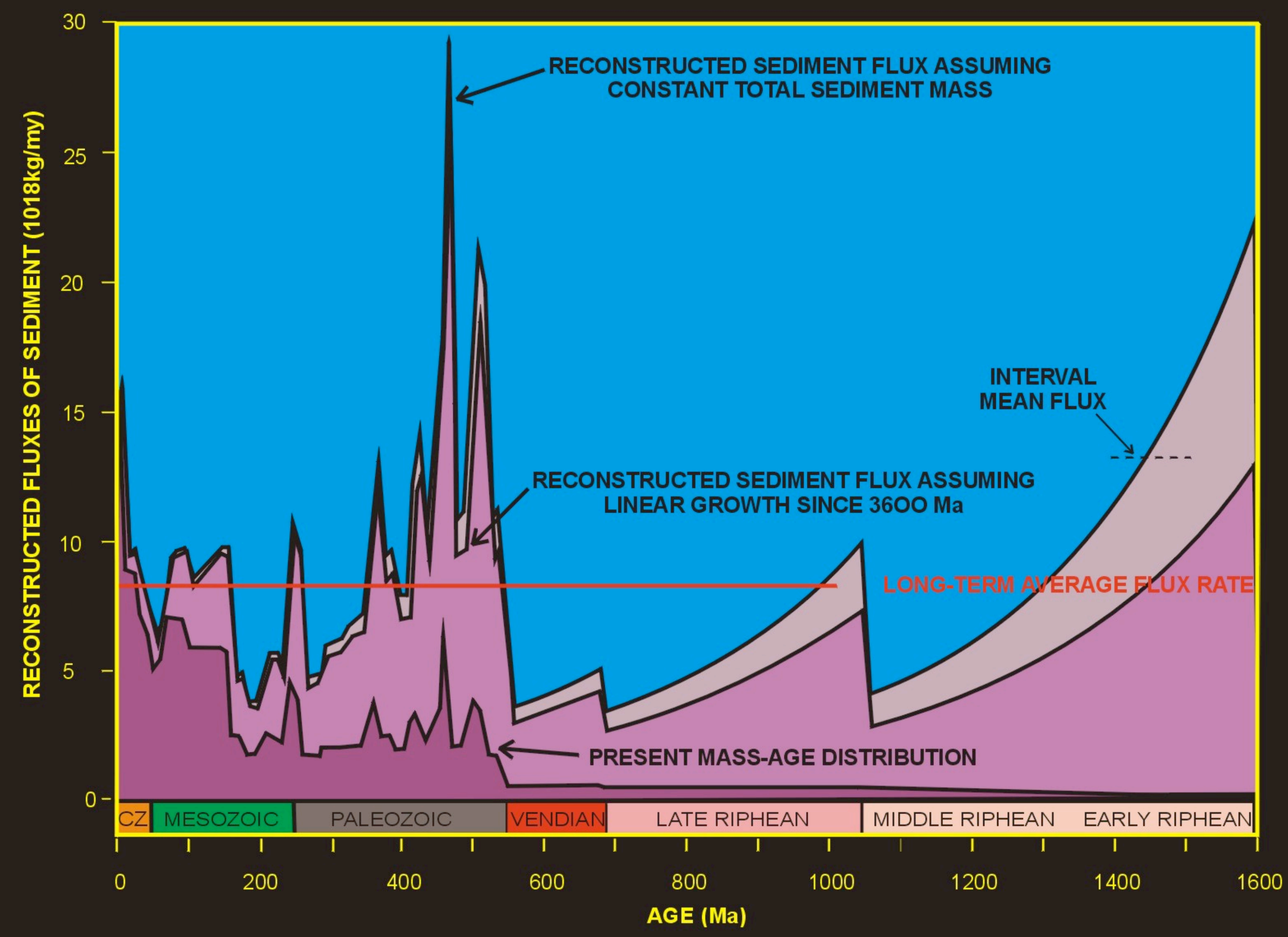
The Global Recycling Rate of Sediment



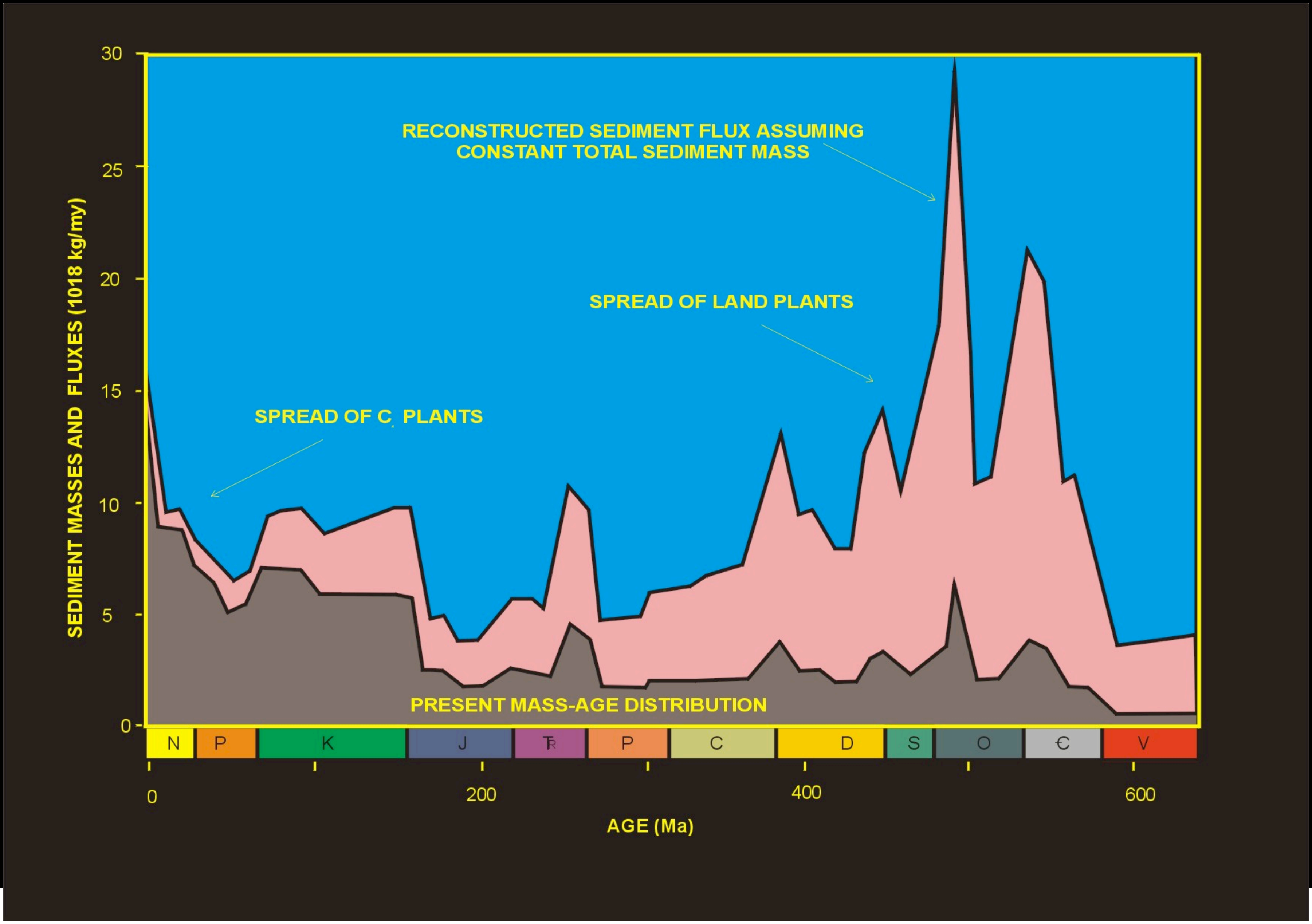
Reconstructed Sediment Fluxes

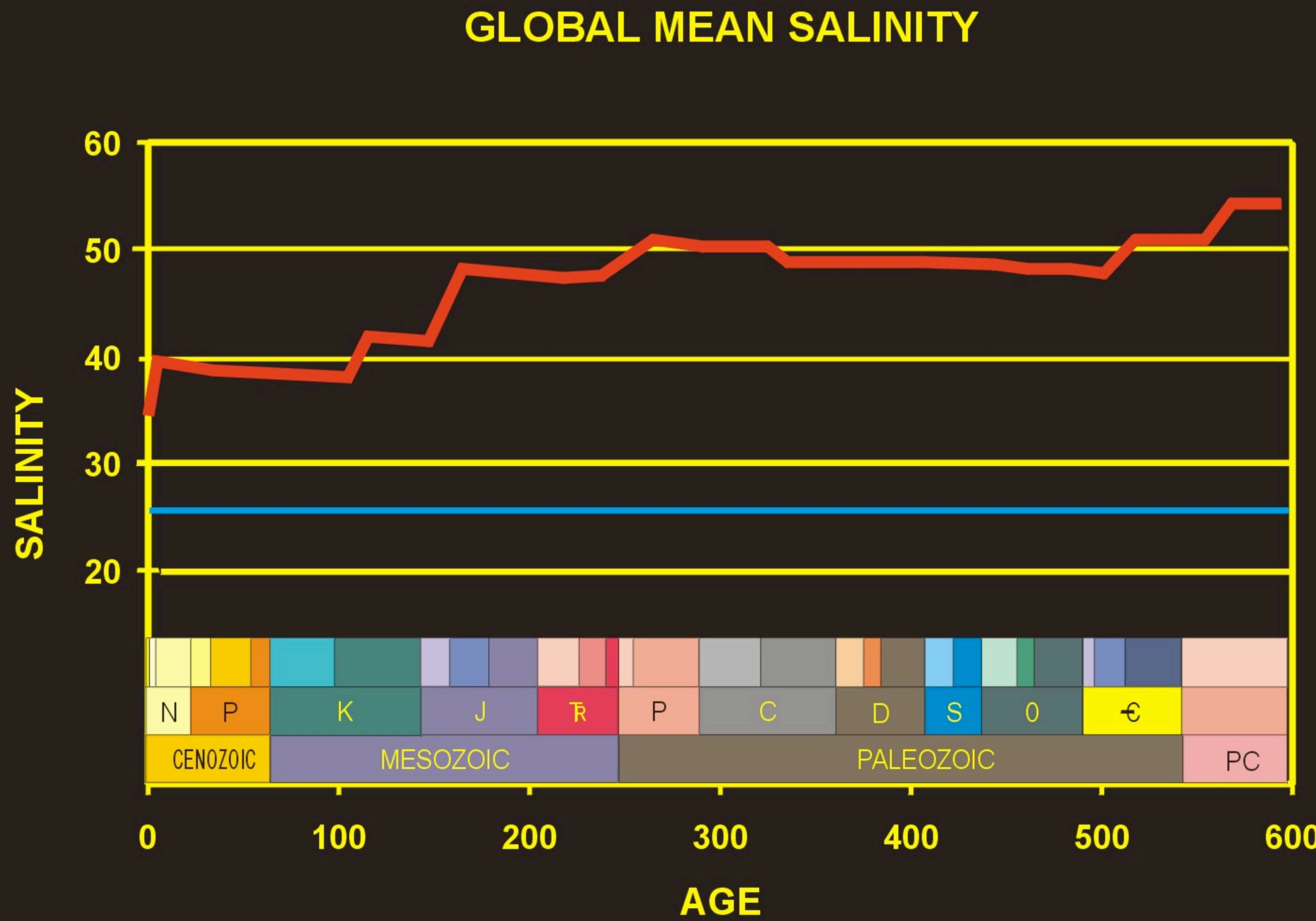


The Long Term Average Sediment Flux



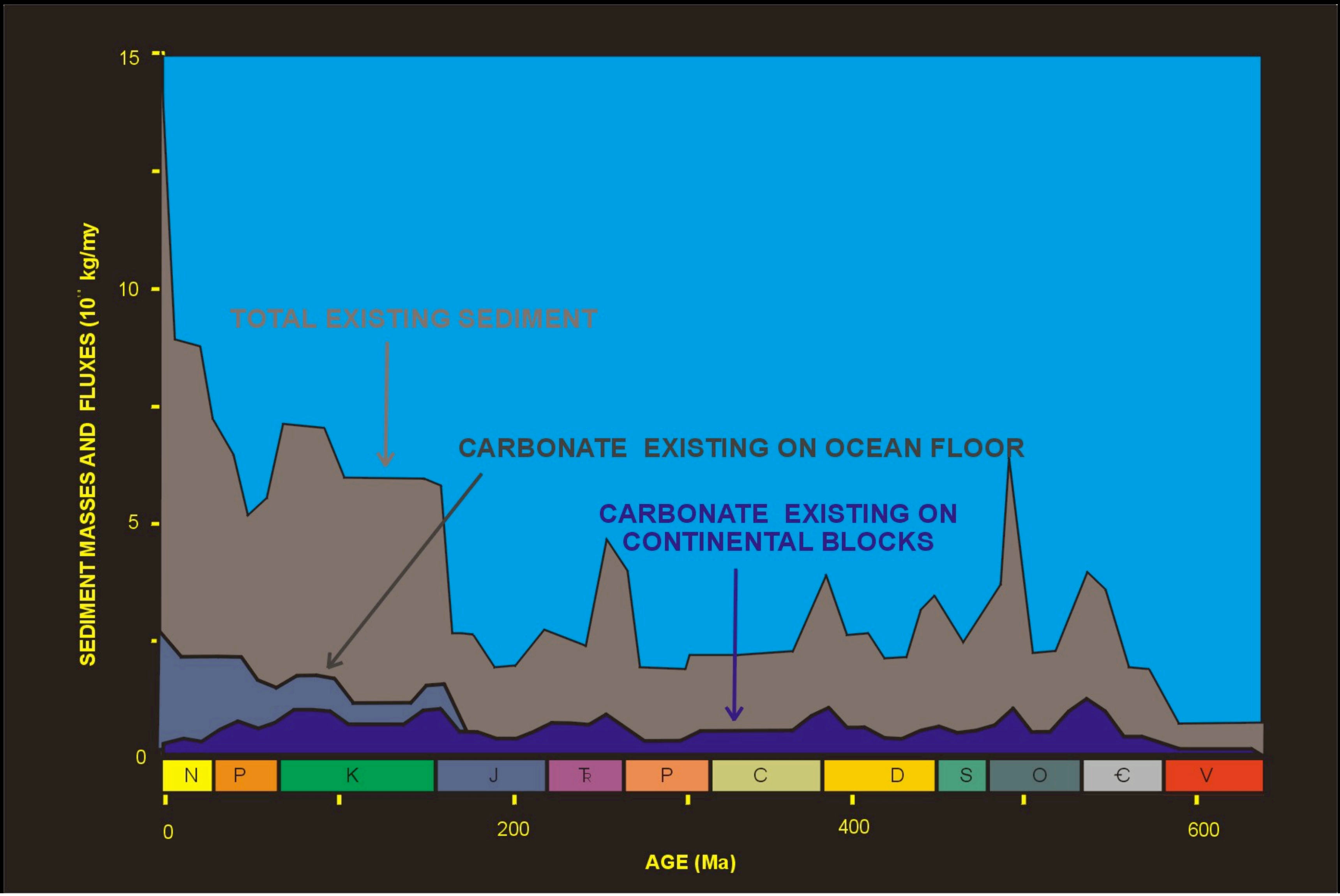
The Phanerozoic Sediment Flux



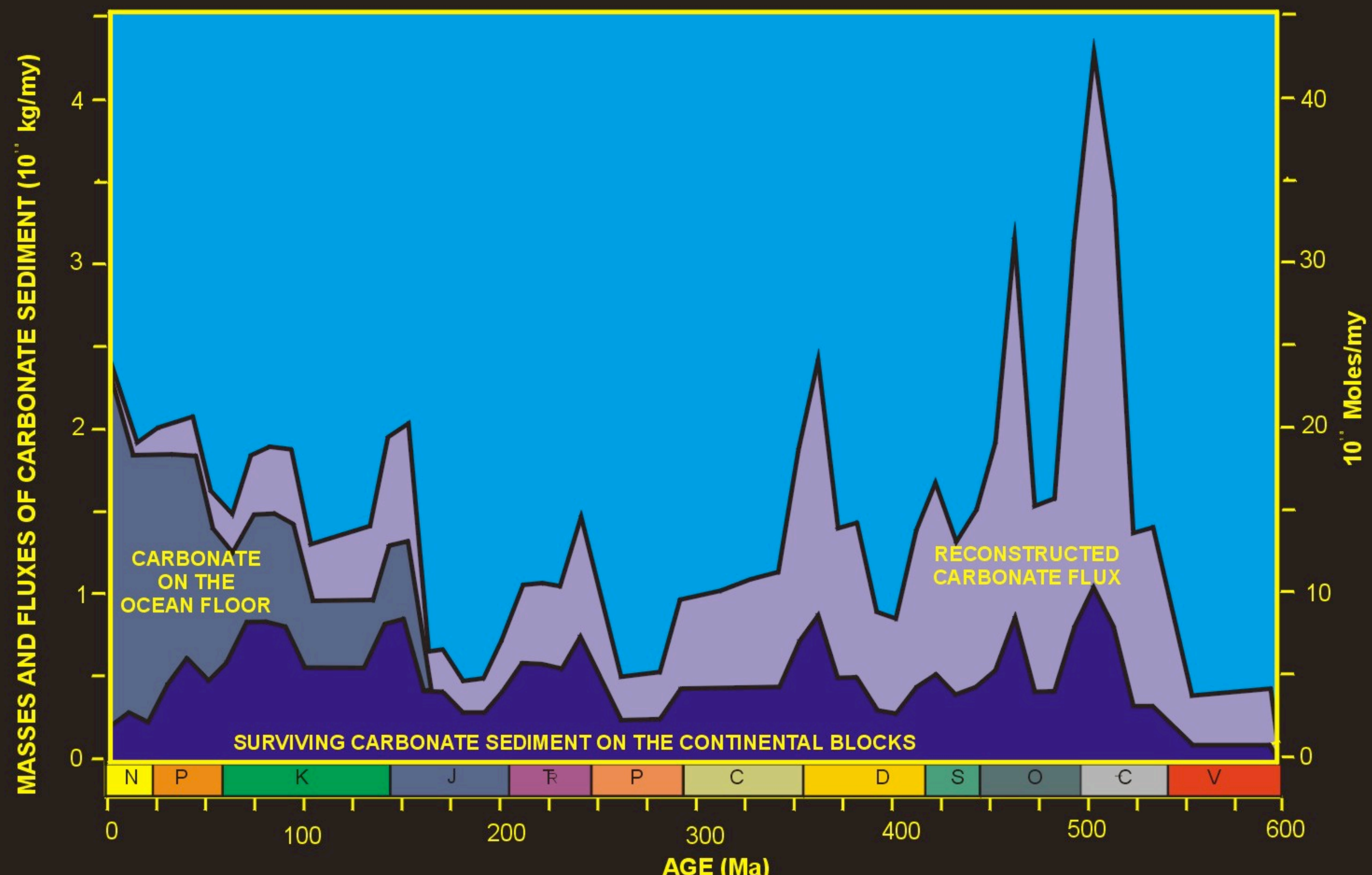


GLOBAL MEAN SALINITY
60
50
40
30
20
SALINITY
N
P
K
J
Ŧ̵R
P
C
D
S
0
Ꞓ
CENOZOIC
MESOZOIC
PALEOZOIC
PC
0
100
200
300
400
500
600
AGE

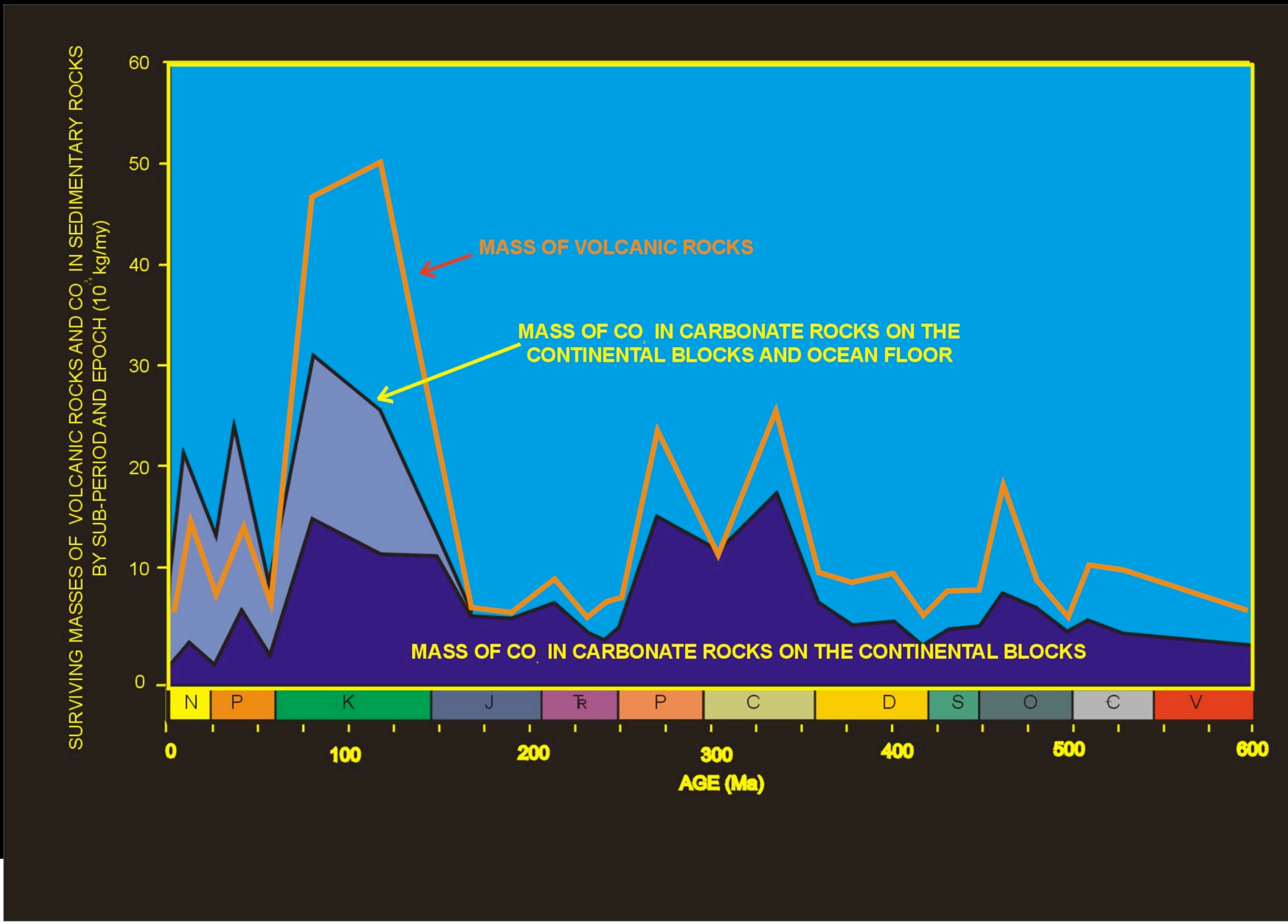
Carbonate is about ¼ of the Existing Phanerozoic Sediment



Phanerozoic Carbonate Flux



The original idea of Budyko and Ronov – that carbonate deposition is linked to volcanism via CO_2 emission may not be so bad



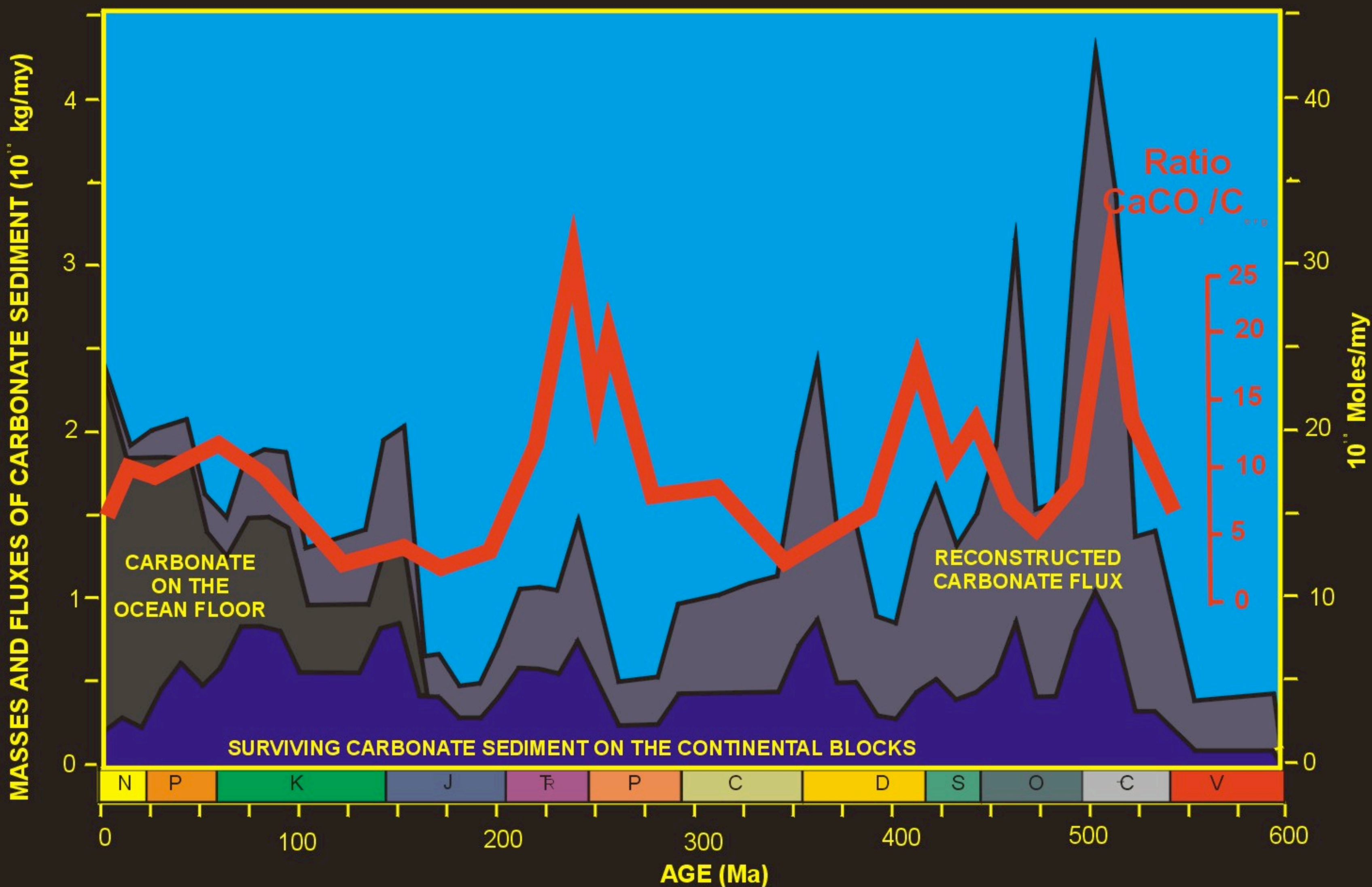
The relative proportions of $CaCO_3$ and C_{org}

- In modern plankton, (>>) 4 moles of C are fixed as C_{org} for every mole fixed as $CaCO_3$

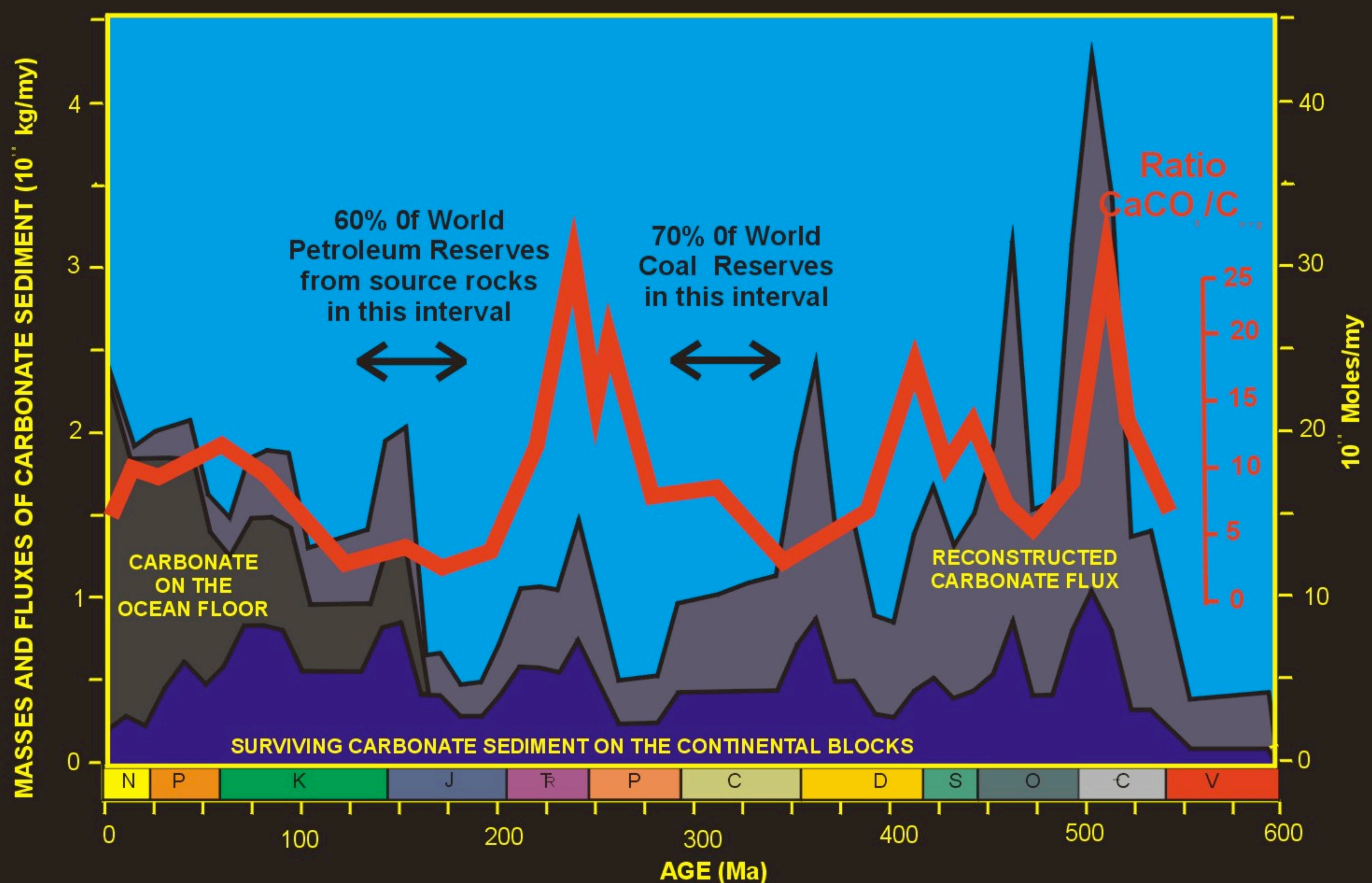
At present about 6 moles of C are buried as $CaCO_3$ for every mole buried as C_{org}

- This ratio has generally been higher in the past

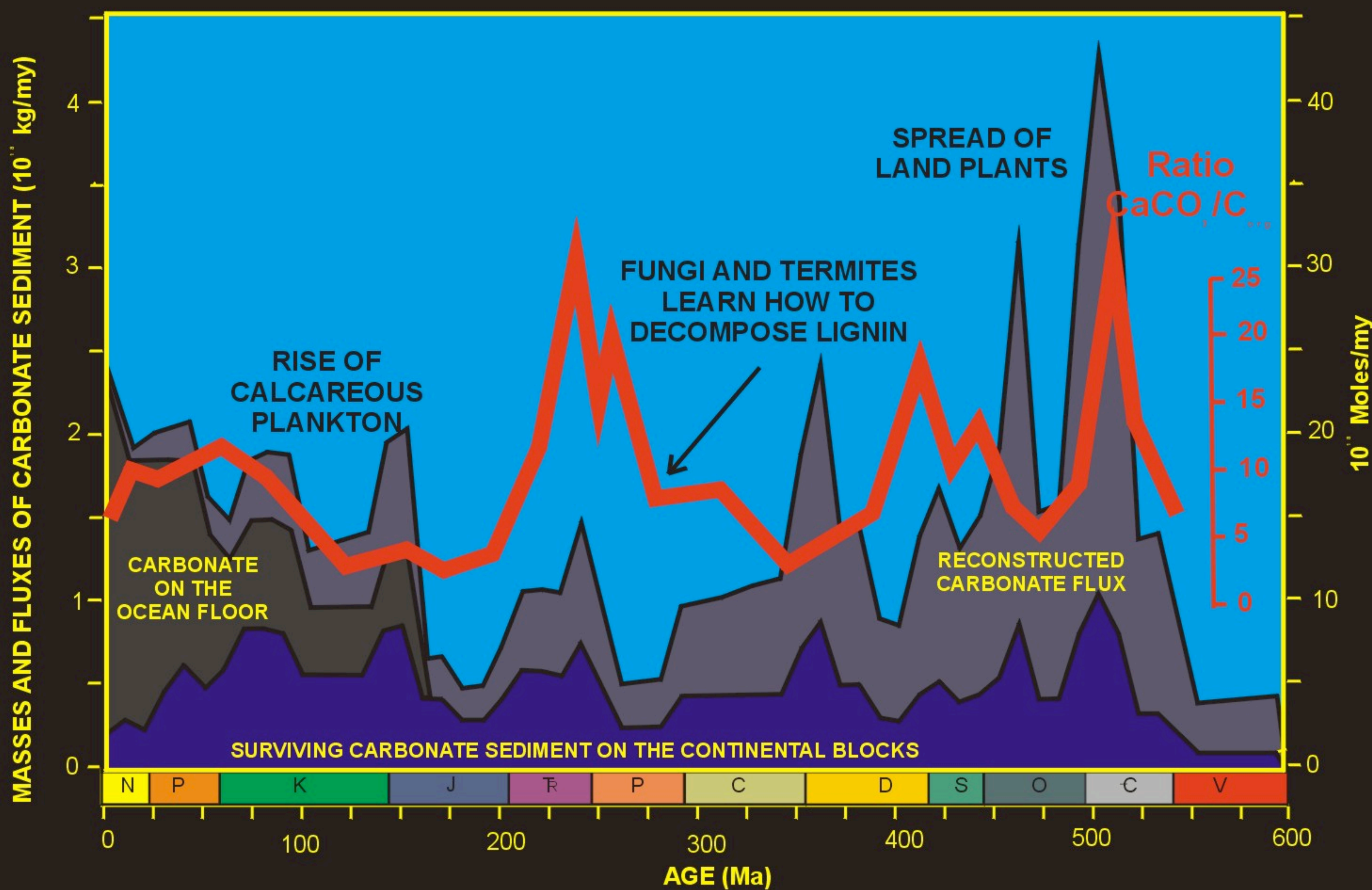
The ratio of C in $CaCO_3$ to C_{org}



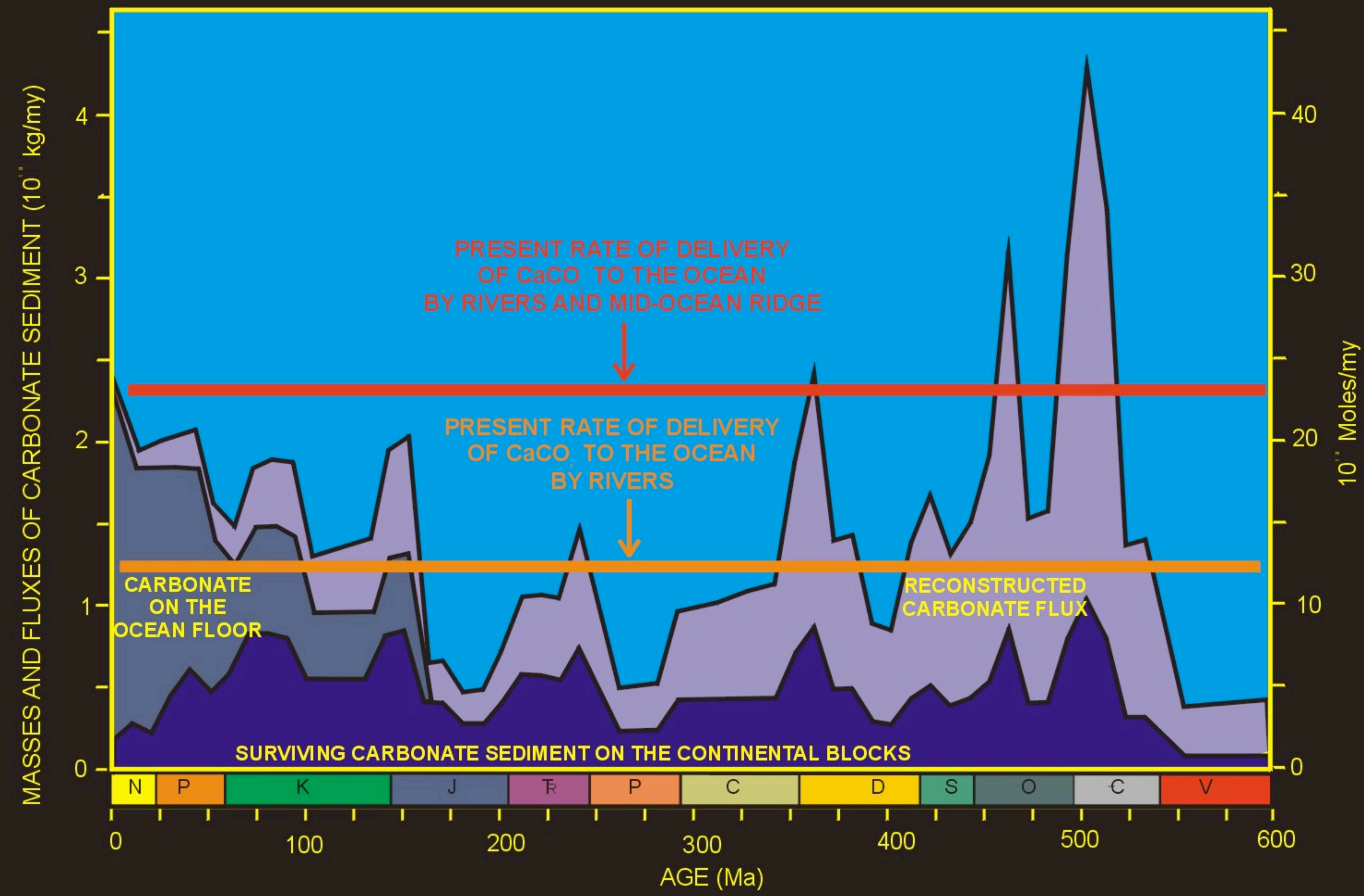
Deposition of C_{org}



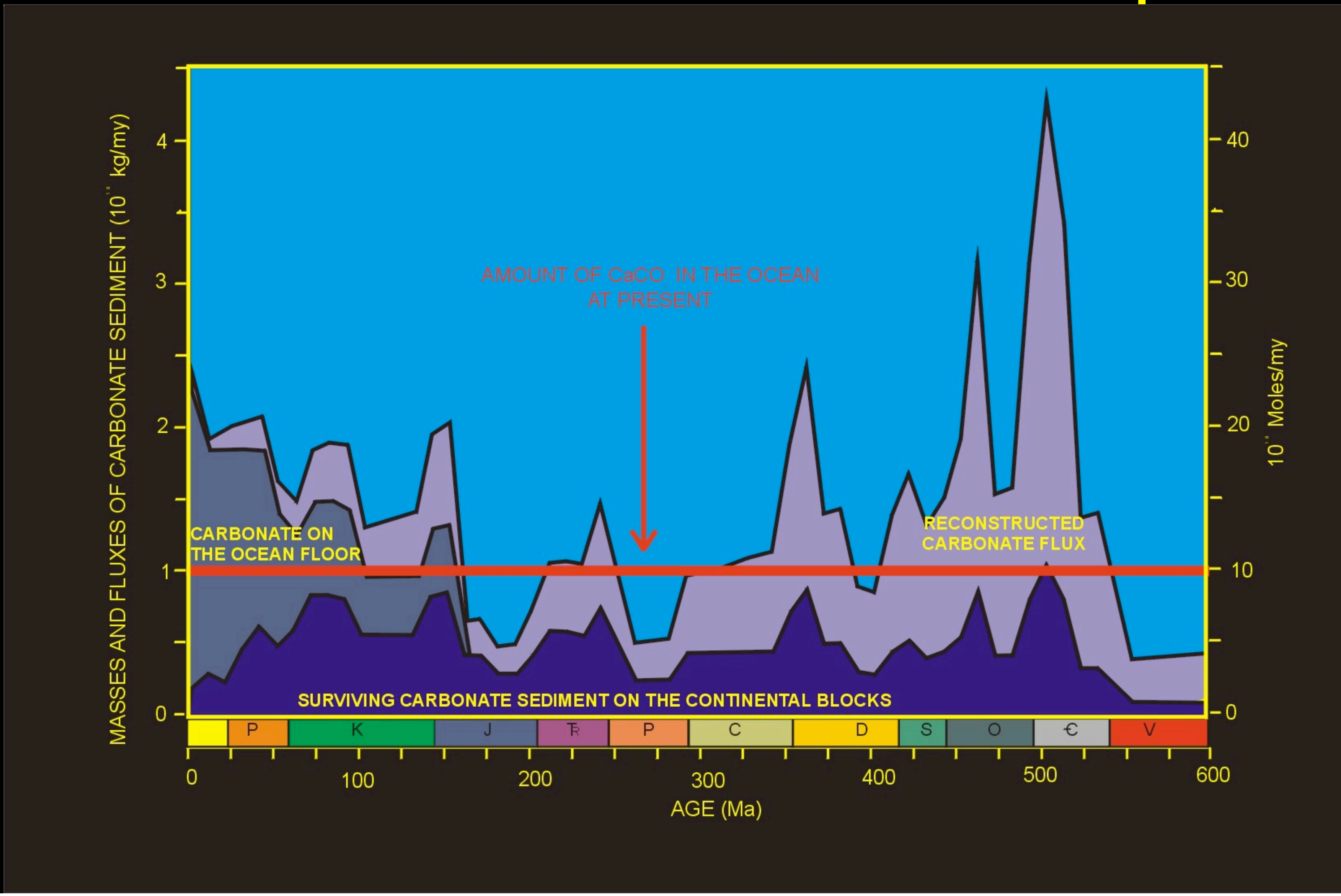
Major Events in C_{org} History



Total Carbonate Flux



Carbonate stored in the ocean is insufficient to maintain output



The Mesozoic – Cenozoic Story

- The major event is a shift of the site of carbnate deposition from the shallow seas to the deep sea
- This was brought on by the development of the calcareous plankton
- The spread of calcareous plankton may be related to declining ocean salinity

Coccoliths as part of the Carbon Flux

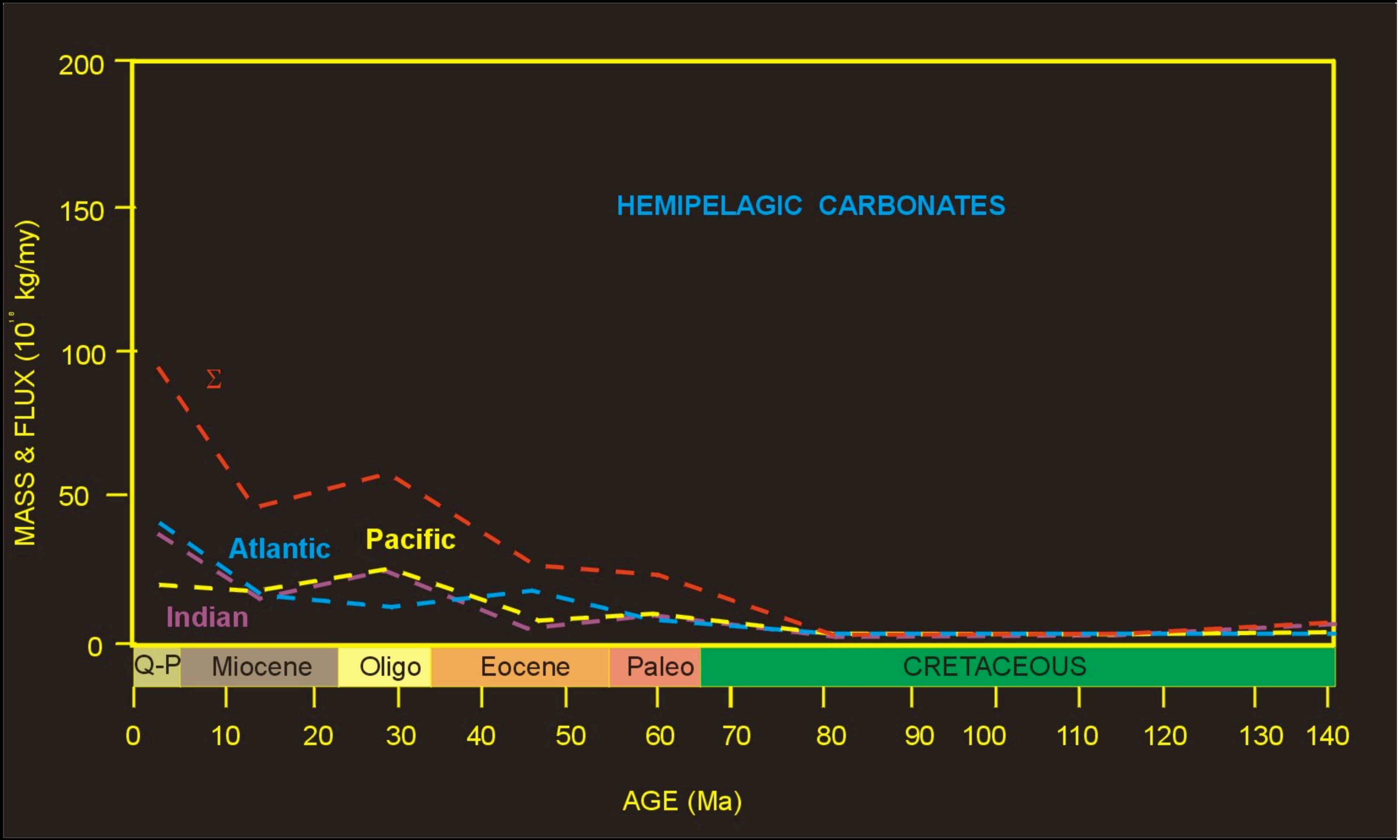
- Coccoliths are part of the pelagic $CaCO_3$ Flux
  - Pteropod shells
  - Planktonic foraminiferal tests
  - Coccoliths

- The oceanic $CaCO_3$ Flux is part of the Σ $CaCO_3$ Flux
  - Pelagic $CaCO_3$ Flux
  - Benthic $CaCO_3$ Flux

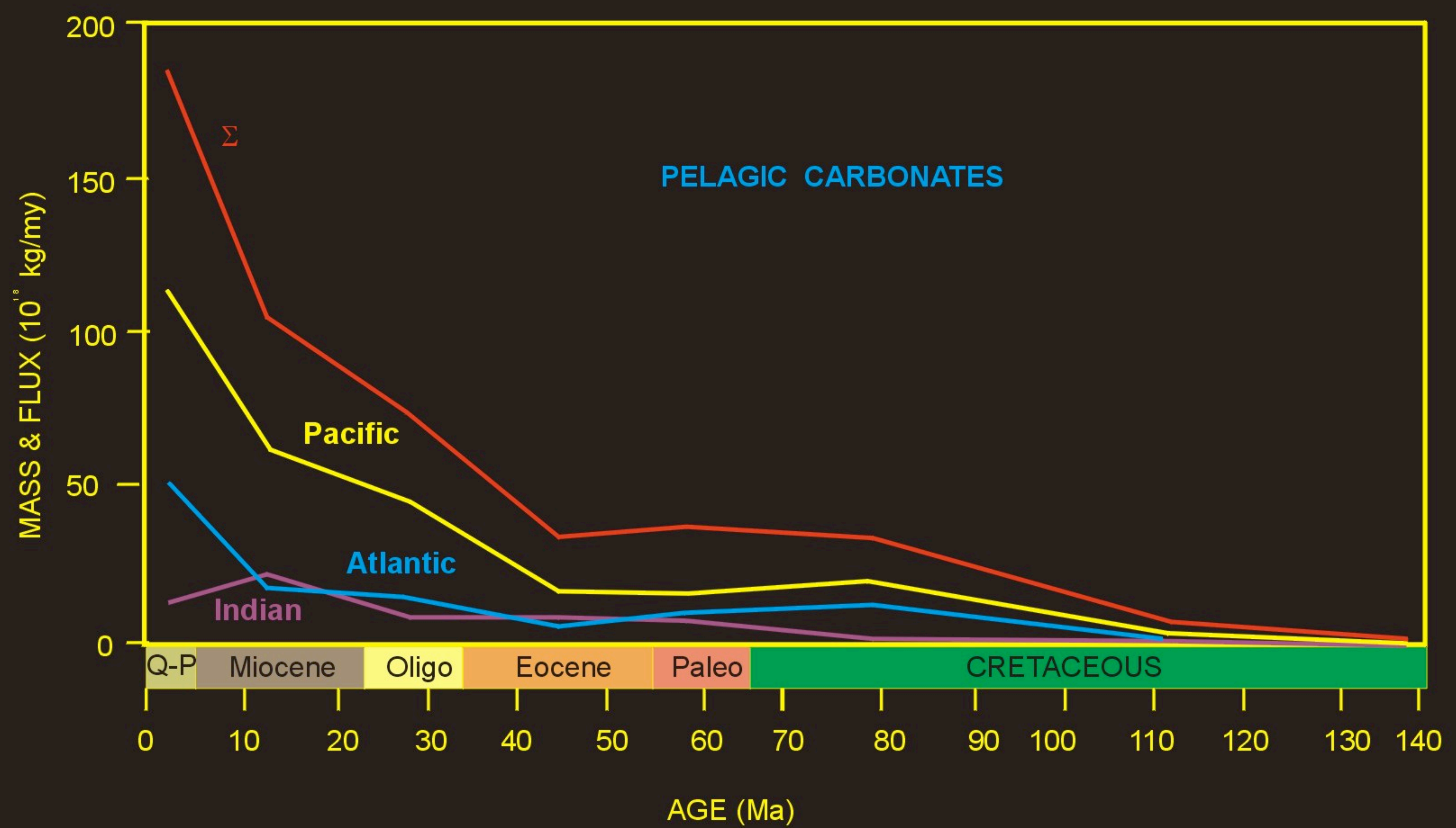
- The $CaCO_3$ Flux is part of the Σ Carbon Flux
  - $CaCO_3$
  - Organic carbon

The Carbon Flux is part of the Σ Sediment Flux

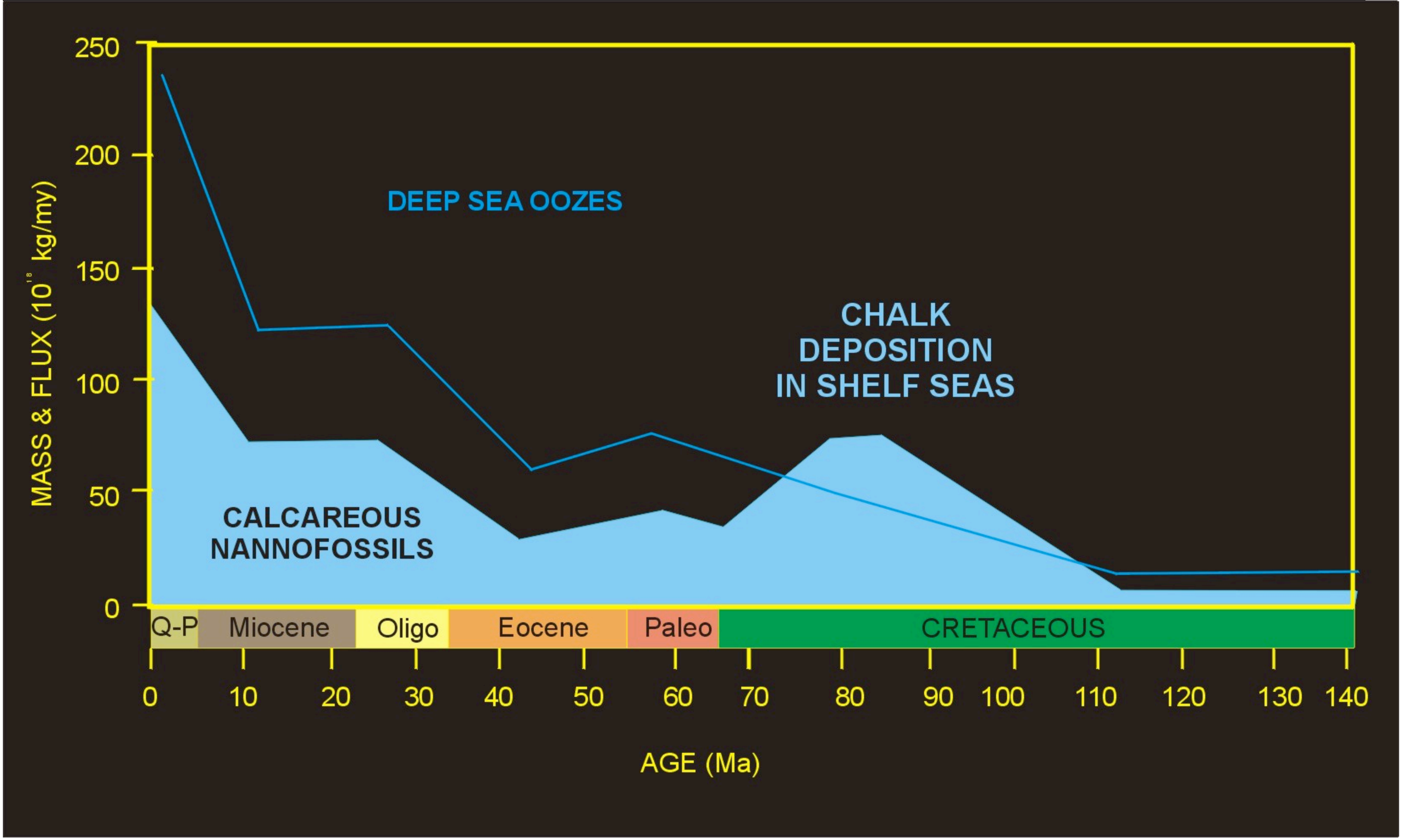
The Increasing Hemipelagic Flux



The Increasing Pelagic Flux



Calcareous Nannoplankton and the Shift from Shallow to Deep Water



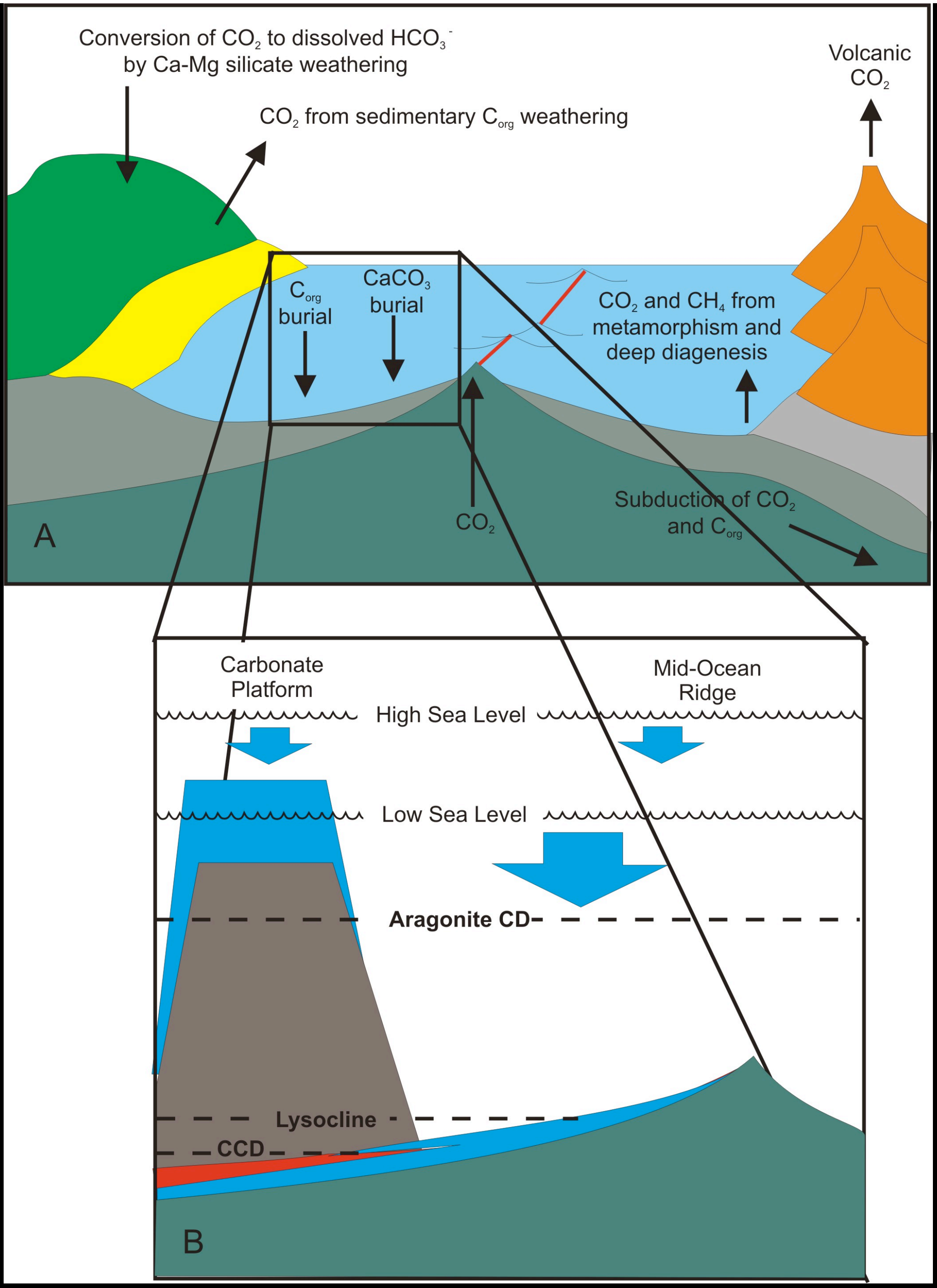
The Calcareous Plankton

- Have shifted the site of carbonate depositon from shallow seas to the deep sea

During the Late Neogene about 95% of $CaCO_3$ deposition has been in the deep sea, 5% in shallow water

But there have been reversals – during the Holocene, after the rapid post-glacial sea level rise, the shallow water $CaCO_3$ depositon rate was about 3 times that of the long term average

The modern system is a complex balance with feedbacks to change the $CO_3^{=}$ – HCO_3^{-} (ocean alkalinity) proportions to adjust for changes in atmospheric CO_2, rapid carbonate output after sea level rise, etc.



The Paleozoic – Early Mesozoic Story –not well known

- Carbonate fluxes onto the continental shelves and epeiric seas were much larger
- The largest carbonate fluxes were in the Cambrian
- Perhaps very high CO_2 = rapid carbonate recycling
- Perhaps the rise of land plants changes the weathering system

Carbonate was not regularly delivered to the deep sea floor before 100 Ma

Older ophiolites have dark shales and cherts resting on basalt

There are no obducted pelagic carbonates in ancient mountain ranges

Where did all the Early Paleozoic carbonate come from

- It must have already existed in the Precambrian
- What caused the massive recycling into the Cambrian?
- Does this have anything to do with the snowball Earth?
- When did the ocean change from a soda to a sodium chloride solution?

Carbonate on the Ocean Floor will be ultimately be subducted

- Does the CO_2 come back through volcanoes?
- Or does it descend into the mantle to form scapolites?
- Scapolites are mantle-stable minterals with the formula

  Feldspar + $CaCO_3$

Have the Calcareous Plankton set in motion a Doomsday Machine?

- Removing C from the Earth‘s surface and storing it in the mantle through subduction?
- By the way, how did the C get onto the surface of the Earth to begin with?

Conclusions

- The calcareous plankton are playing a major role in the global carbon cycle
- The calcareous nannoplankton have the largest share
- For the past 100 million years they have been actively altering the global geochemical balance
- In the Early Mesozoic and Paleozoic carbonates were almost entirely restricted to the continental blocks
- Even taking this into account, there were much larger amounts of carbonate deposited in the Paleozoic than since

[redacted]