Paleogene Oceanography and Climate of the North Atlantic

The key to a regional biostratigraphic scheme

Dr Jonathan Bujak

Bujak Research International Ltd

The Challenge

To erect a palynological-foraminiferal zonation

for the North Atlantic region including

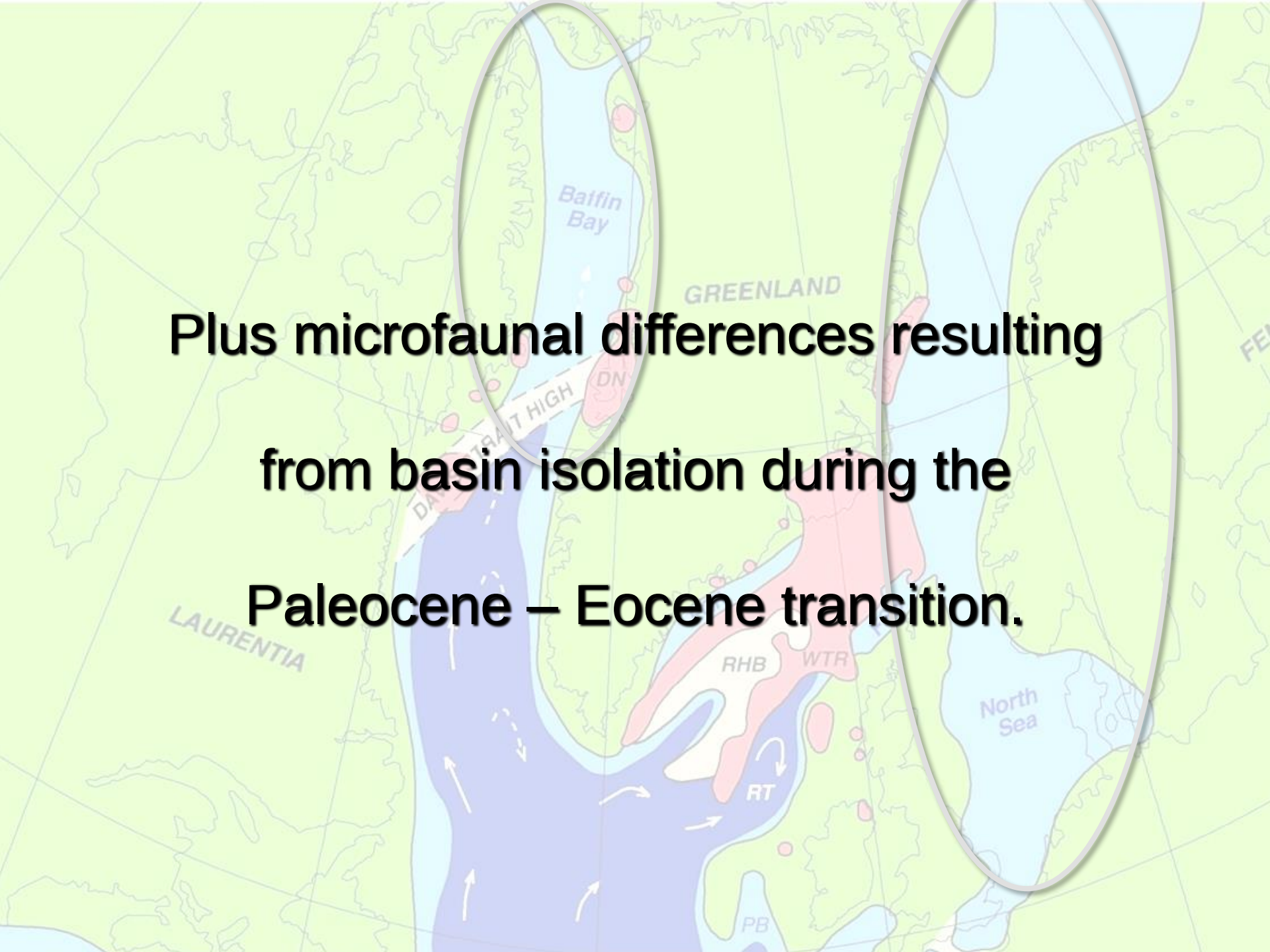
the North Sea and adjacent basins.

The Strategy

Integrate the zonation with plate tectonic, mantle plume, oceanographic and climatic events that affected the region.

Spinoffs

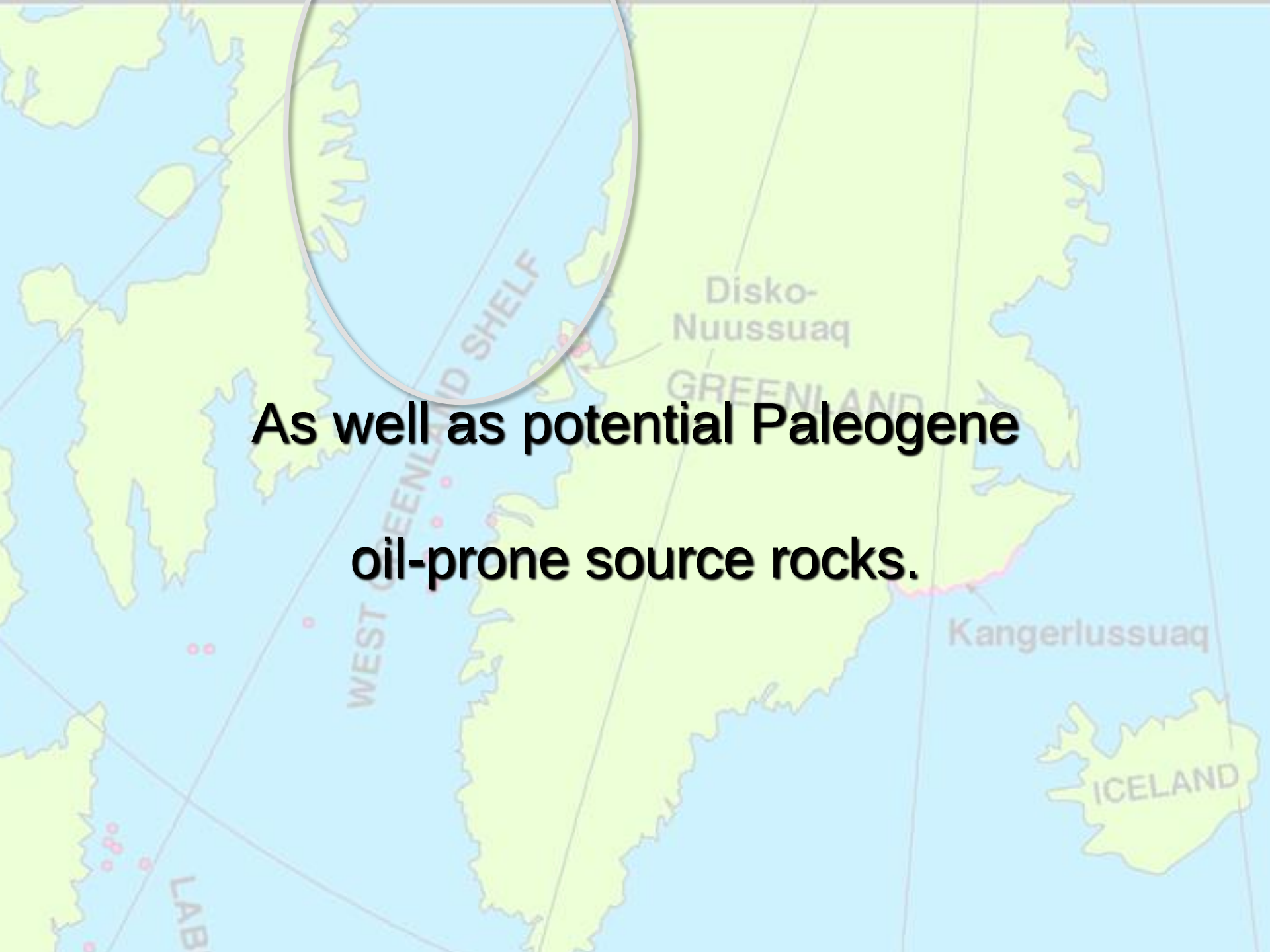
The integrated zonation highlights bioevent diachronism in different basins that resulted from the greenhouse to icehouse shift.



Plus microfaunal differences resulting

from basin isolation during the

Paleocene – Eocene transition.



As well as potential Paleogene

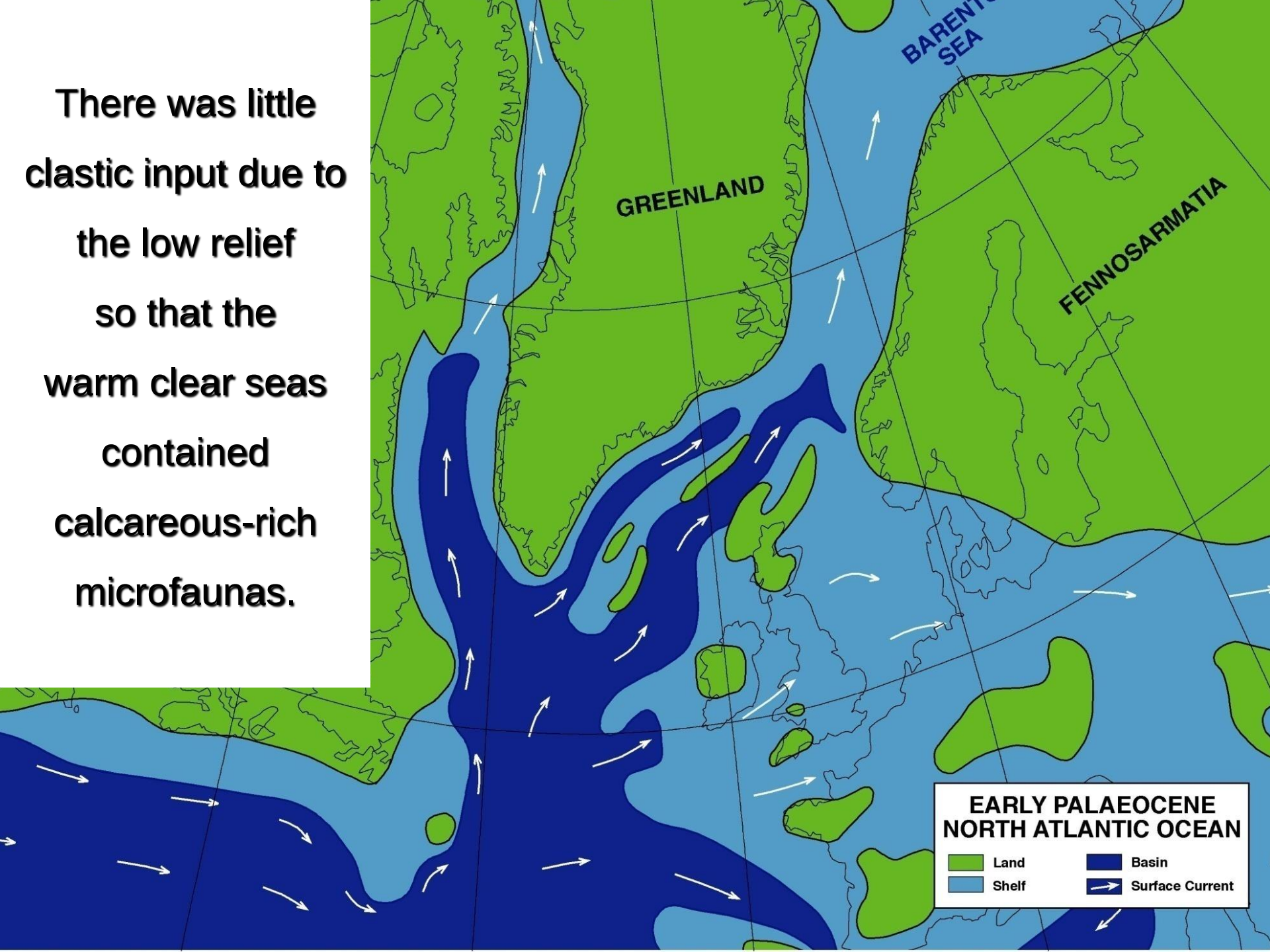
oil-prone source rocks.

First let's look at how plate tectonic opening and Greenland mantel plume uplift affected North Atlantic oceanography.

Early Paleocene

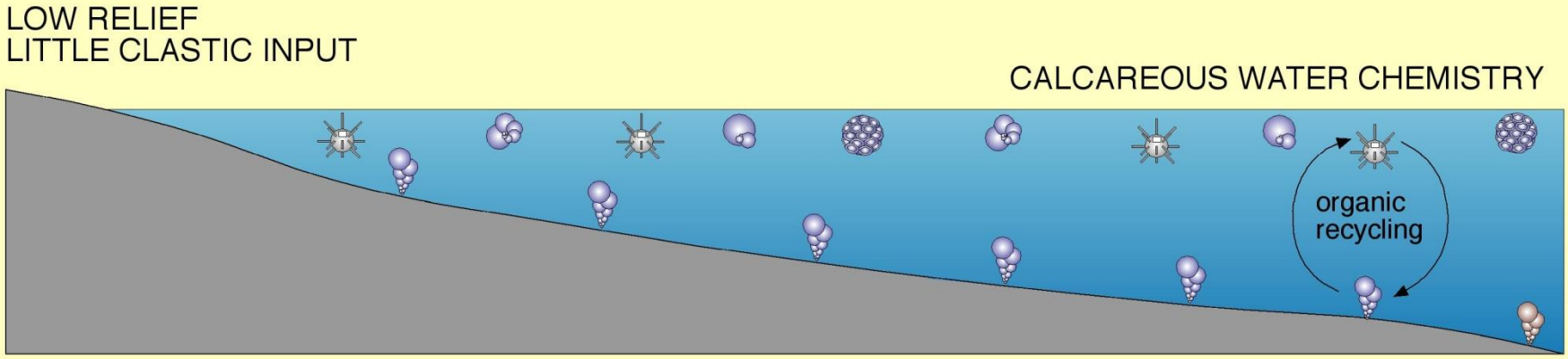
Prior to uplift of the Greenland plume the North Atlantic and NW Europe comprised an open marine region dotted with low subtropical islands.

There was little clastic input due to the low relief so that the warm clear seas contained calcareous-rich microfaunas.



Including calcareous foraminifera and nannoplankton

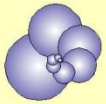
NORTH SEA DANIAN MARINE BIOFACIES



CALCAREOUS

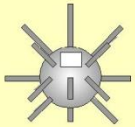
benthic foraminifer

CALCAREOUS



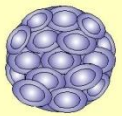
planktonic foraminifera

ORGANIC WALLED



dinoflagellate cysts

CALCAREOUS



coccoliths

Late Paleocene

But uplift of the Greenland mantle plume had a major impact on both the sedimentation and microfaunas.

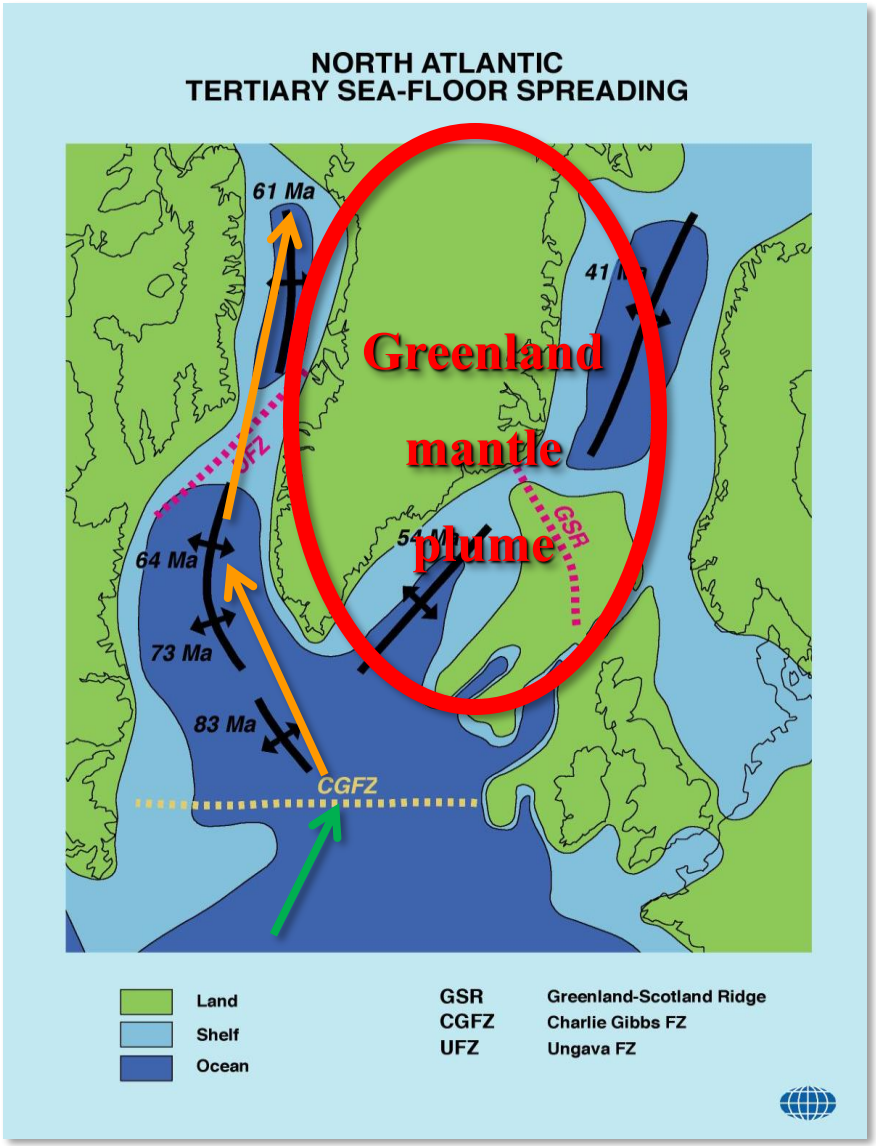
It diverted North Atlantic plate

tectonic opening to the west

of Greenland

late Paleocene

Late Cretaceous

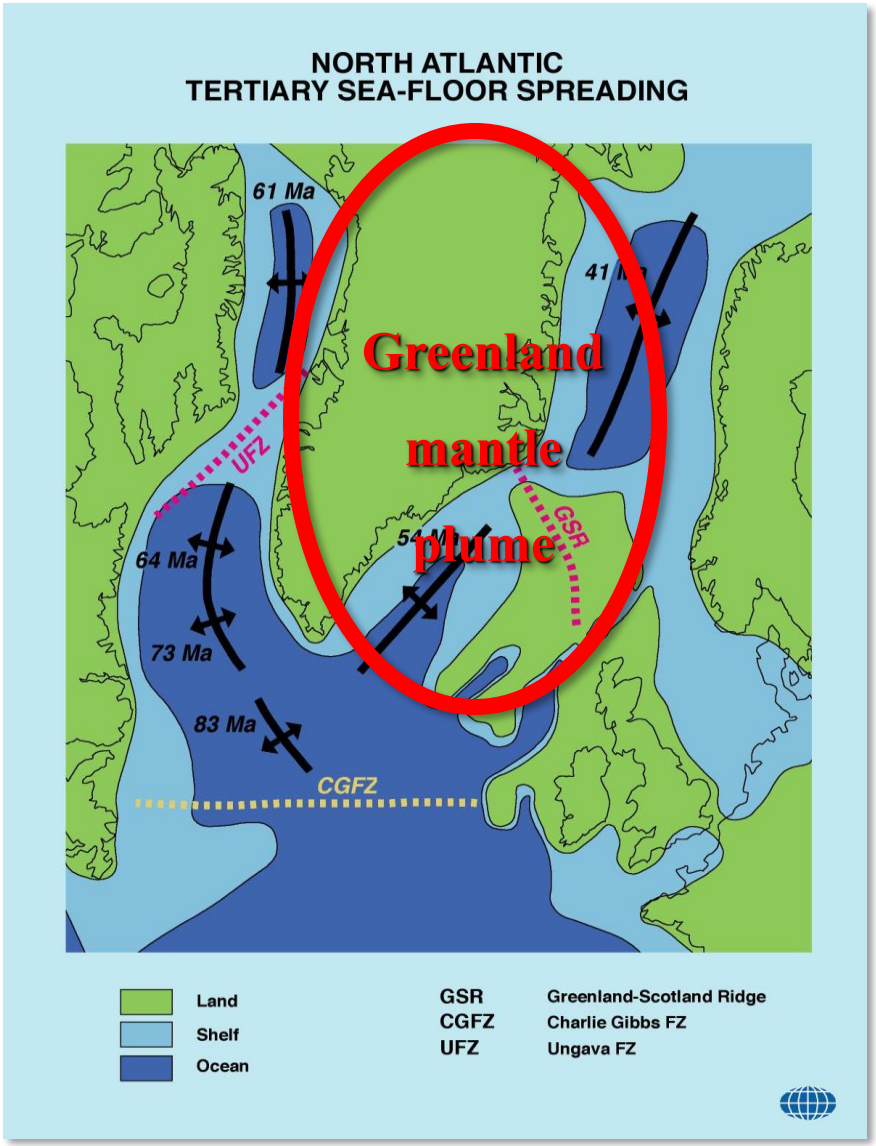


and it increased the amount

of clastic input into the basin

around the

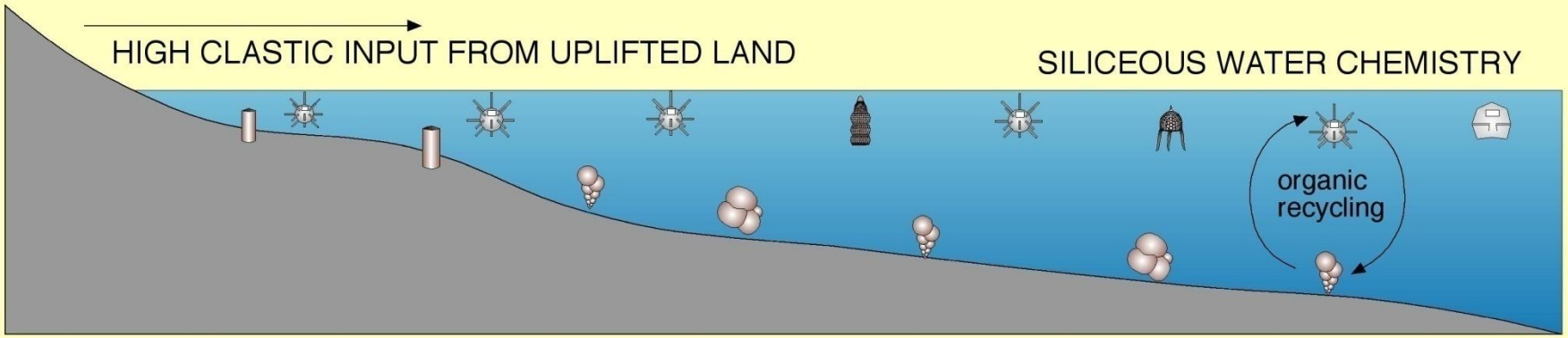
uplifted plume…..



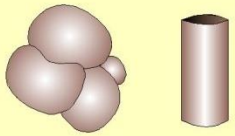
…..resulting in a shift from calcareous to siliceous microfossils

especially in the North Sea, Norwegian-Greenland Sea and NW Europe

NORTH SEA SILICEOUS MARINE BIOFACIES



SILICEOUS BENTHIC



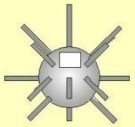
arenaceous
foraminifera

SILICEOUS PLANKTONIC

radiolaria

sporadic diatoms

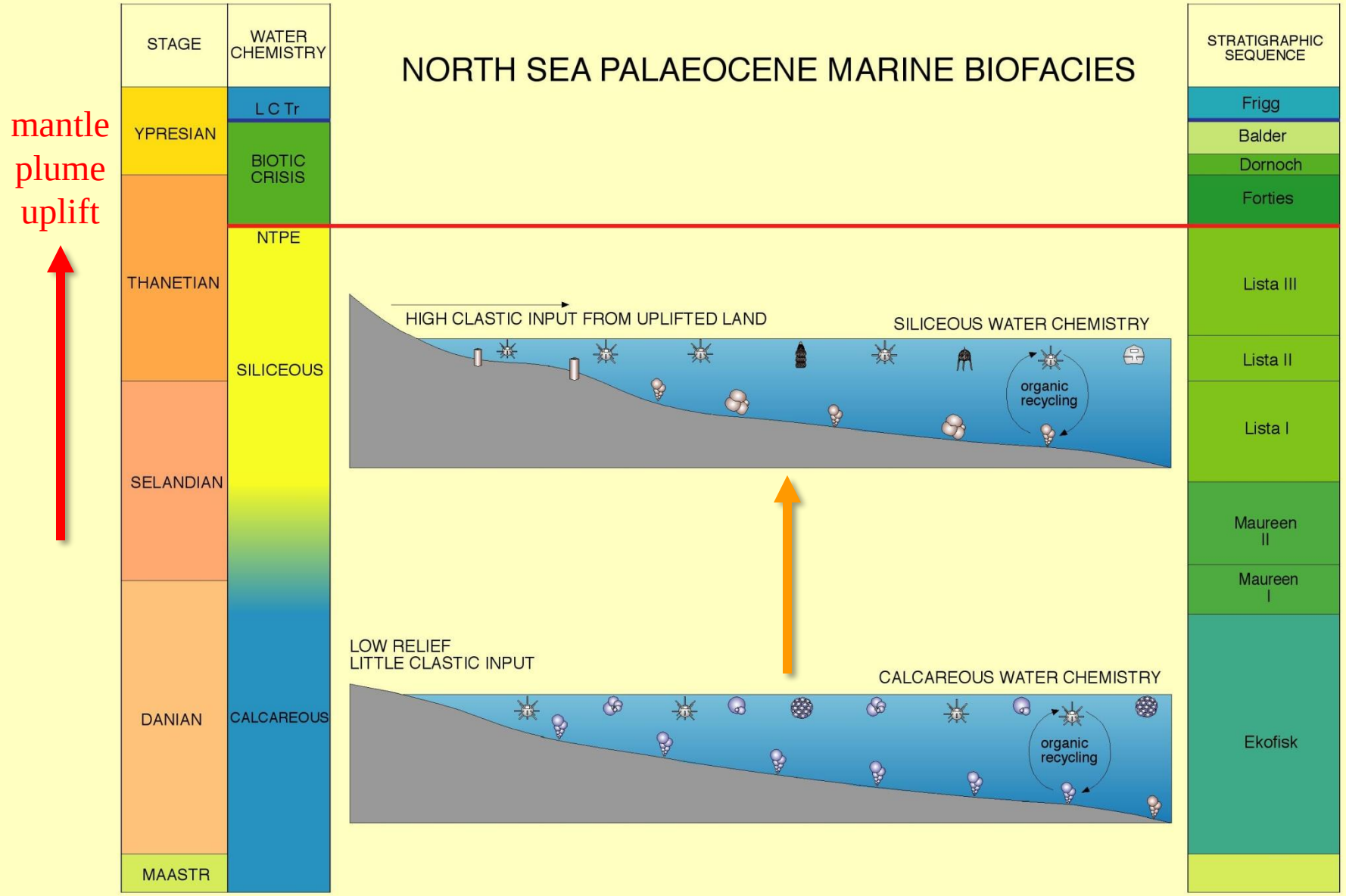
ORGANIC WALLED PLANKTONIC



photosynthetic
dinoflagellates

carnivorous
dinoflagellates

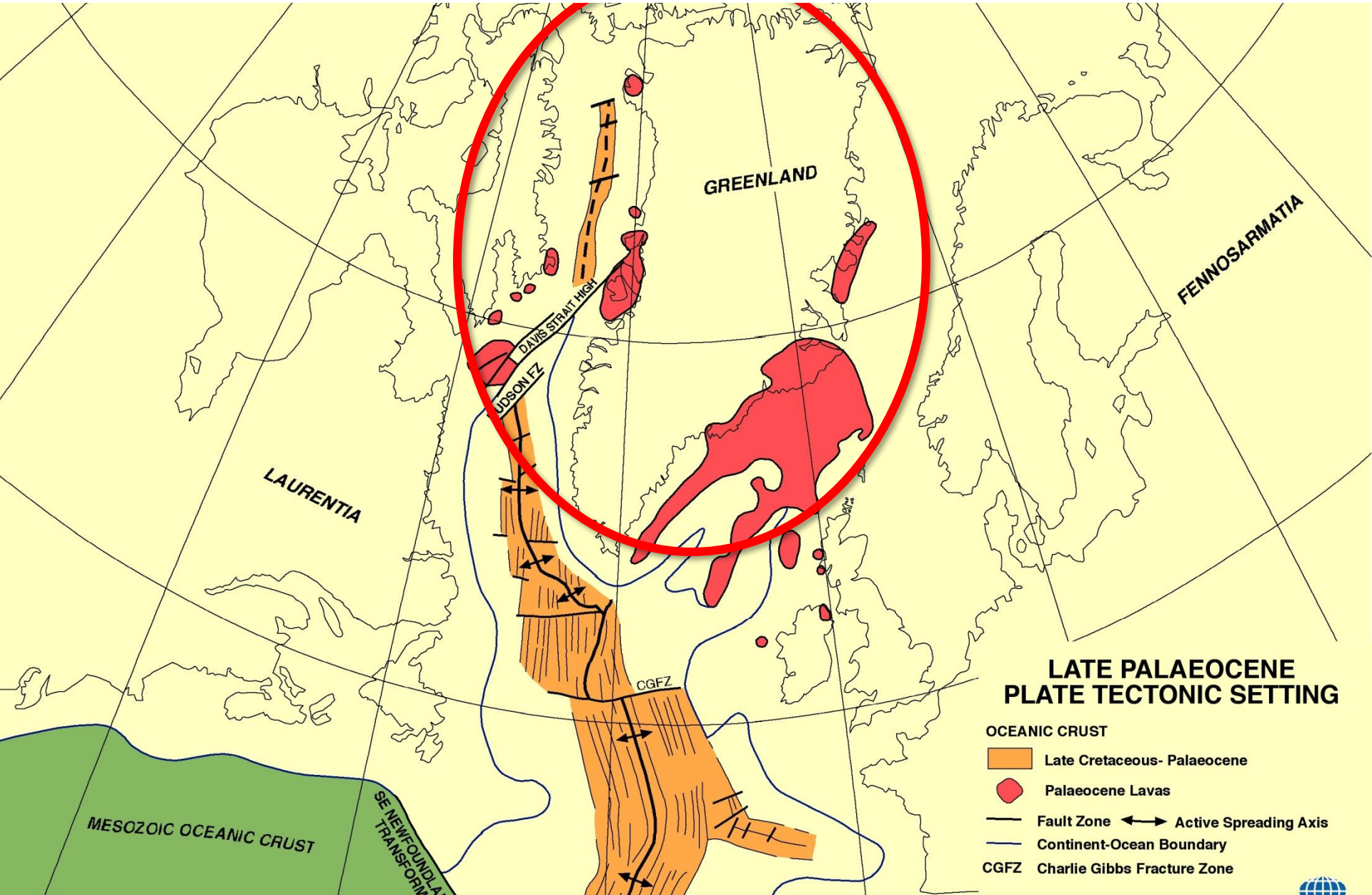
as seen in the early to late Paleocene shift from calcareous-rich to siliceous-rich assemblages



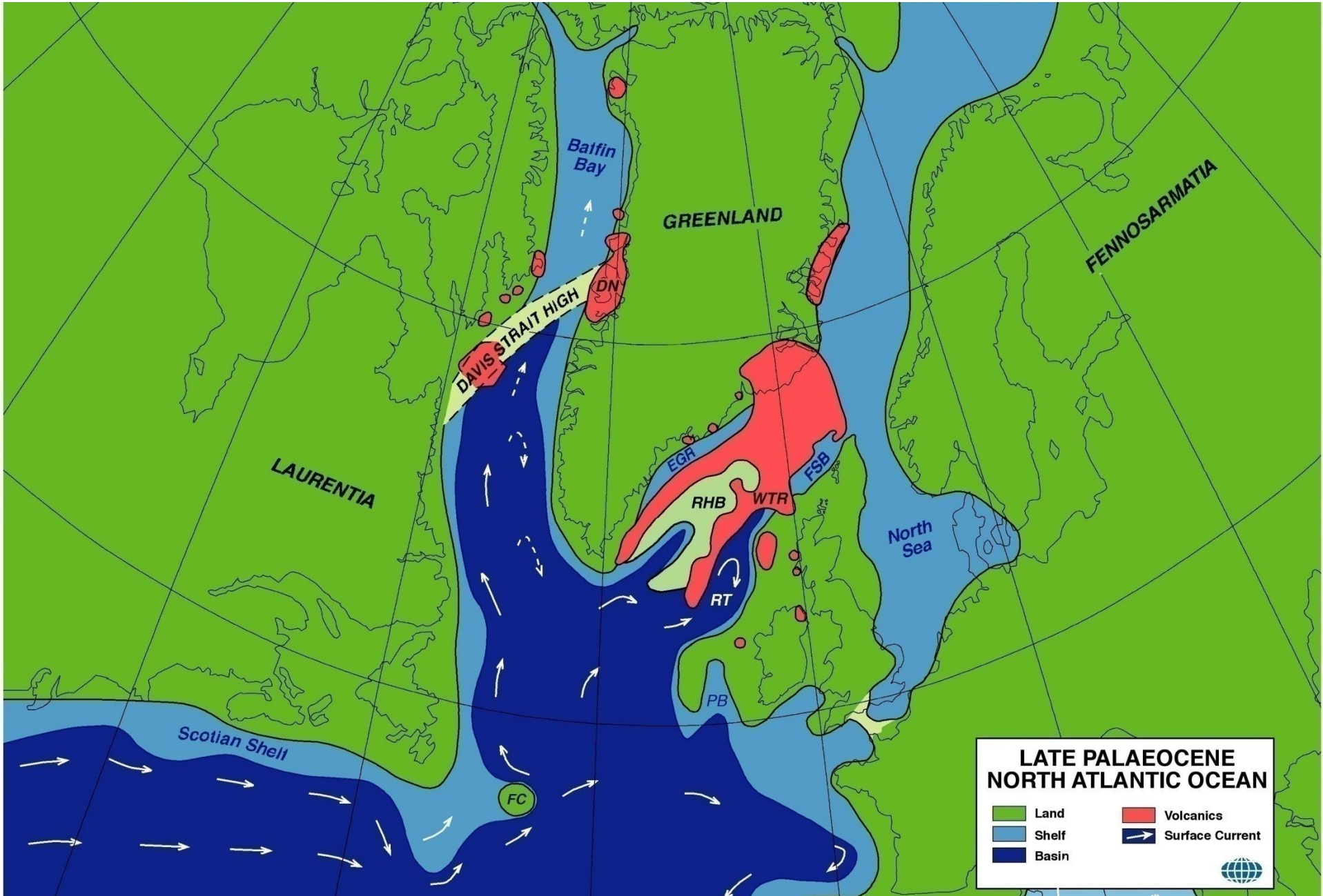
But the greatest change occurred during

the Paleocene-Eocene transition

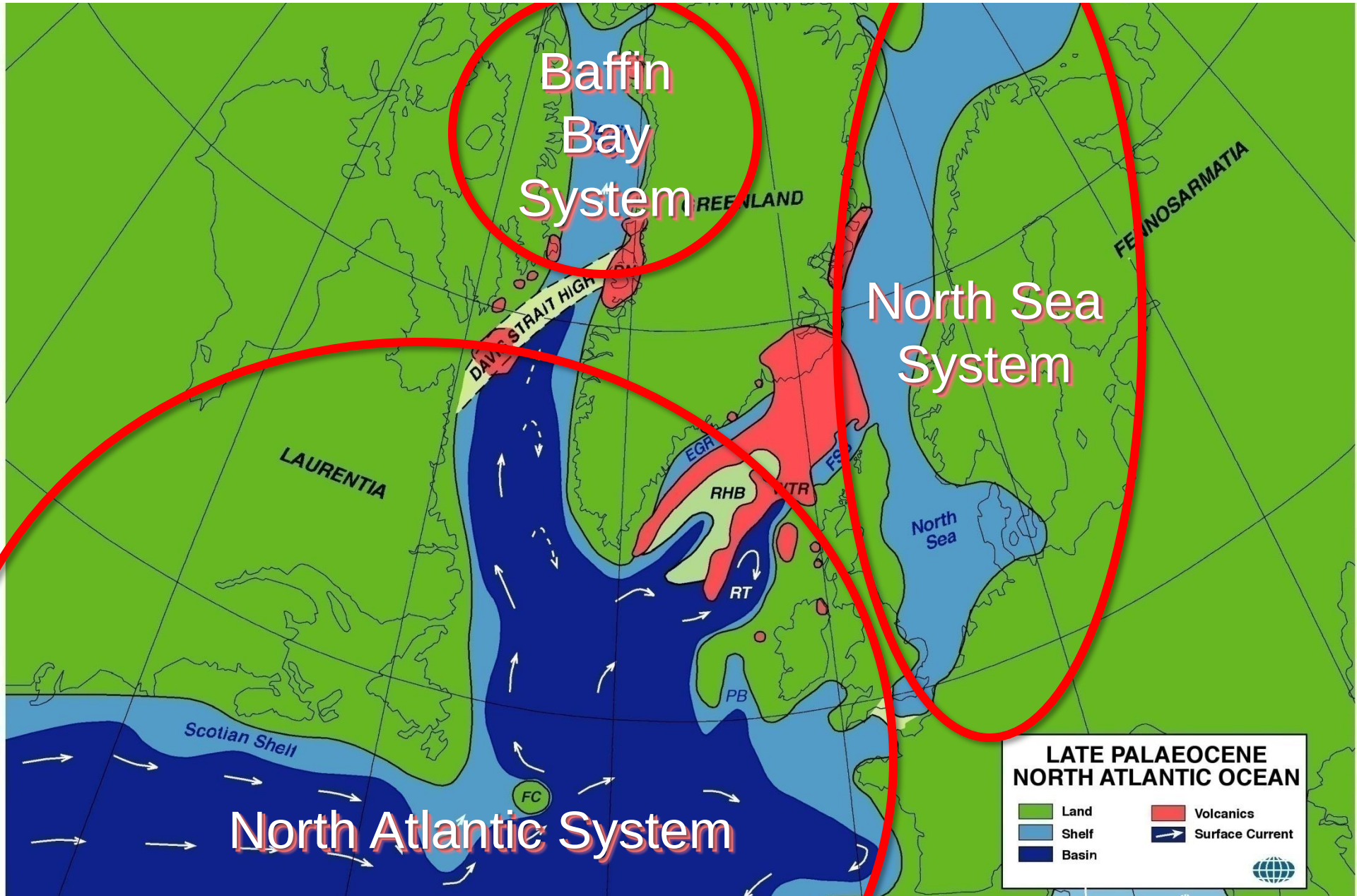
because this was the period of maximum mantle plume uplift

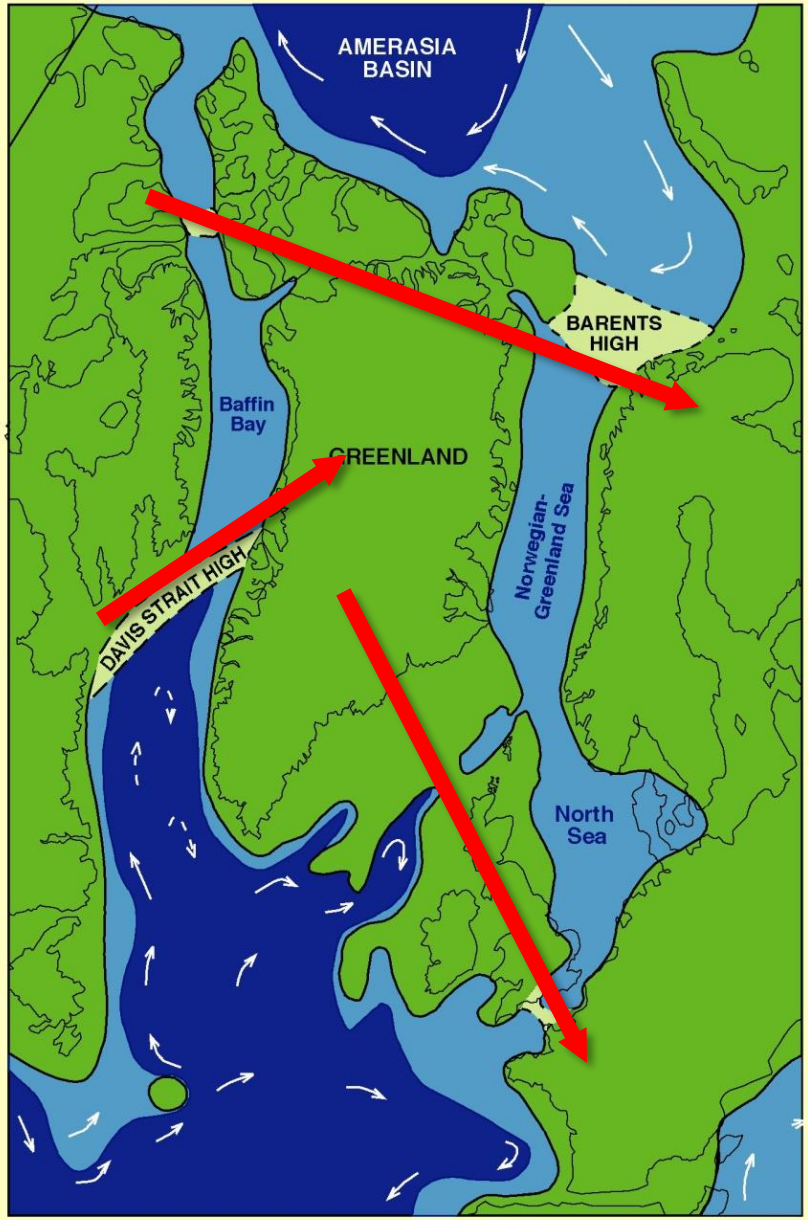


resulting in an enormous shift in the oceanographic framework



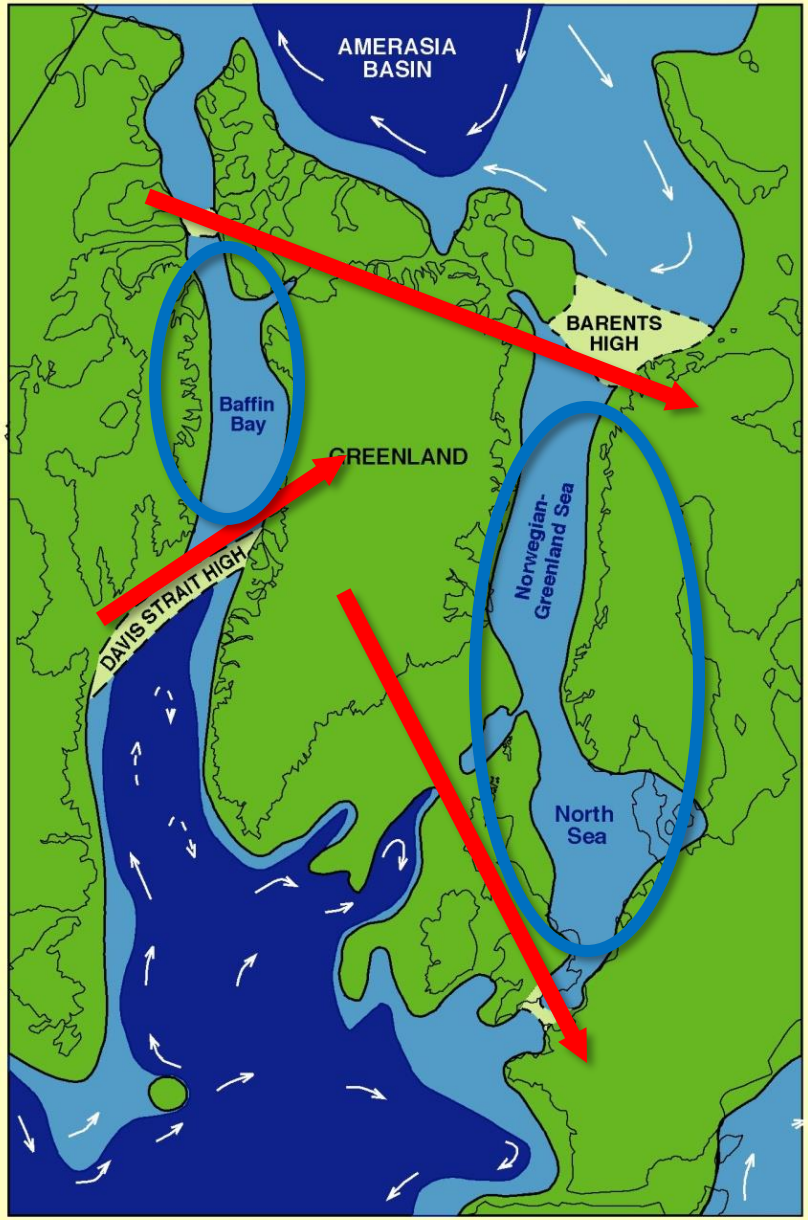
and the separation of three distinct marine systems.





LATEST PALEOCENE AND EARLIEST EOCENE BASIN ENCLOSURE

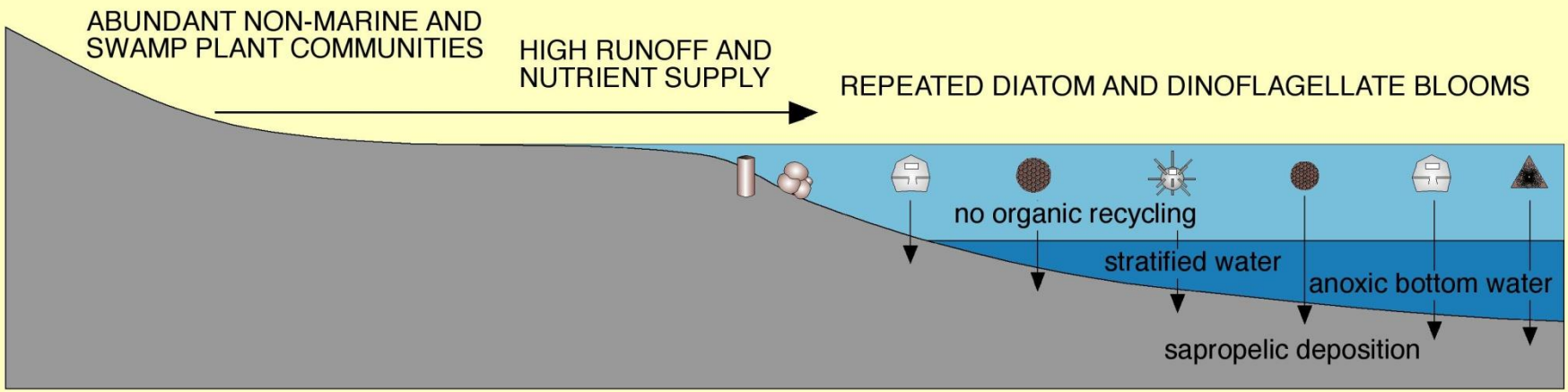
It also resulted in land bridges used for mammalian migrations

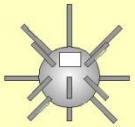


LATEST PALEOCENE AND EARLIEST EOCENE BASIN ENCLOSURE

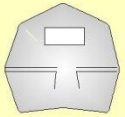
as well as massive changes in marine biotas within the enclosed basins

causing the North Sea biotic crisis



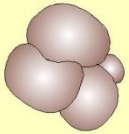


photosynthetic dinoflagellates



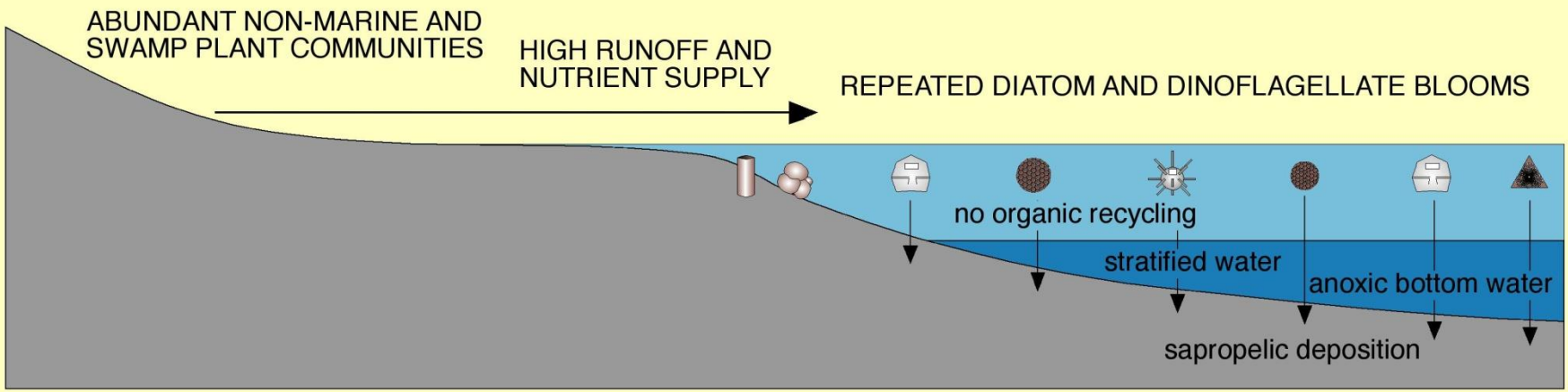
carnivorous dinoflagellates

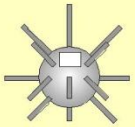
diatoms



arenaceous
foraminifera

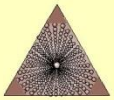
with the microfaunal assemblages becoming dominated first by arenaceous forams and then by coscinodiscid diatoms……



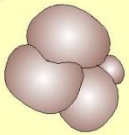


photosynthetic dinoflagellates

carnivorous dinoflagellates

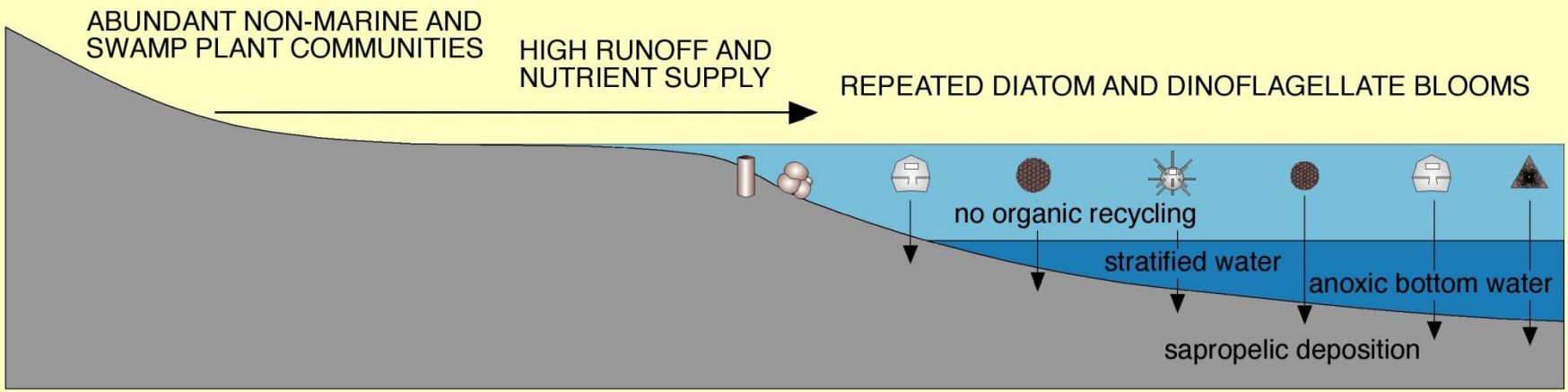


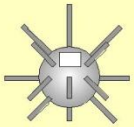
diatoms



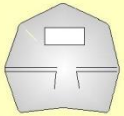
arenaceous foraminifera

that were preyed upon by the diatom-eating carnivorous dinoflagellates such as Apectodinium, Ceratium and Deflandrea

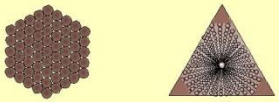




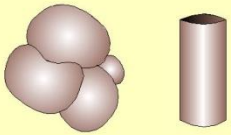
photosynthetic dinoflagellates



carnivorous dinoflagellates

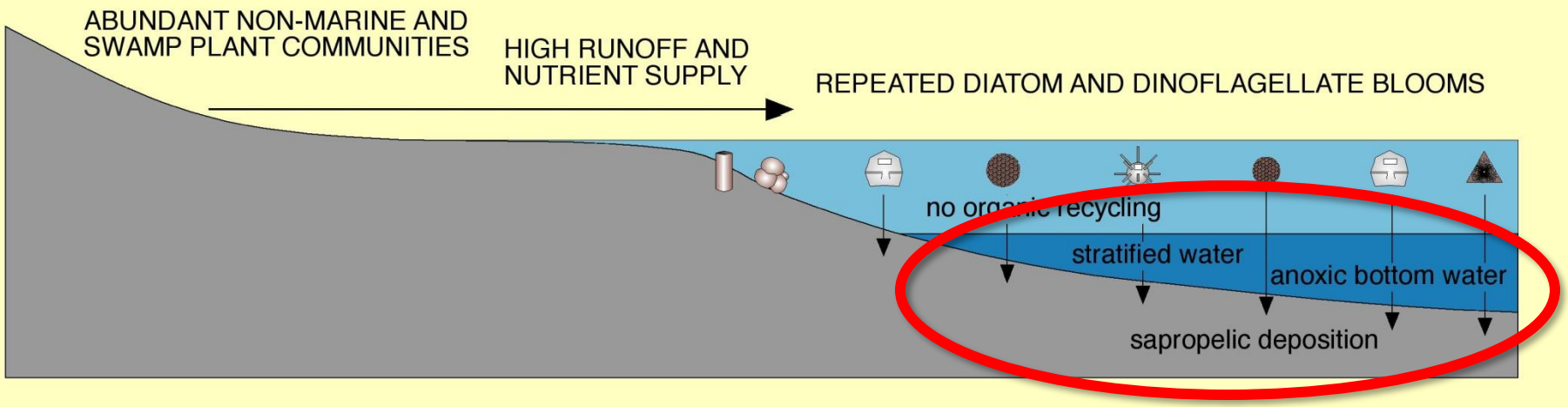


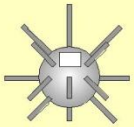
diatoms



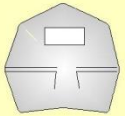
arenaceous foraminifera

with basin stratification causing bottom-water anoxia and the deposition of oil-prone sapropel rocks.



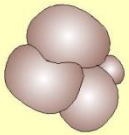


photosynthetic dinoflagellates

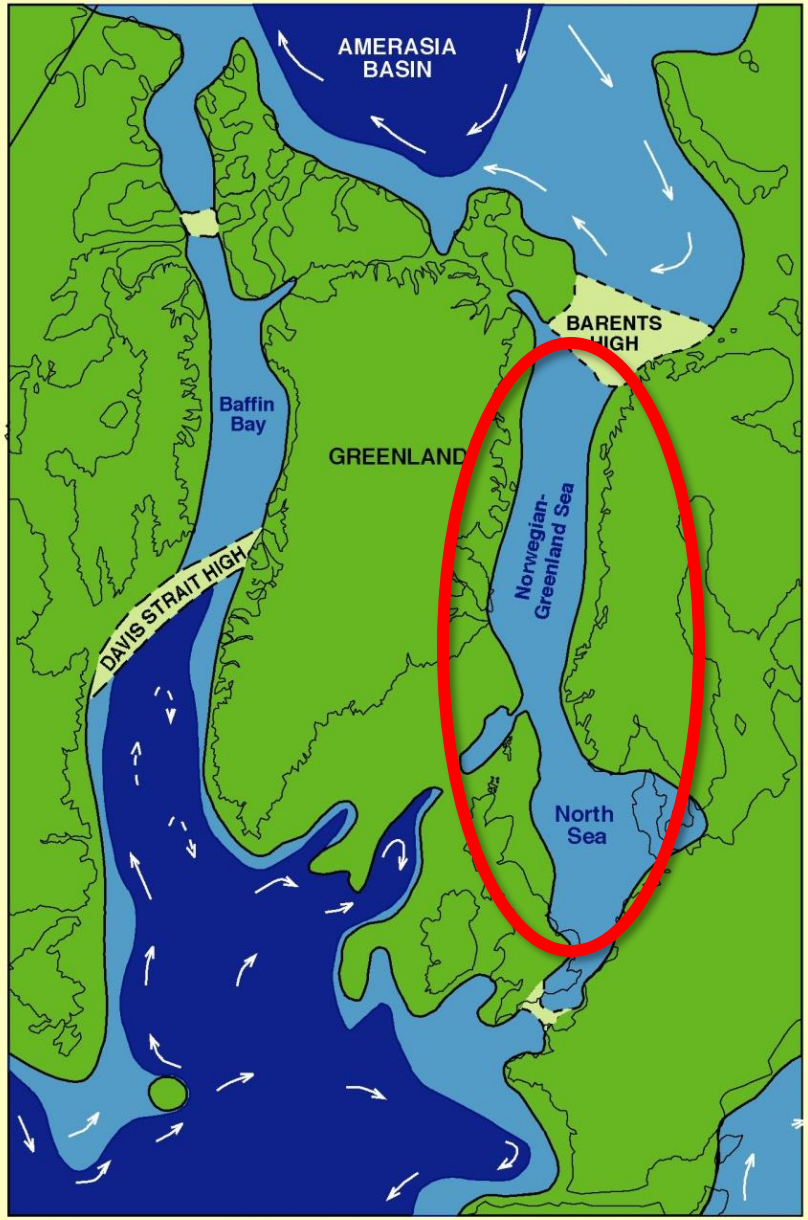


carnivorous dinoflagellates

diatoms

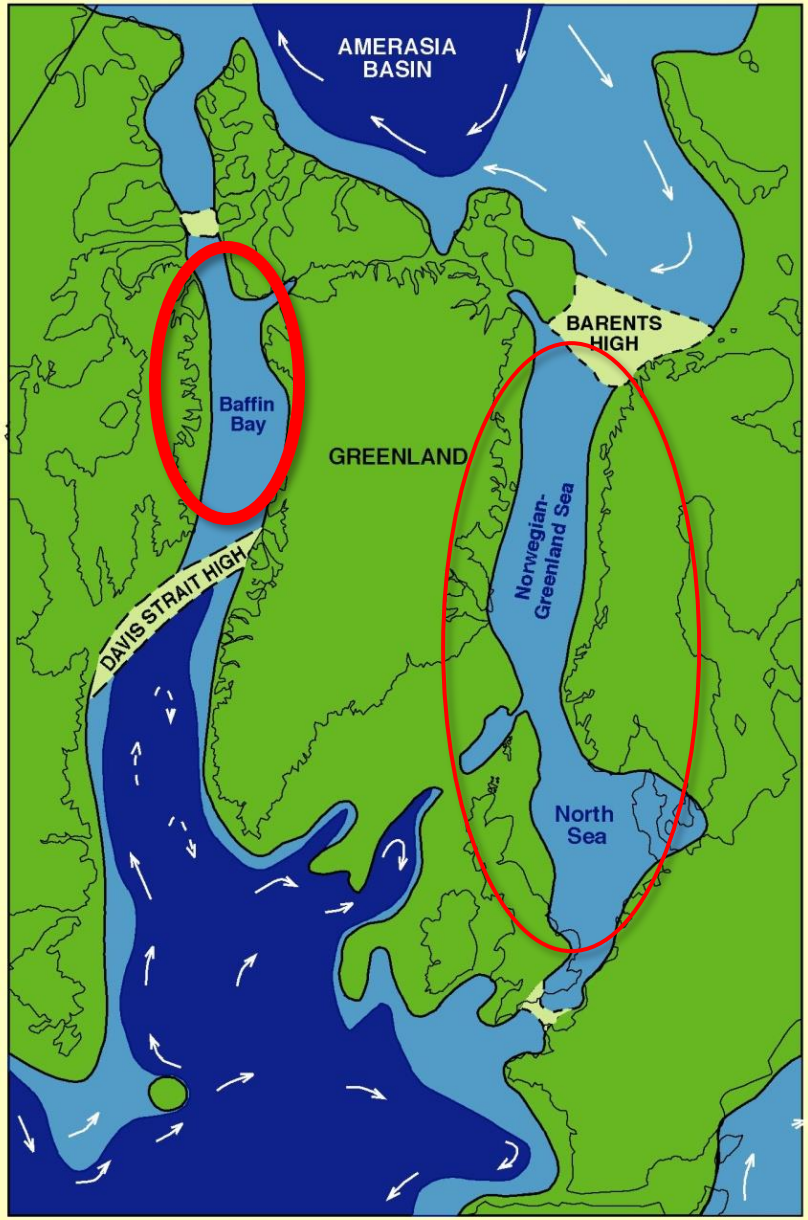


arenaceous foraminifera



LATEST PALEOCENE AND EARLIEST EOCENE BASIN ENCLOSURE

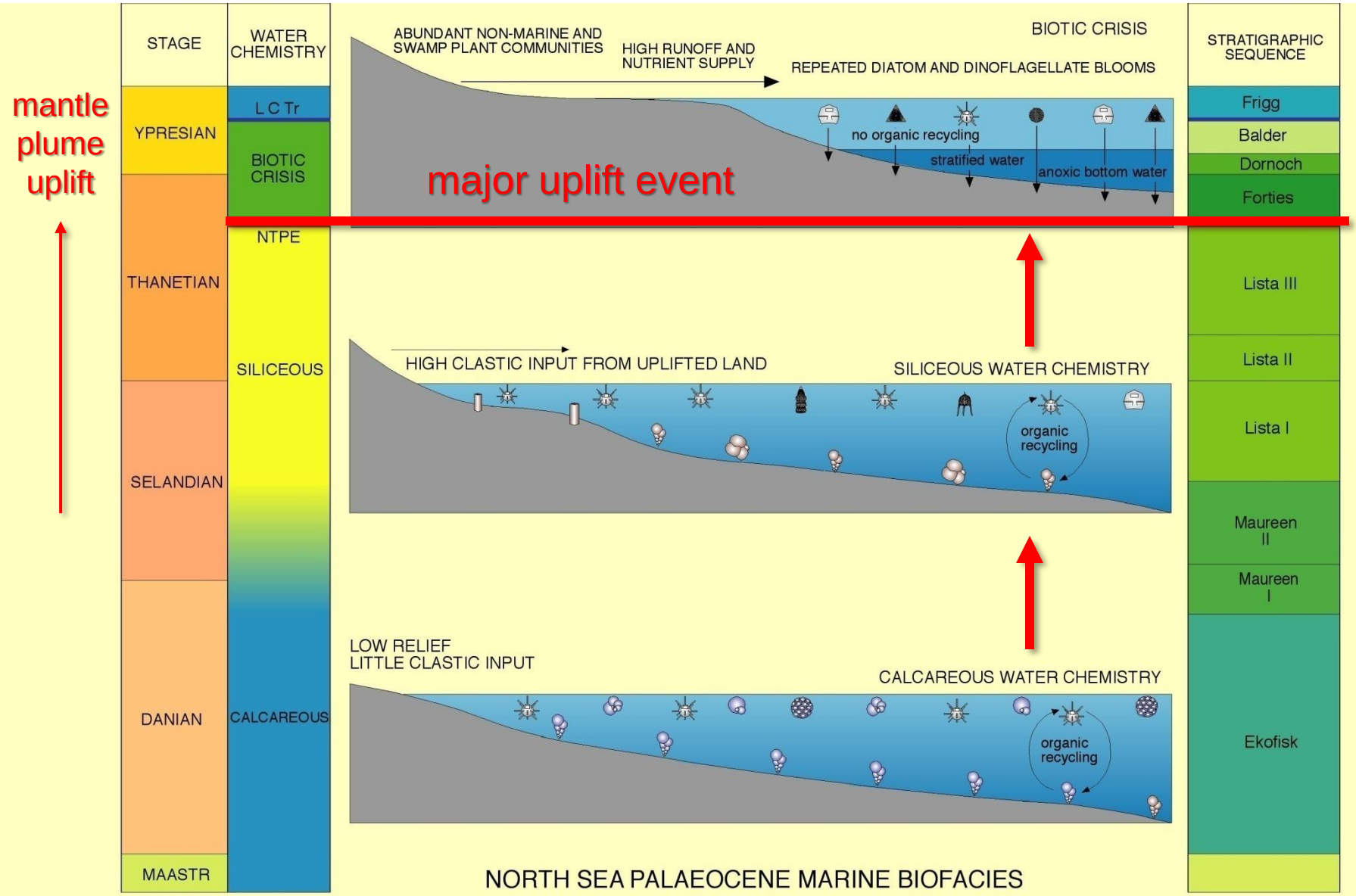
This situation is well-documented in the North Sea basin system including the Norwegian-Greenland Sea and Faroe Shetland Basin



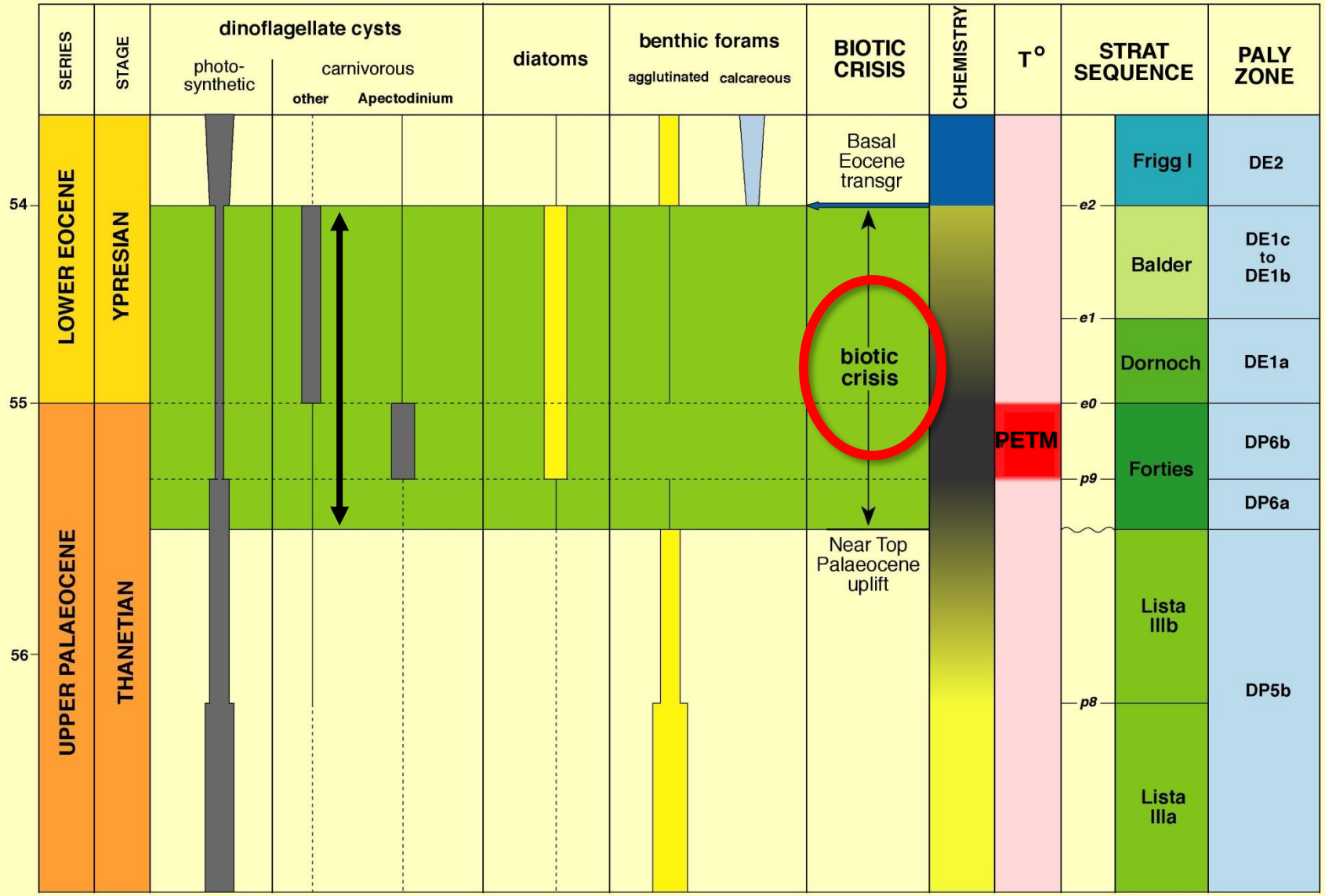
LATEST PALEOCENE AND EARLIEST EOCENE BASIN ENCLOSURE

and it is predicted in the Labrador / Baffin seaway where existing but limited data indicate diatom-dominated microfaunas similar to those in the North Sea

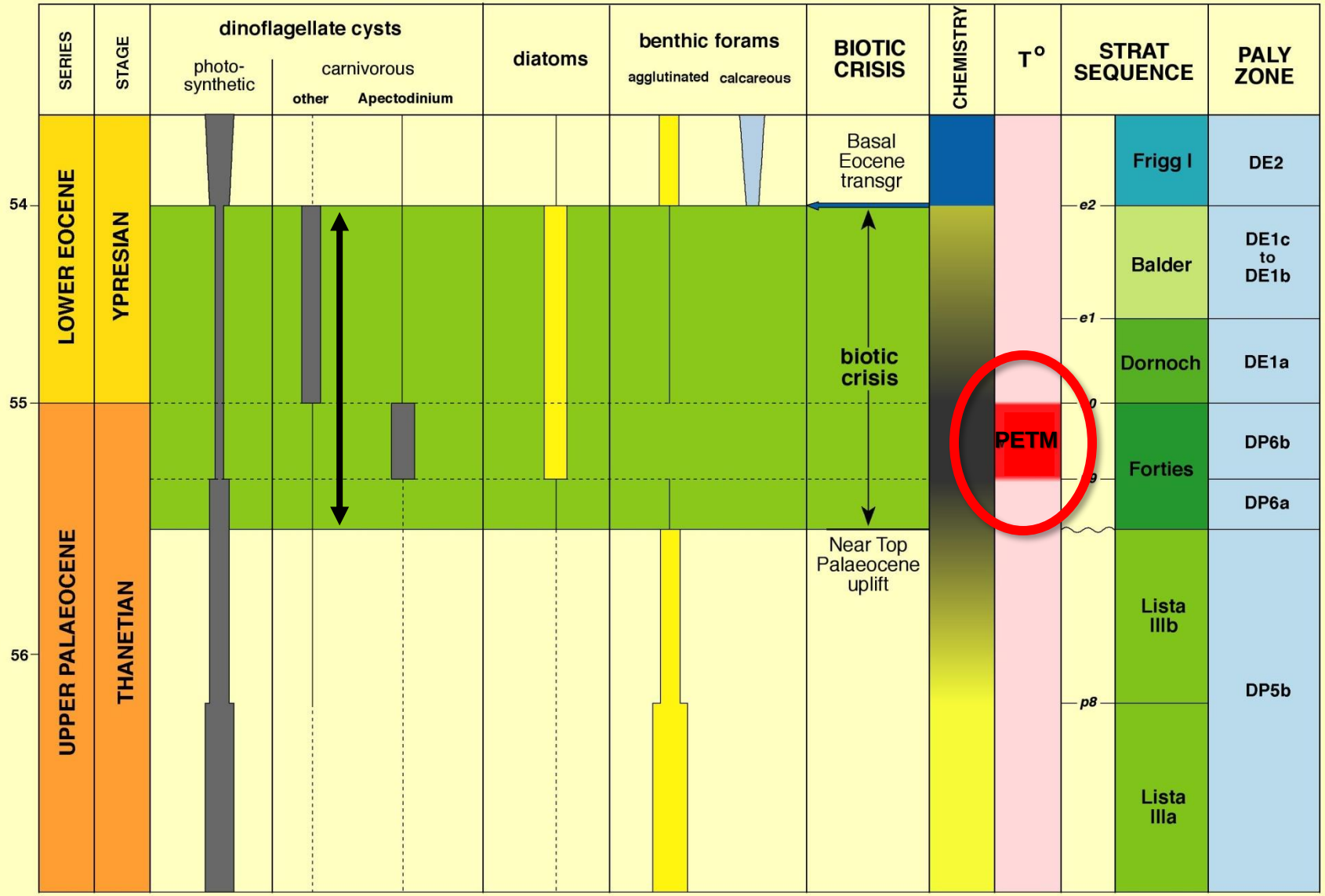
So our integrated model explains the assemblage changes that occurred during the Paleocene



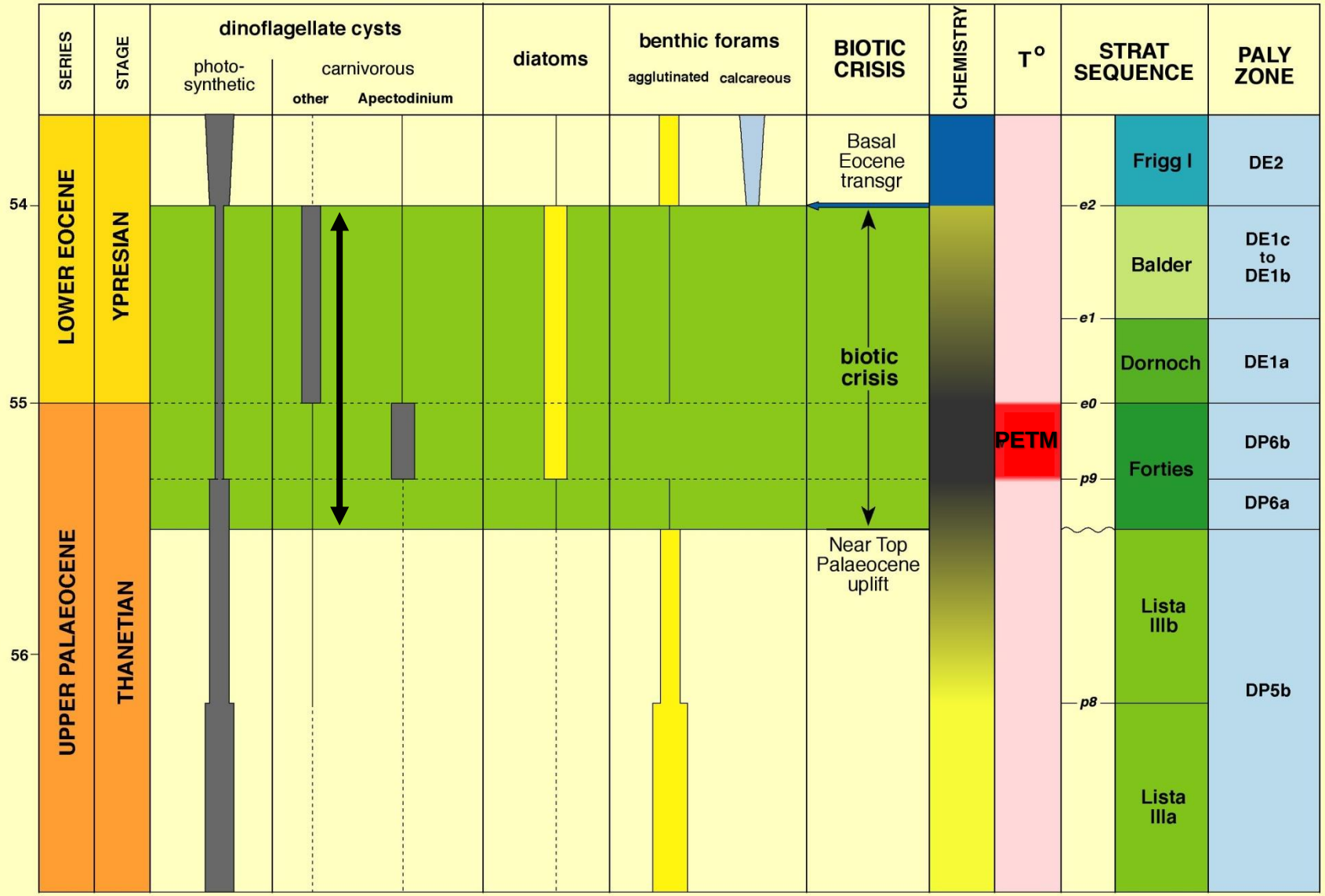
and the biotic crisis spanning the Paleocene-Eocene transition



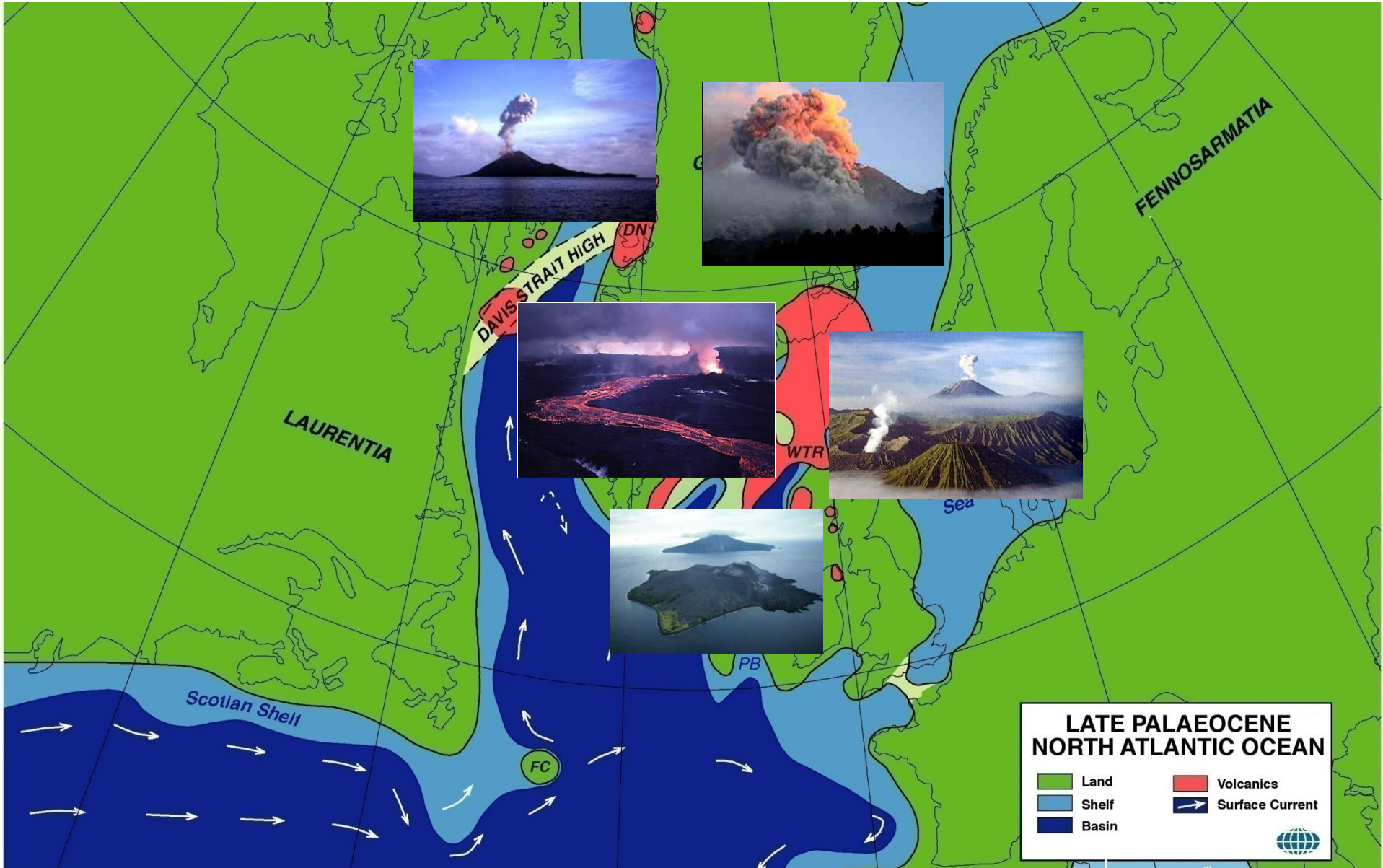
But how does this relate to the Palaeocene Eocene Thermal Maximum?



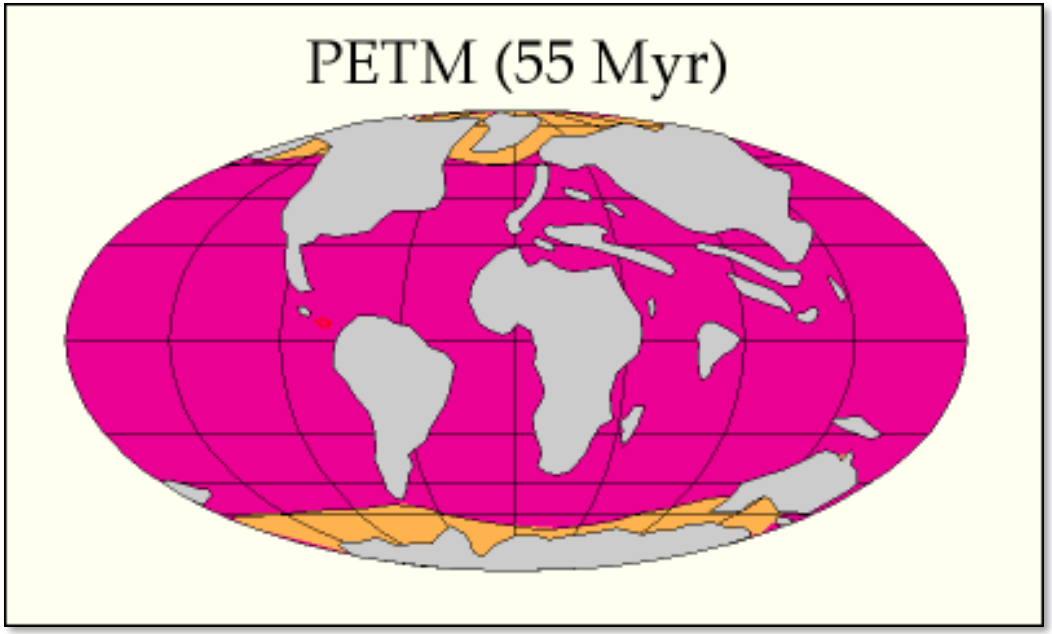
The biotic crisis and PETM were both caused by Greenland plume uplift

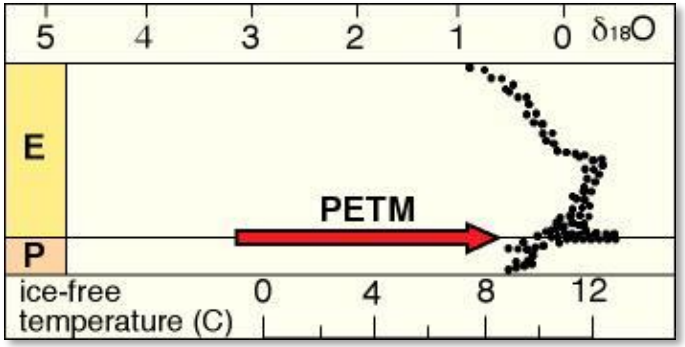


because the PETM was triggered by greenhouse gases associated with extensive Greenland plume volcanism

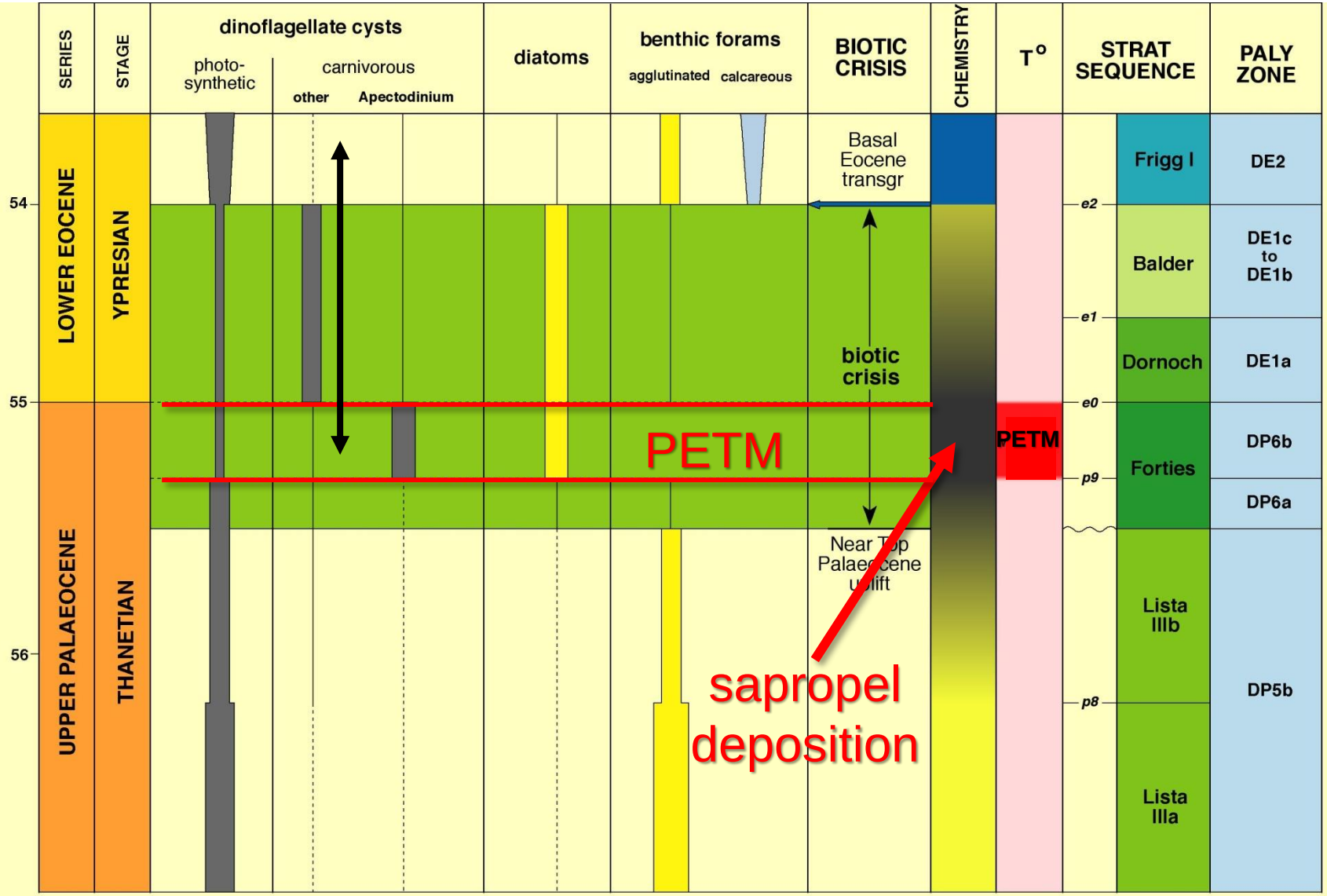


With greenhouse levels being amplified by methane expulsion from submarine gas hydrates (methane clathrates)

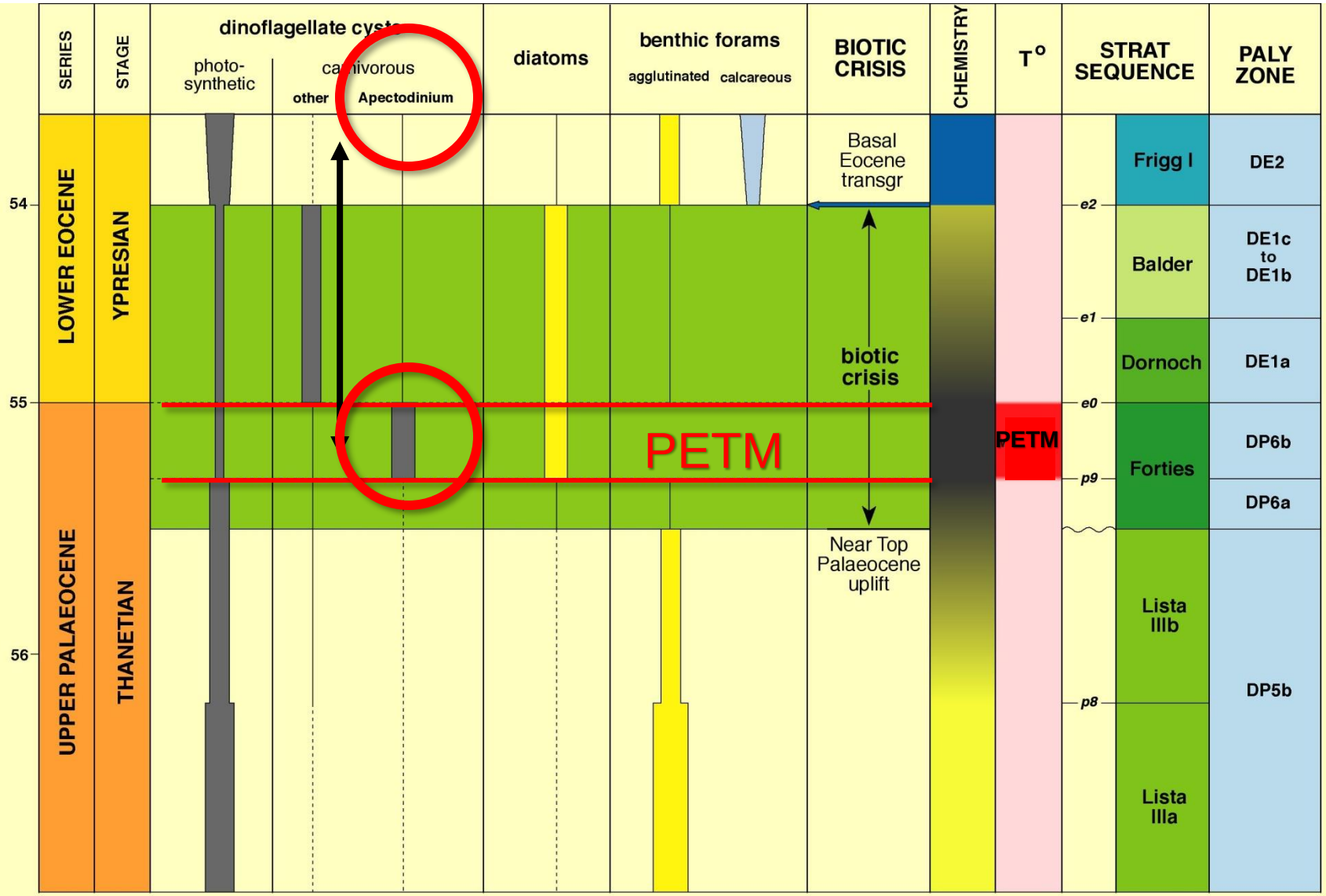




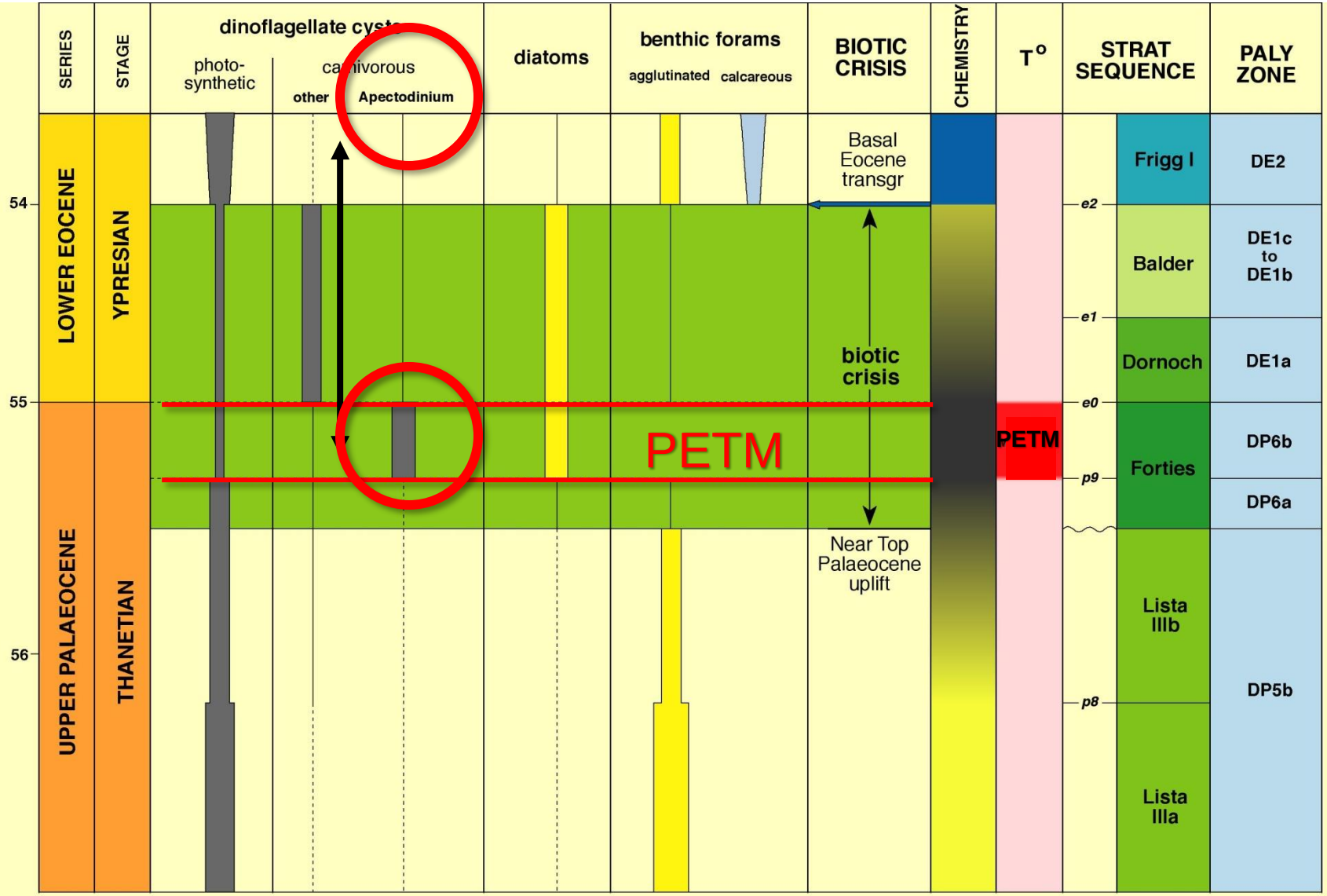
sapropel deposition due to basin enclosure was amplified by the PETM which increased water temperature and reduced oxygenation still further



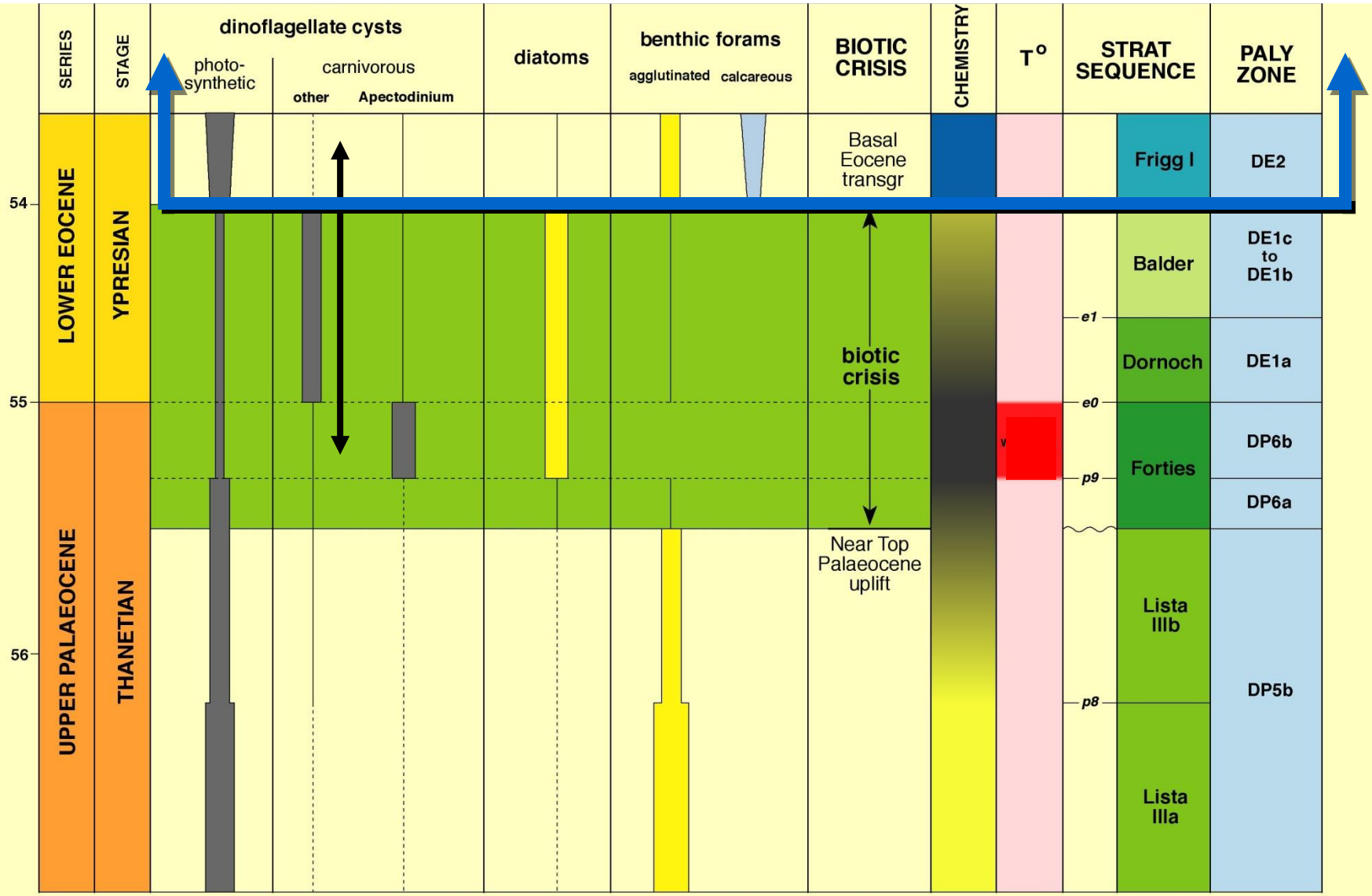
with the warm-water Apectodinium acme resulting from the PETM



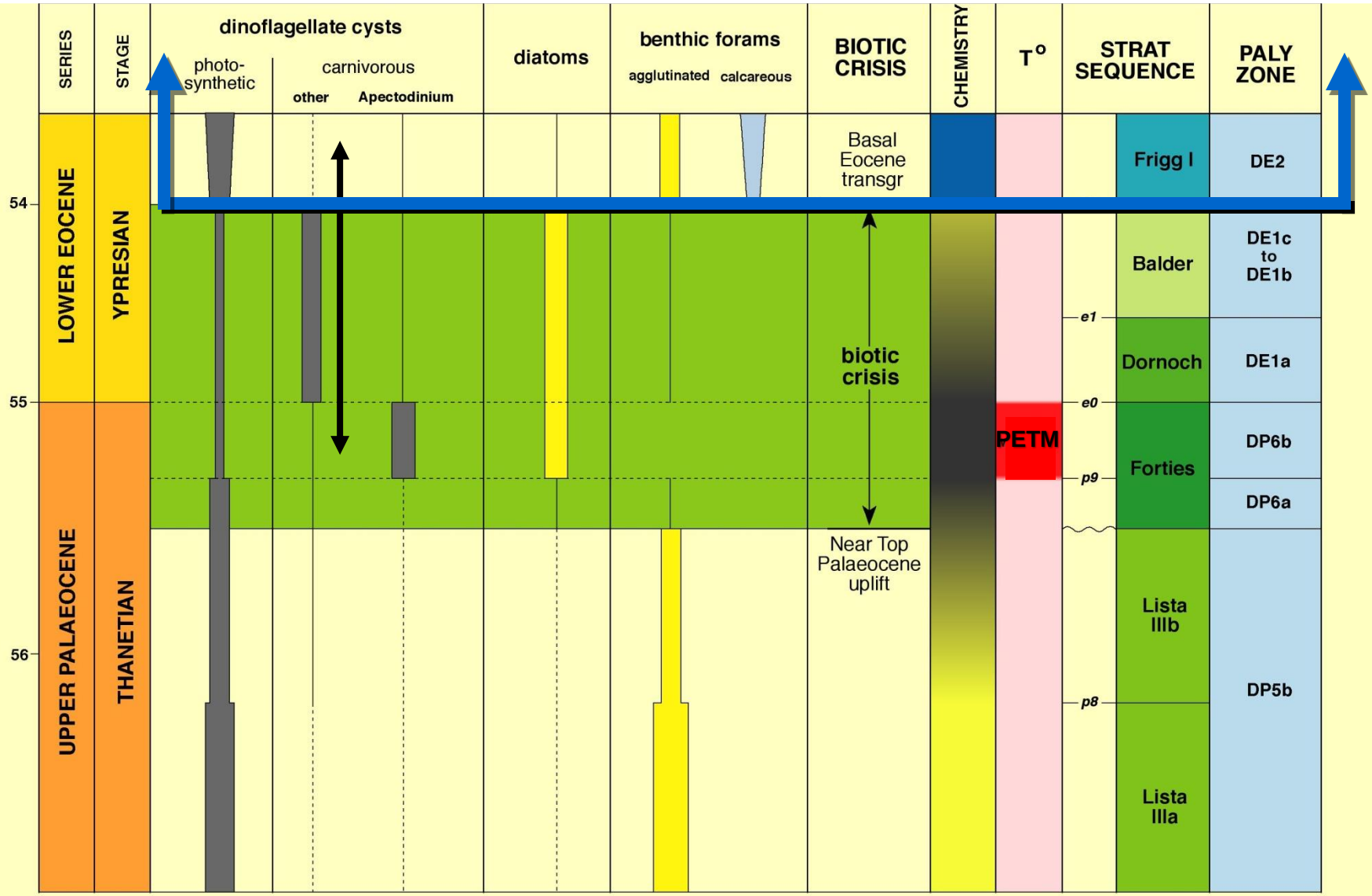
which was first proposed by Bujak & Brinkhuis in 1997



The biotic crisis was terminated by mantle plume collapse and the Ypresian marine transgression that extended across the entire region

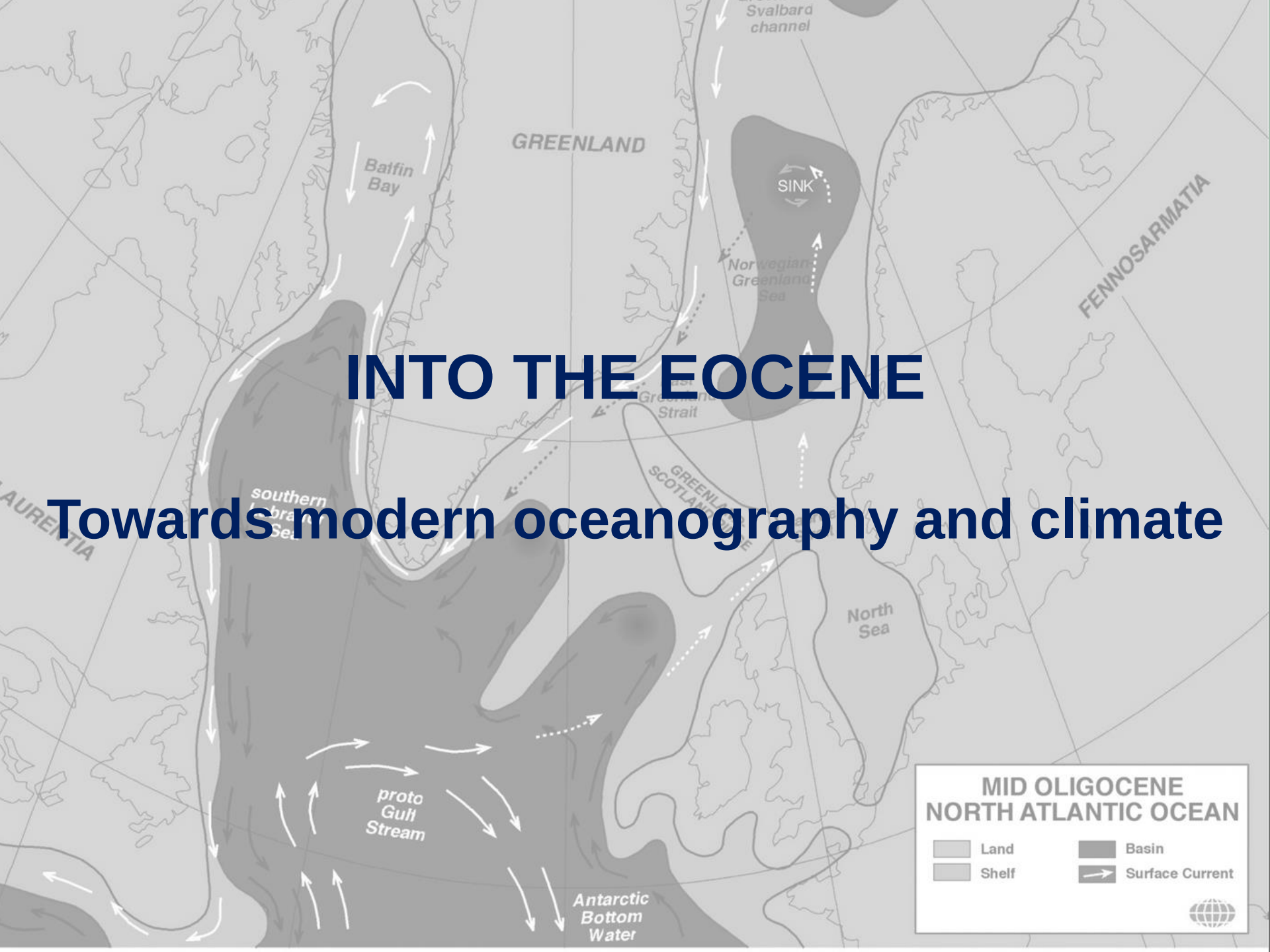


marking the break between Paleocene and Eocene tectonics and oceanography in the North Atlantic and NW European region

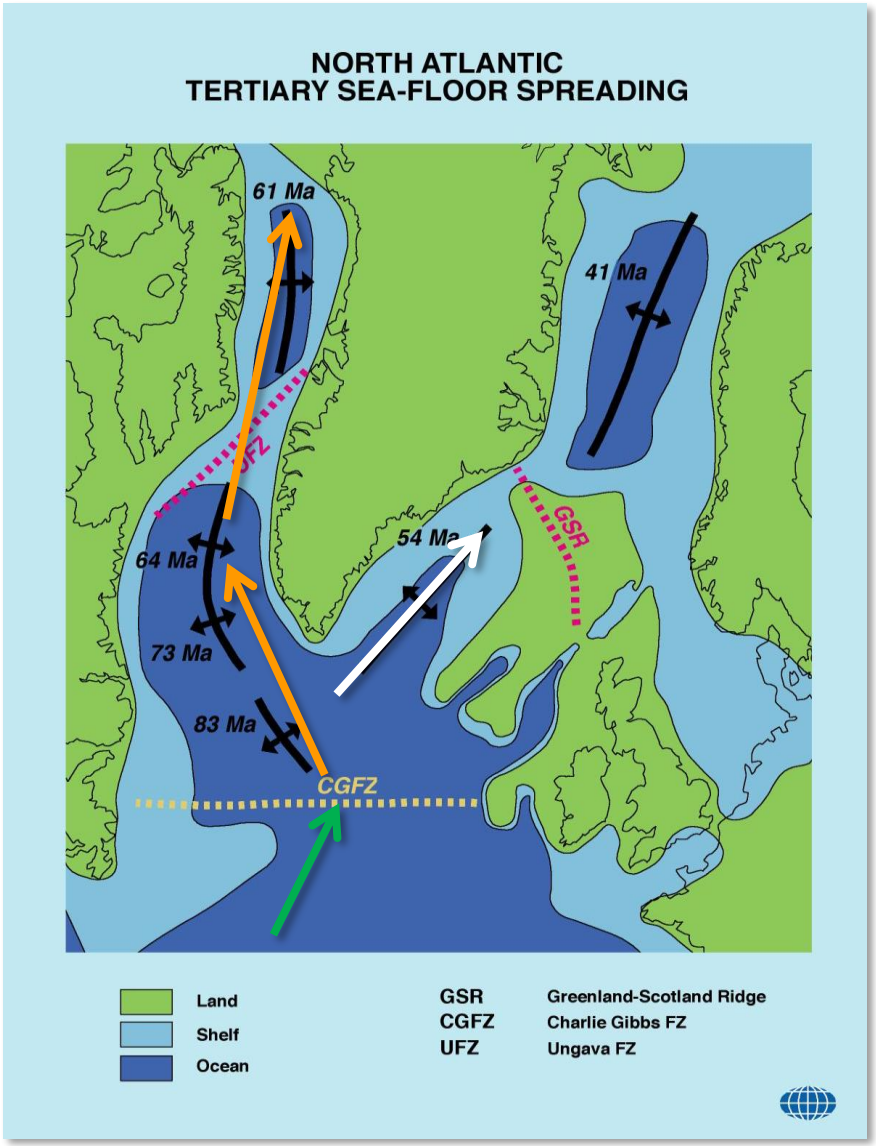


INTO THE EOCENE

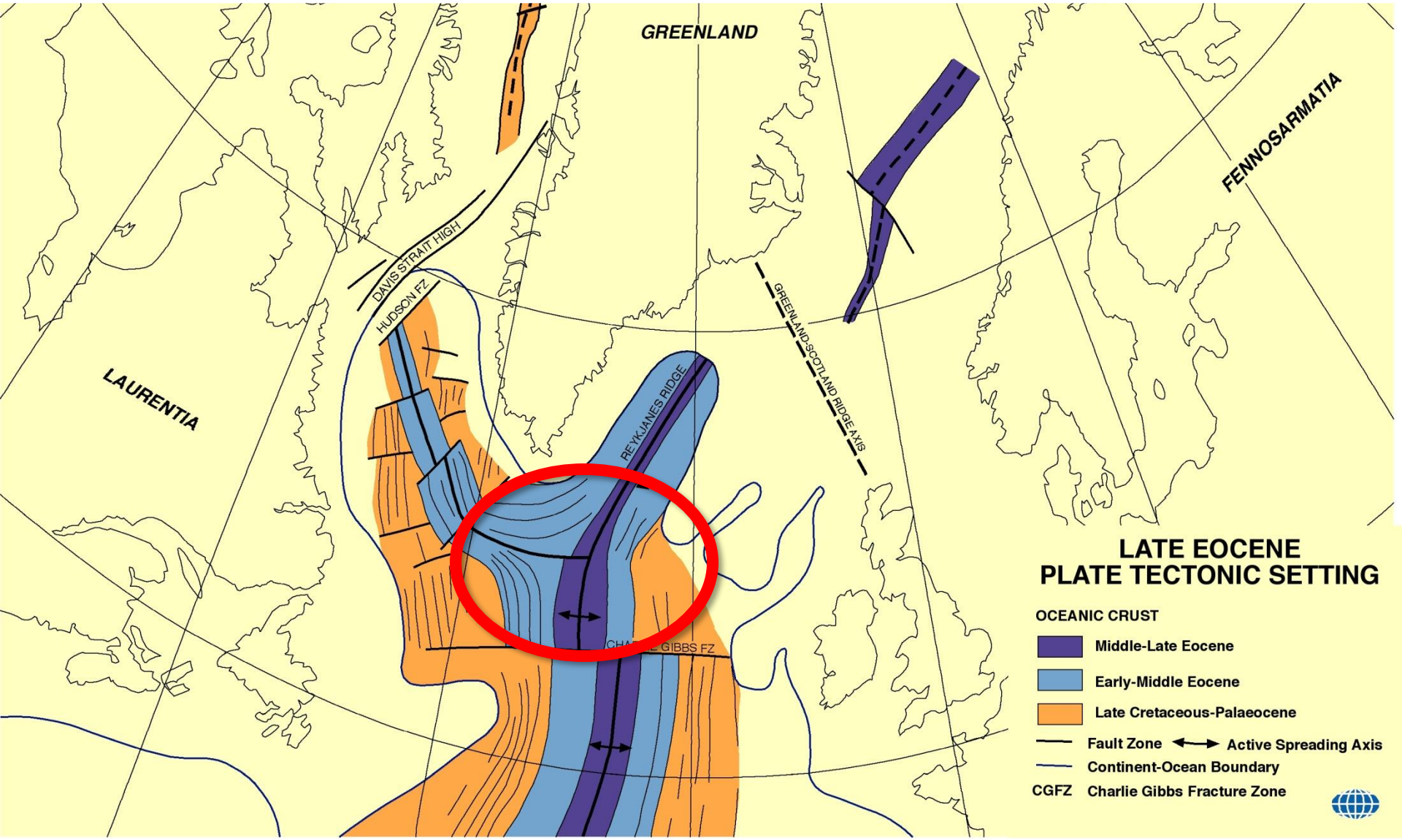
Towards modern oceanography and climate



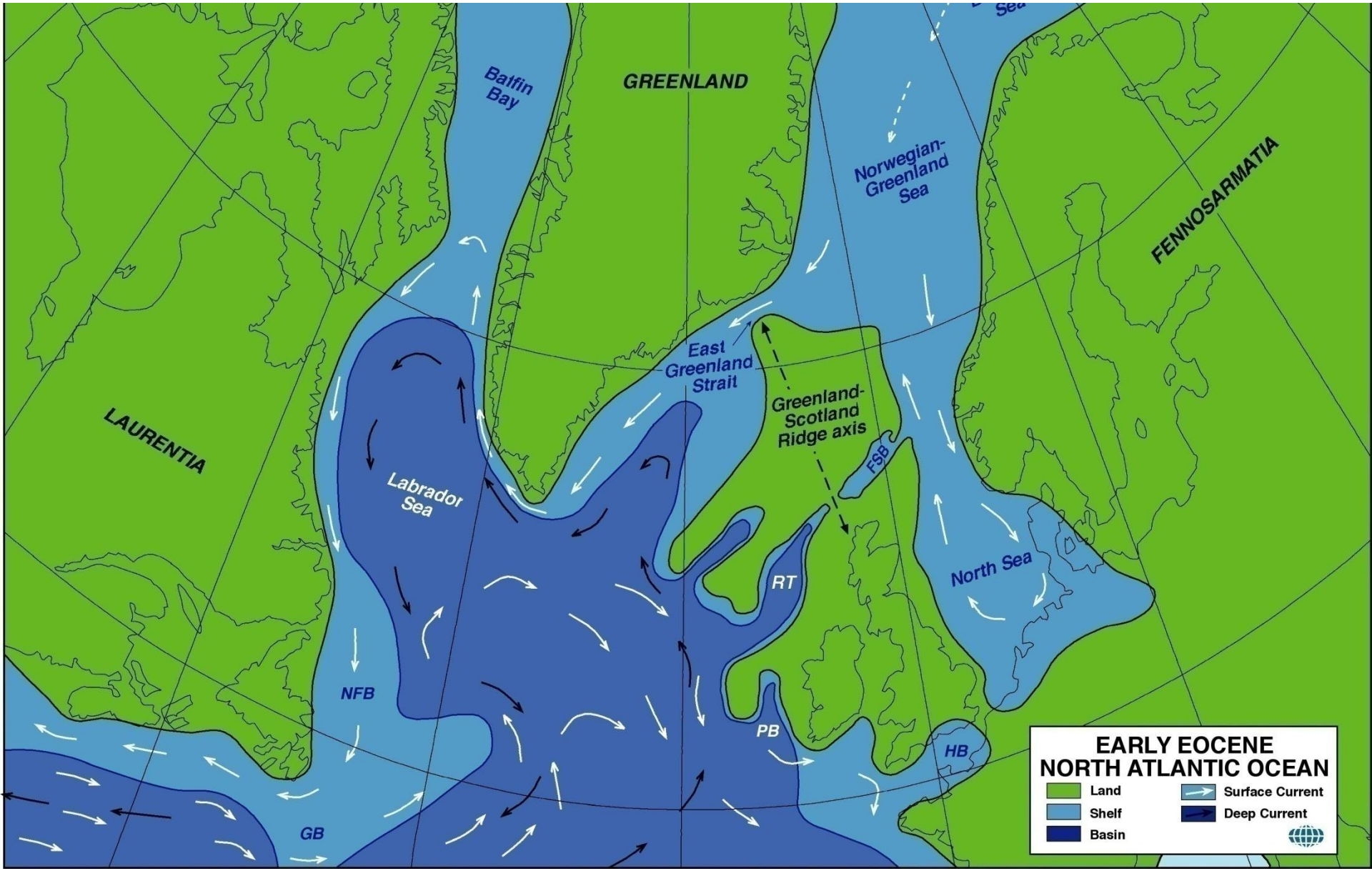
Collapse of the Greenland mantle plume allowed spreading to revert to its original north-eastward direction



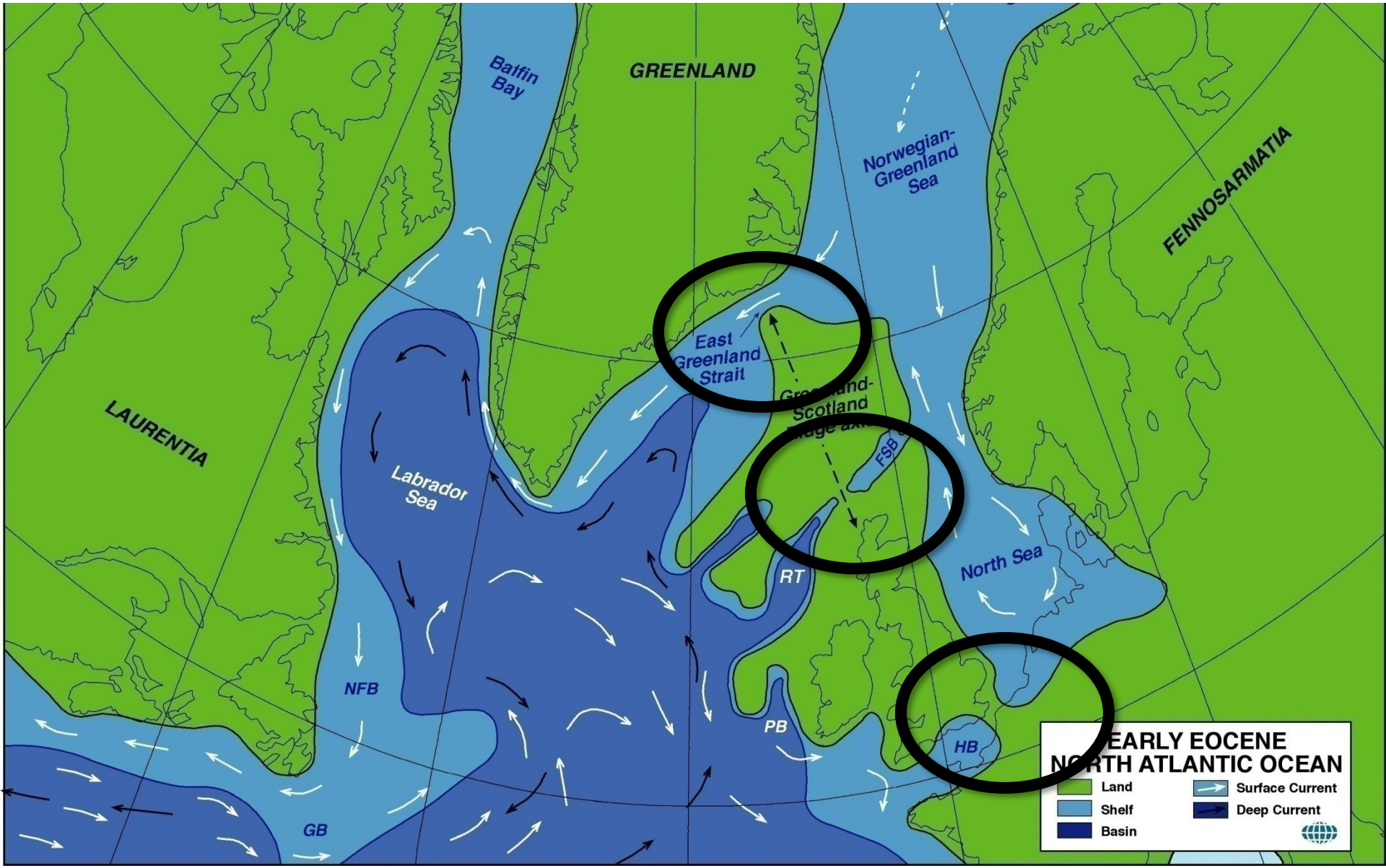
but spreading continuing to the west of Greenland until the middle Eocene - resulting in a triple junction



Collapse of the plume also caused widespread marine transgression



but connections between the northern Atlantic and North Sea / Norwegian-Sea system were still narrow or remained closed



icehouse

This lack of open oceanic connection

played a major role during the

greenhouse to icehouse shift

greenhouse

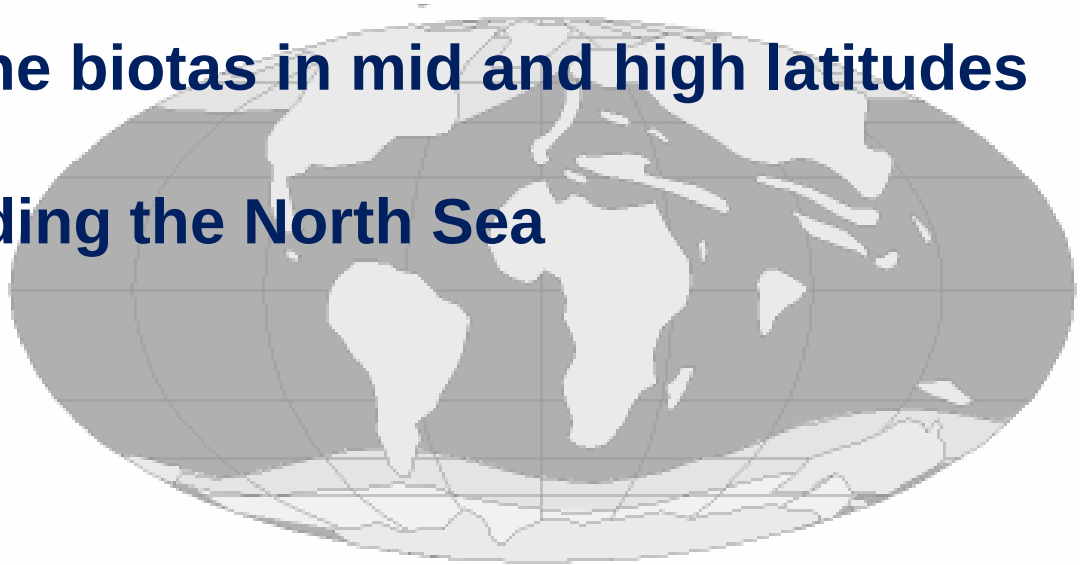
icehouse

because the associated fall in air and

sea-surface temperature (SST) had an enormous impact

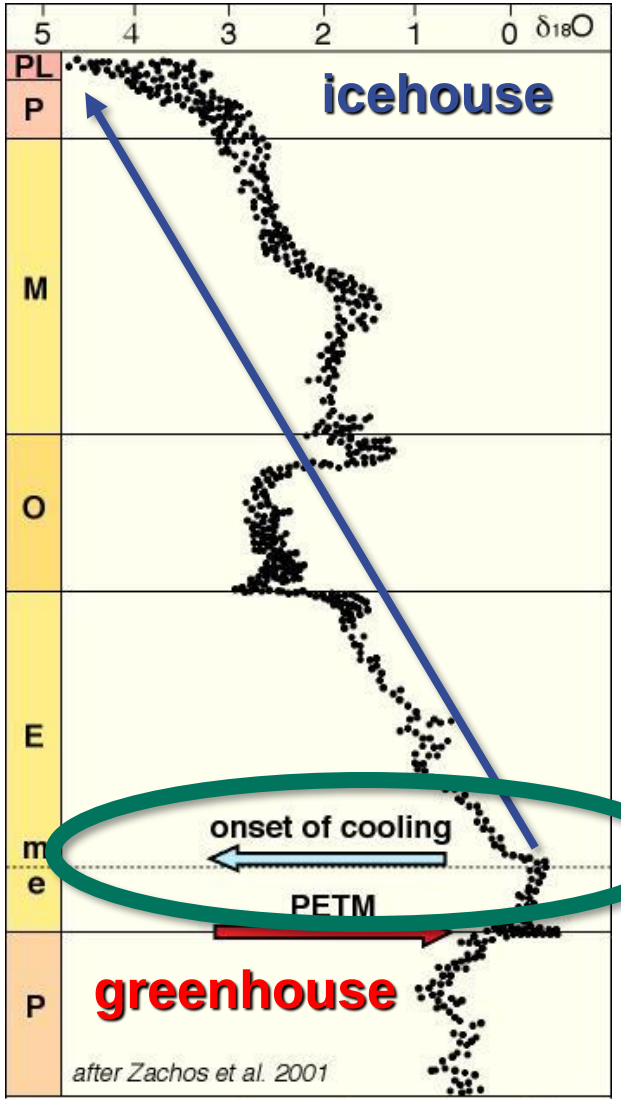
on Eocene to Holocene biotas in mid and high latitudes

including the North Sea

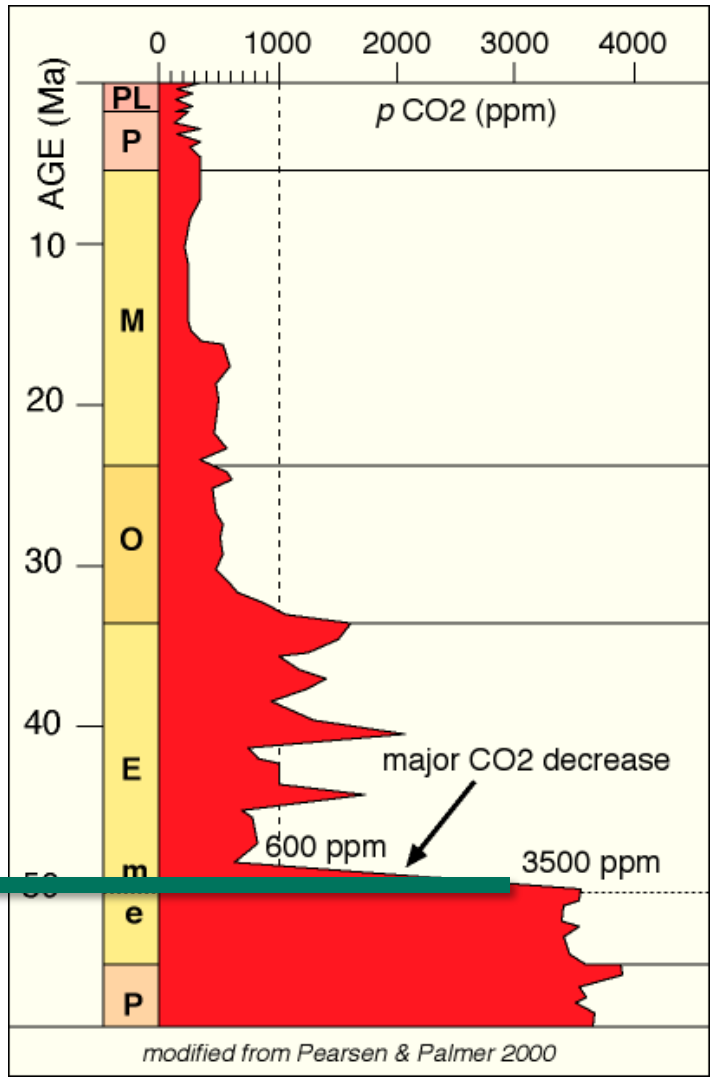


greenhouse

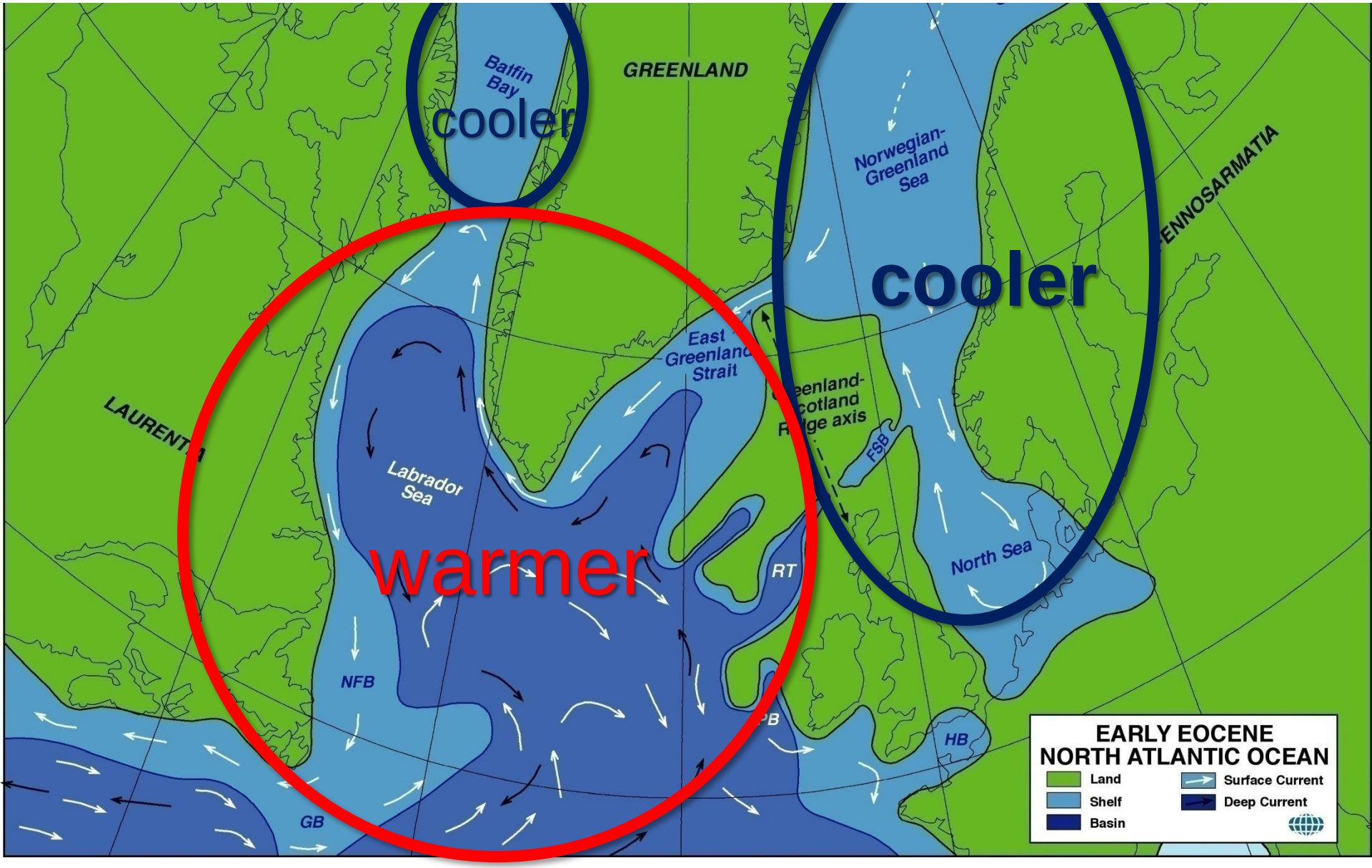
The base Middle Eocene Arctic Azolla event was the initial trigger for the greenhouse to icehouse shift



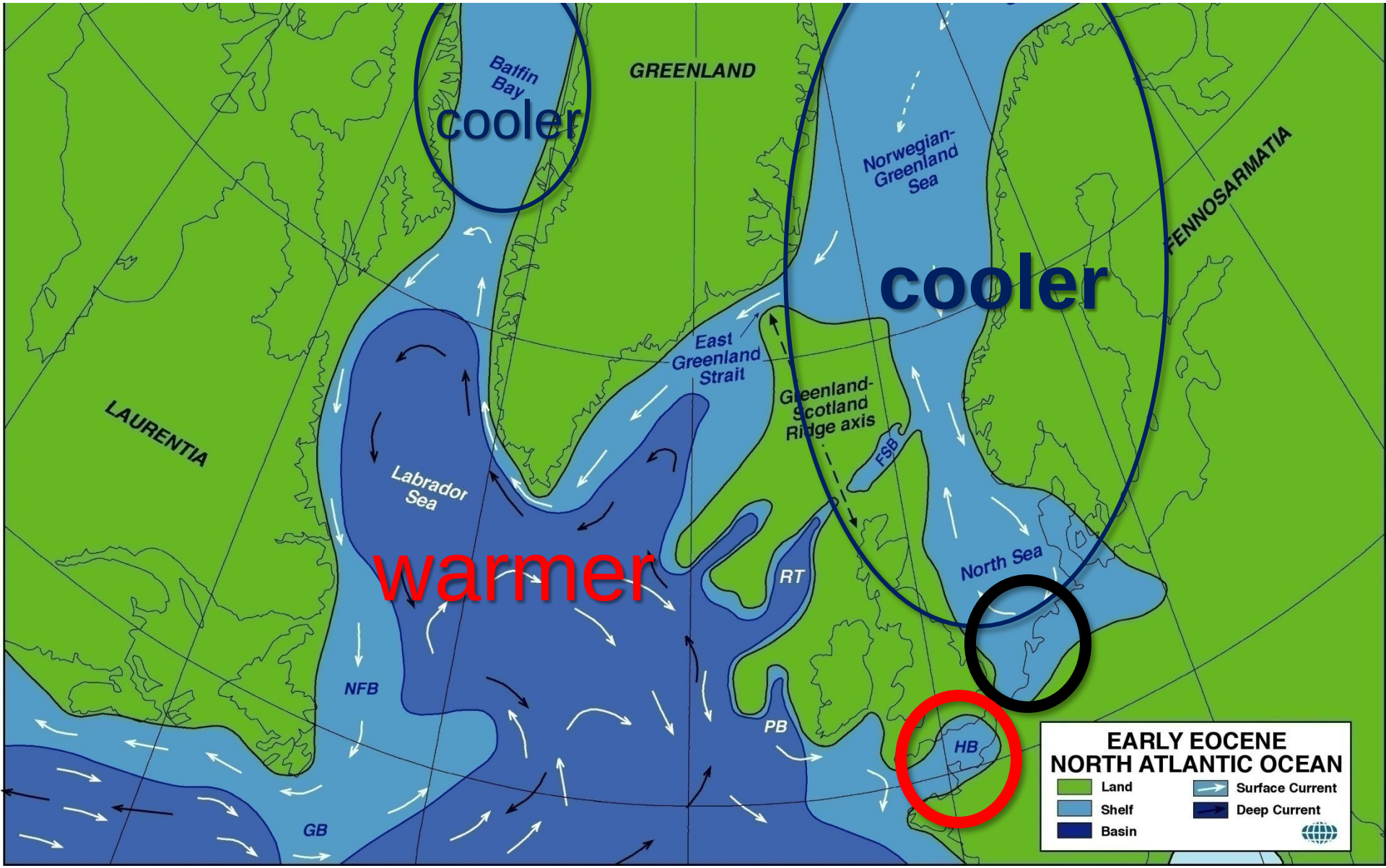
Azolla event



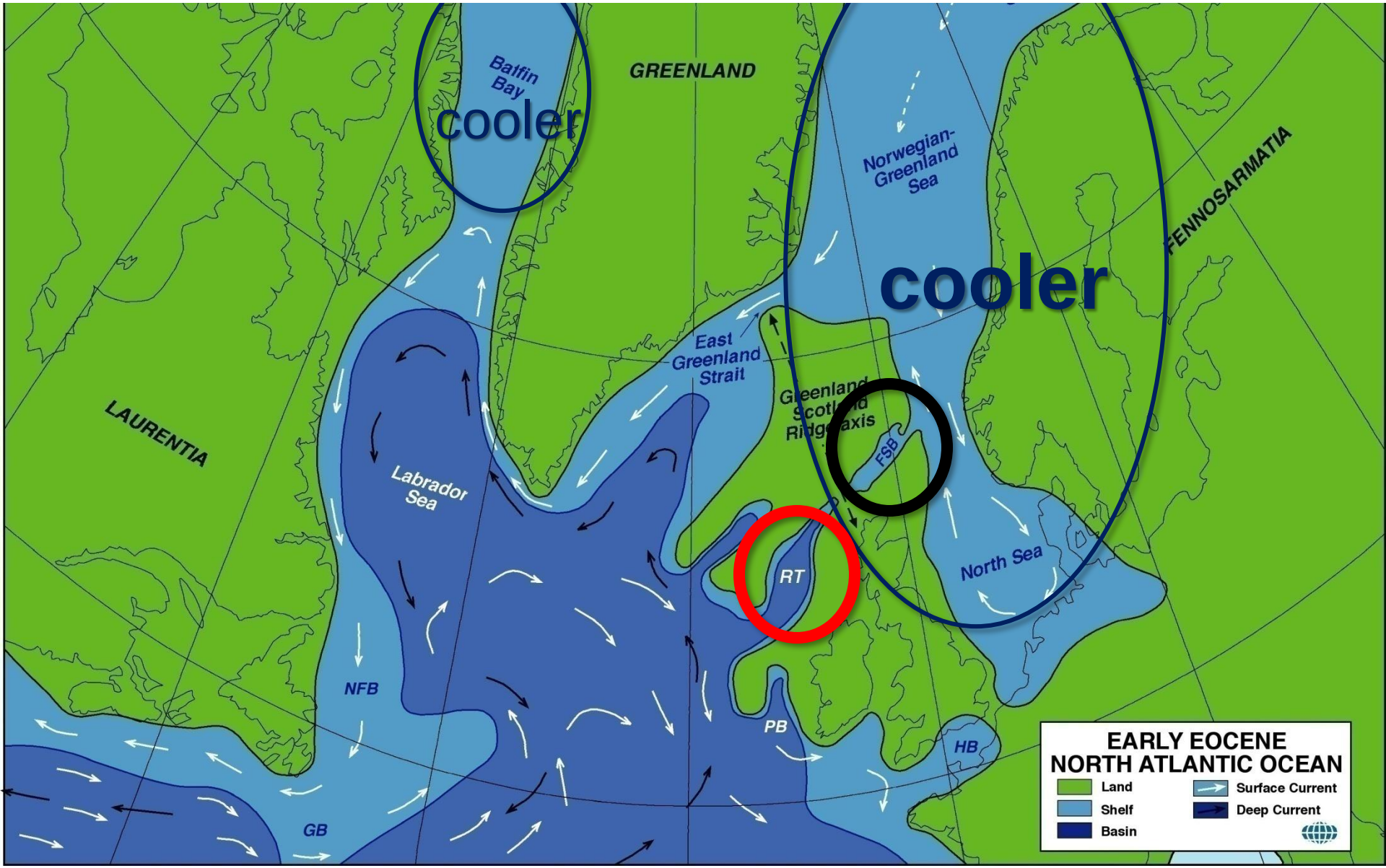
The associated cooling resulted in diachronous ranges because the three N Atlantic basin systems retained their independent temperature regimes



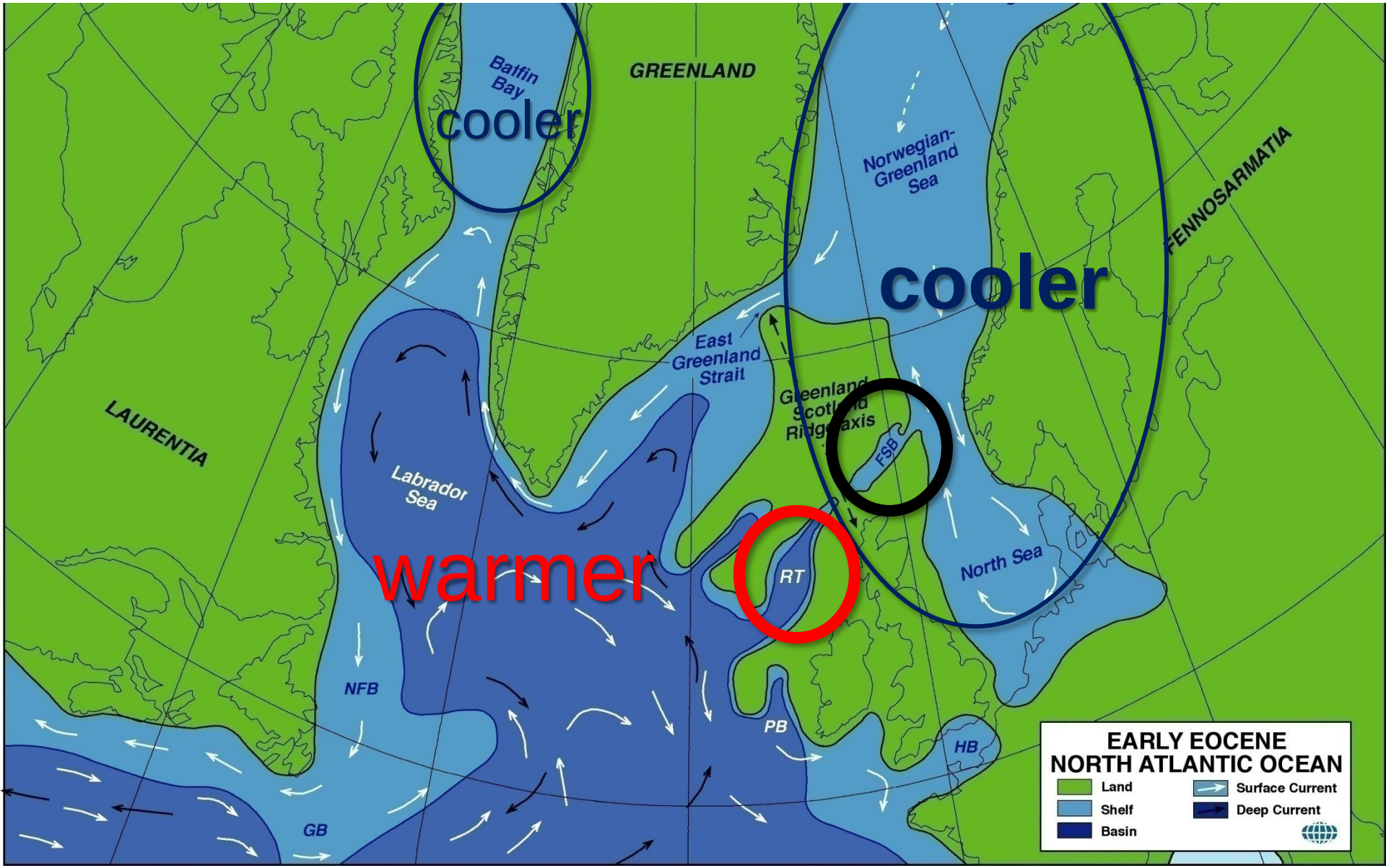
So we see this temperature difference in subbasins that are just a few kilometres apart such as the southern North Sea and Hampshire Basin



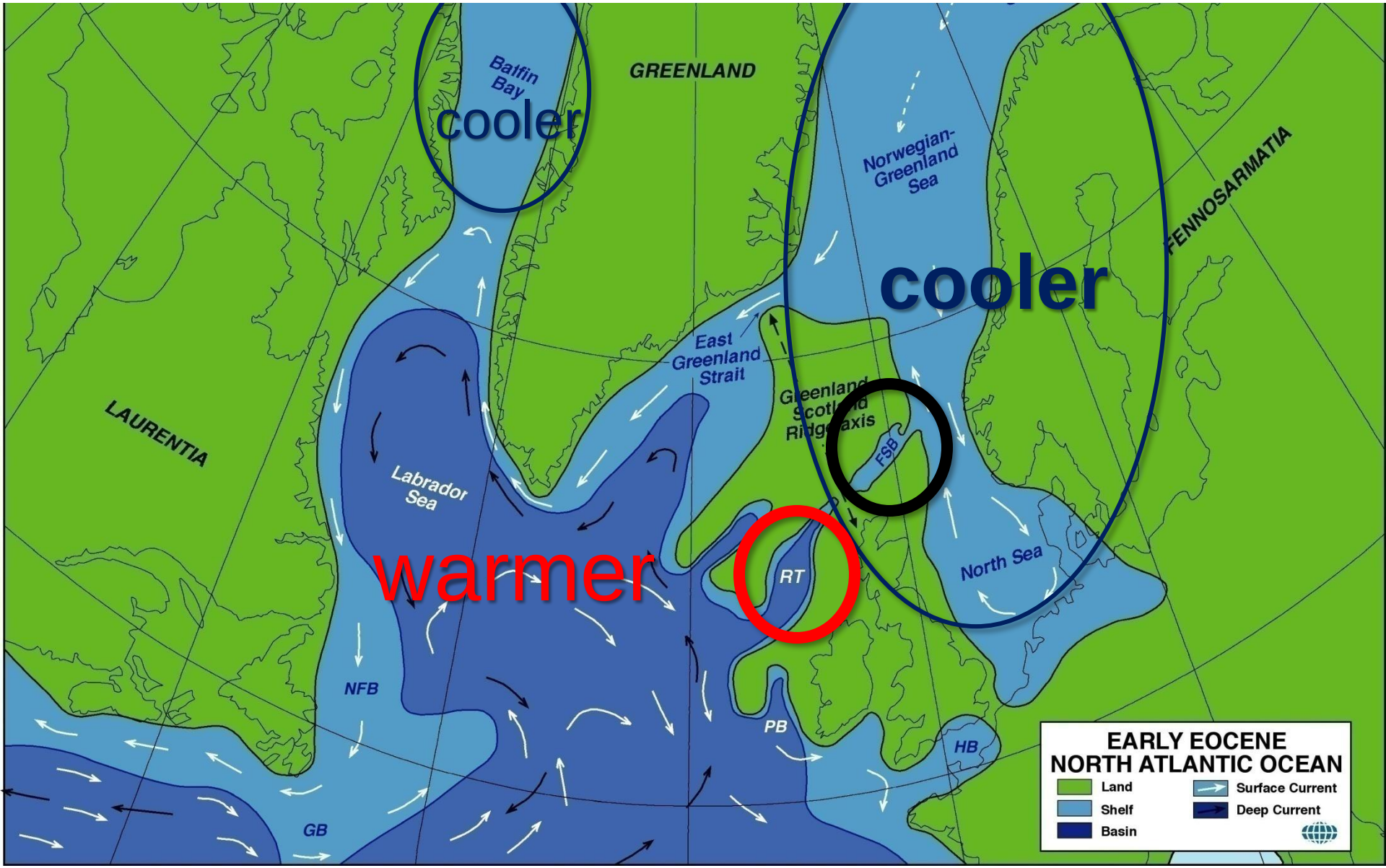
and between the Rockall Trough and Faroe Shetland Basin

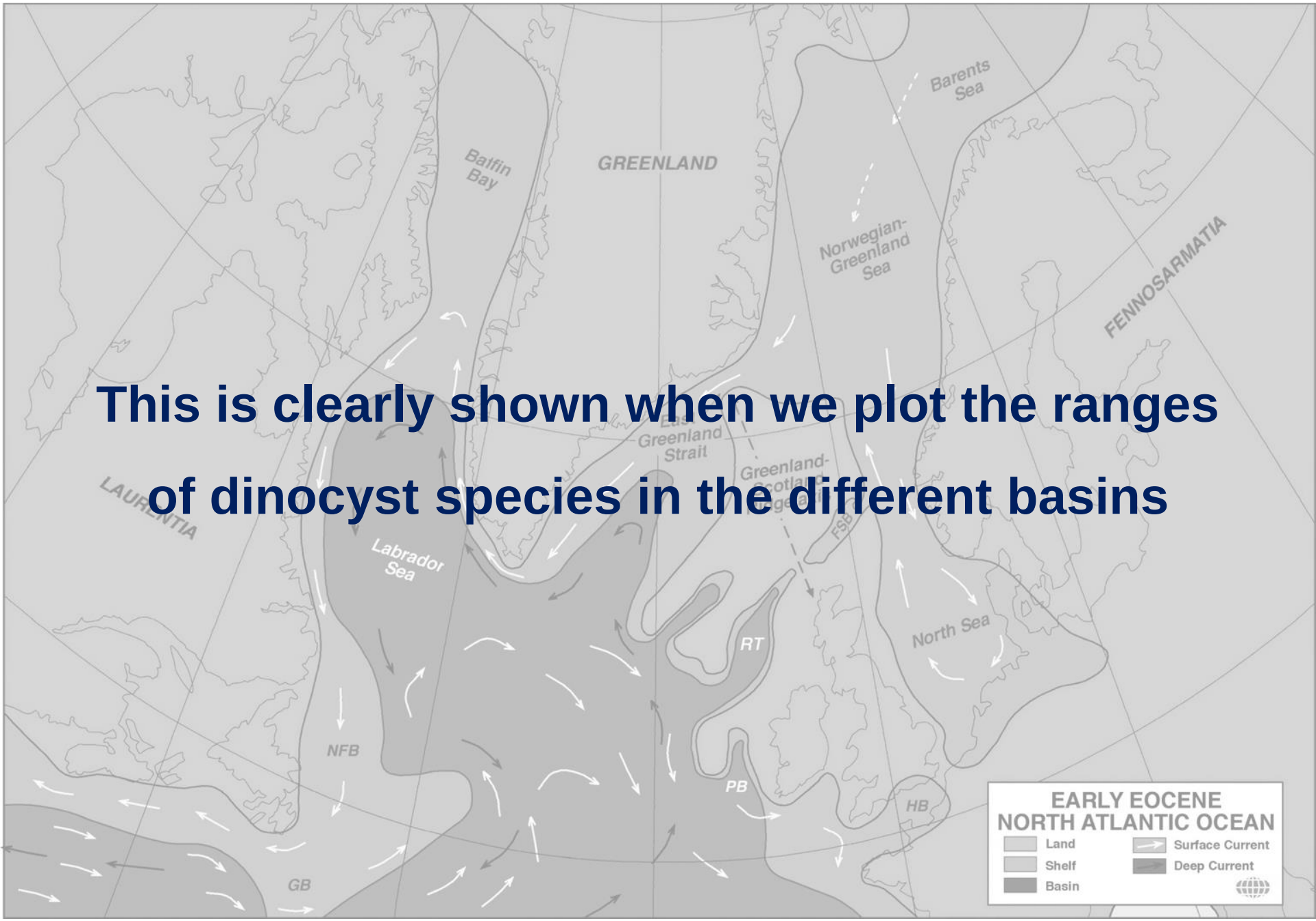


This is why North Sea dinocyst ranges can result in erroneous ages assignments in Rockall wells

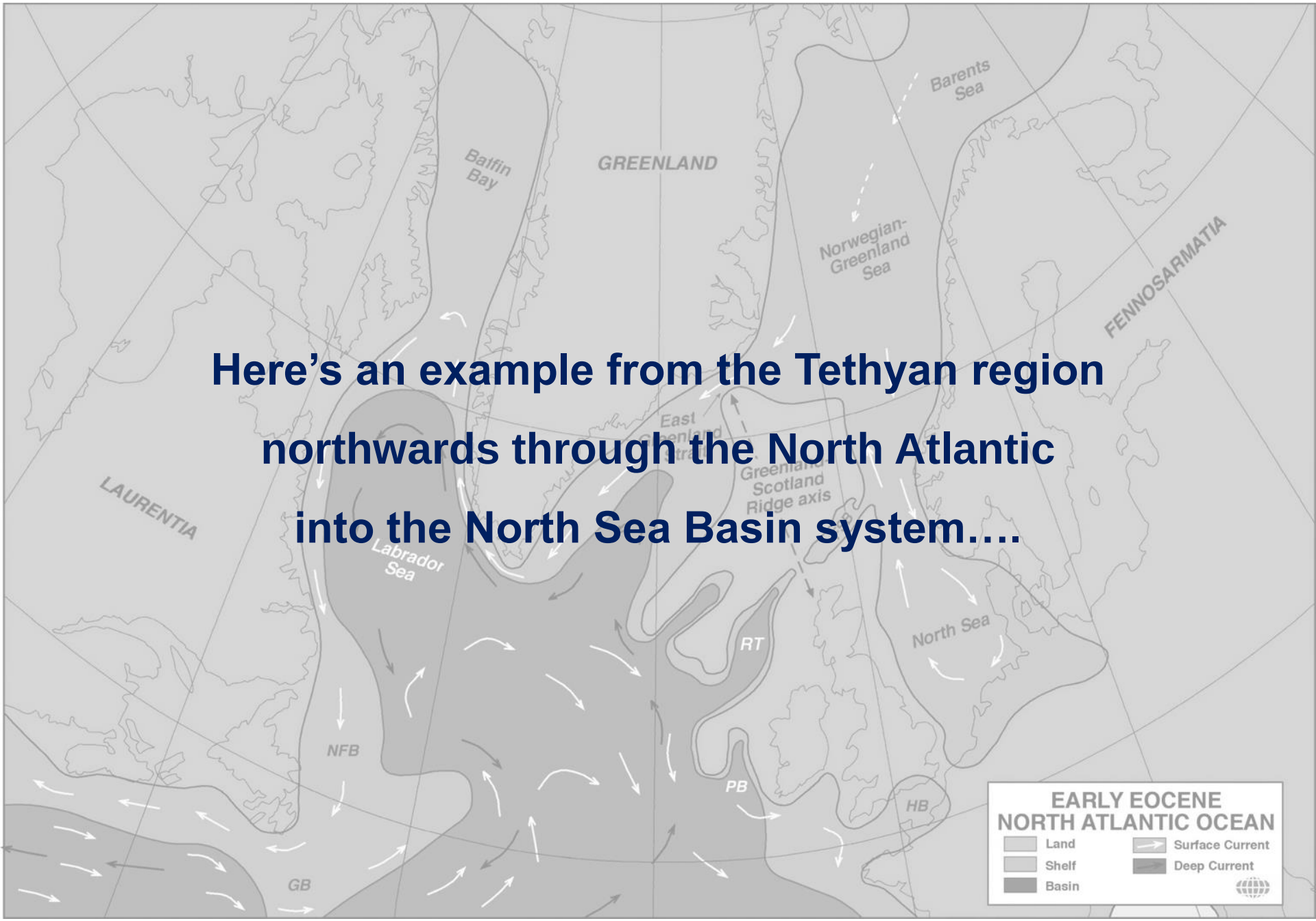


…..which have a biostratigraphic succession that is more similar to that of the Scotian Shelf, Grand Banks and NE Newfoundland basins



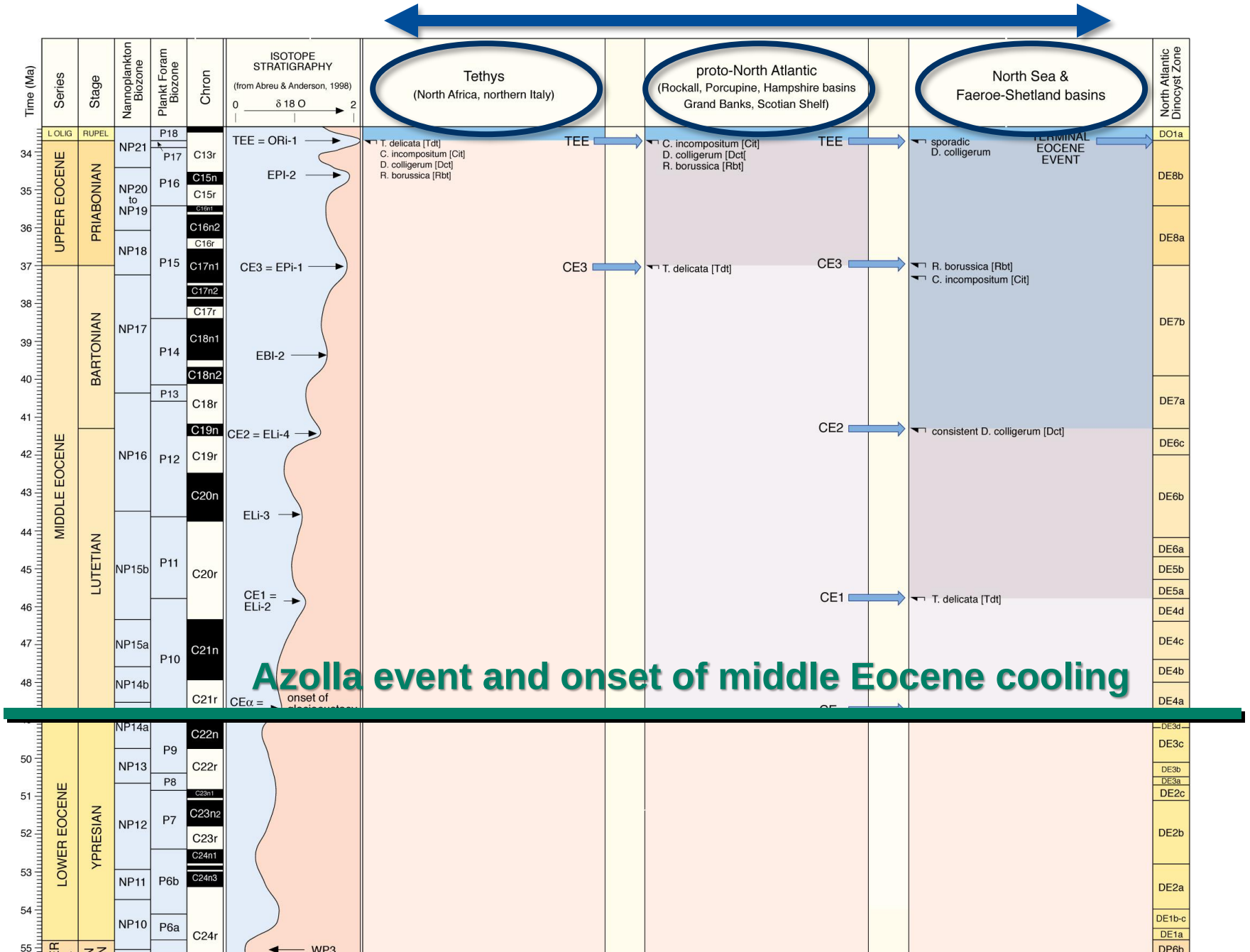


This is clearly shown when we plot the ranges of dinocyst species in the different basins

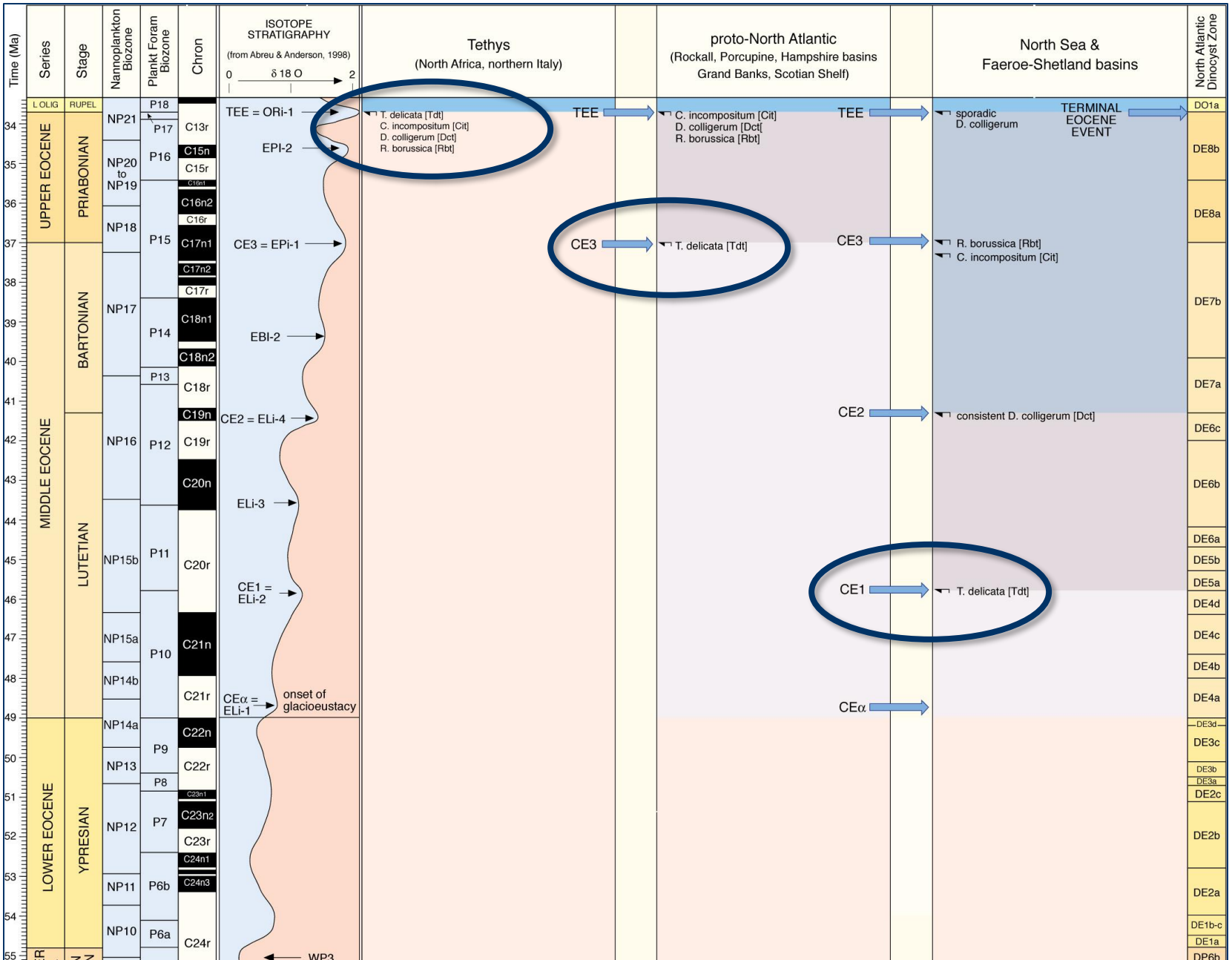


Here's an example from the Tethyan region northwards through the North Atlantic into the North Sea Basin system….

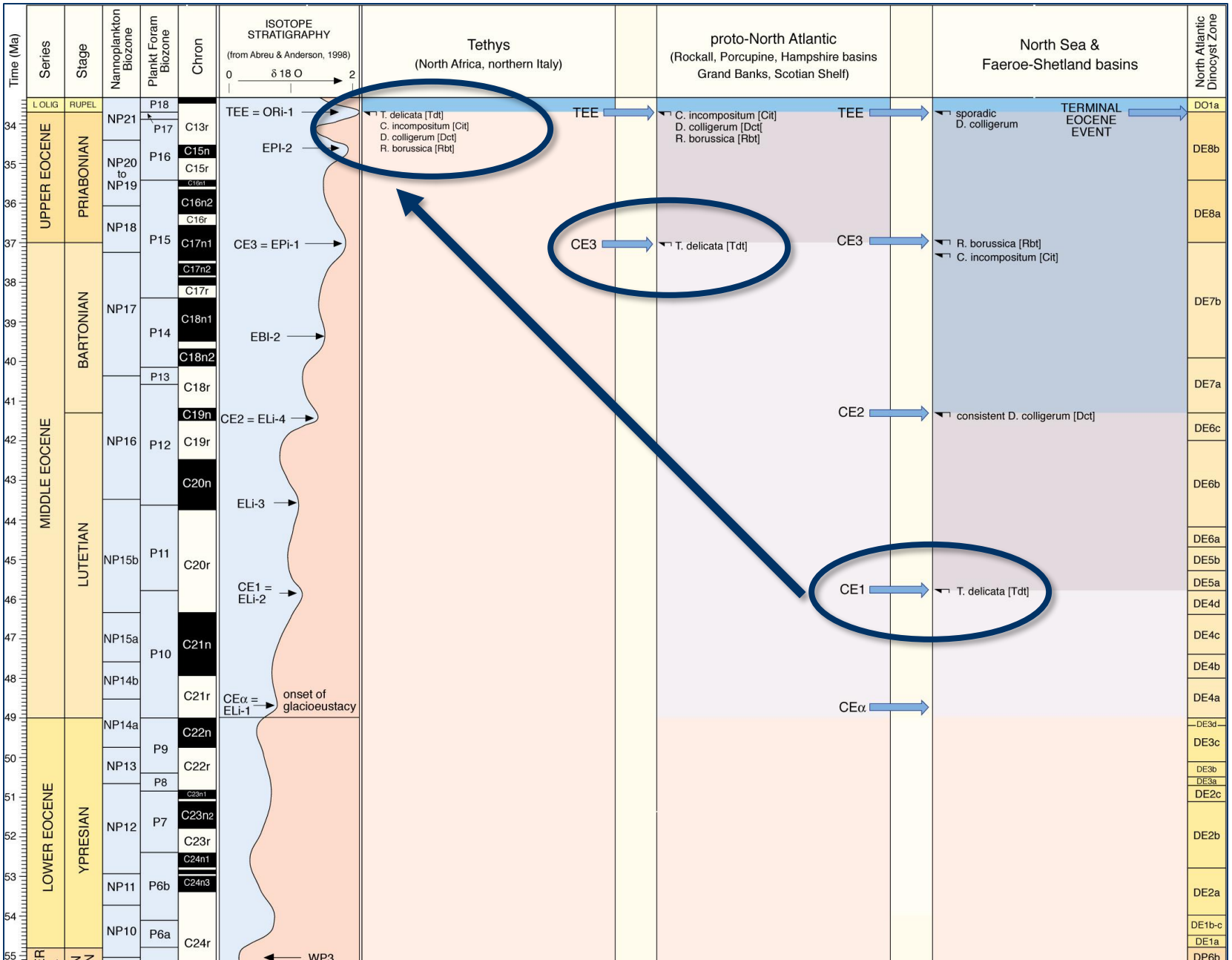
…..a Tethyan – N Atlantic – N Sea / Norwegian-Greenland Sea transect through time



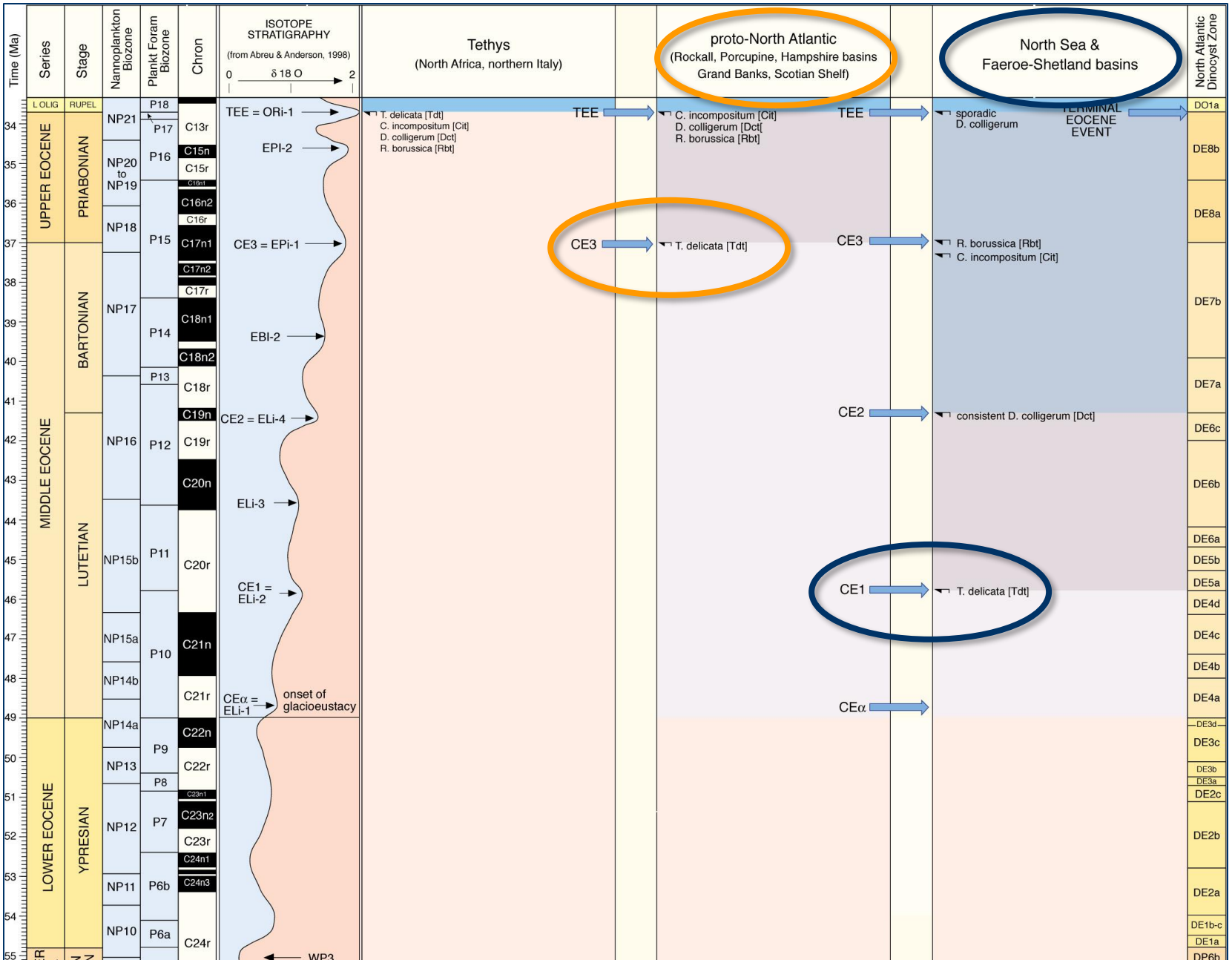
which shows that the extinction of temperature-sensitive dinocysts is diachronous in different SST regimes (e.g. Thalassiphora delicata)



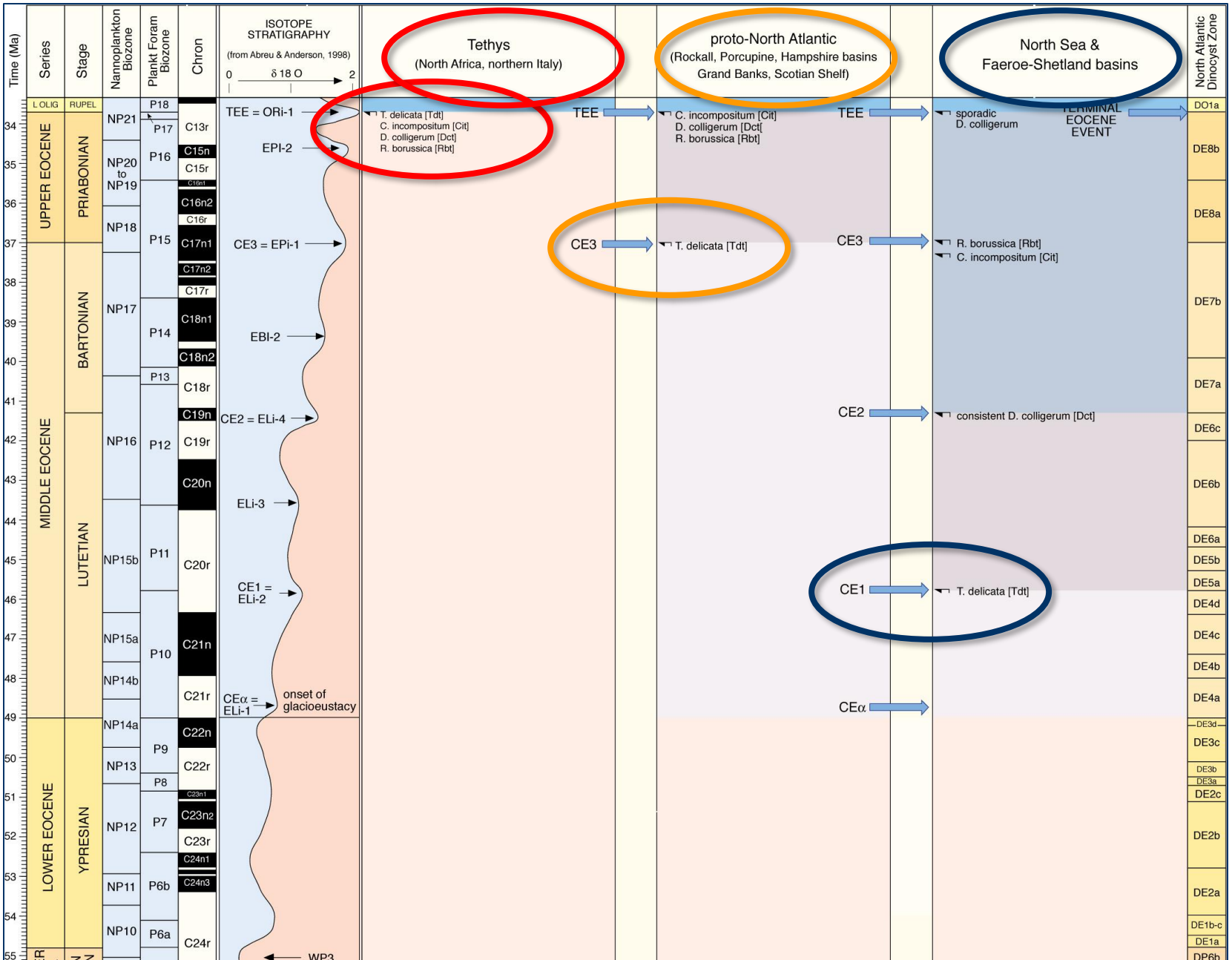
and that they occur later to the south



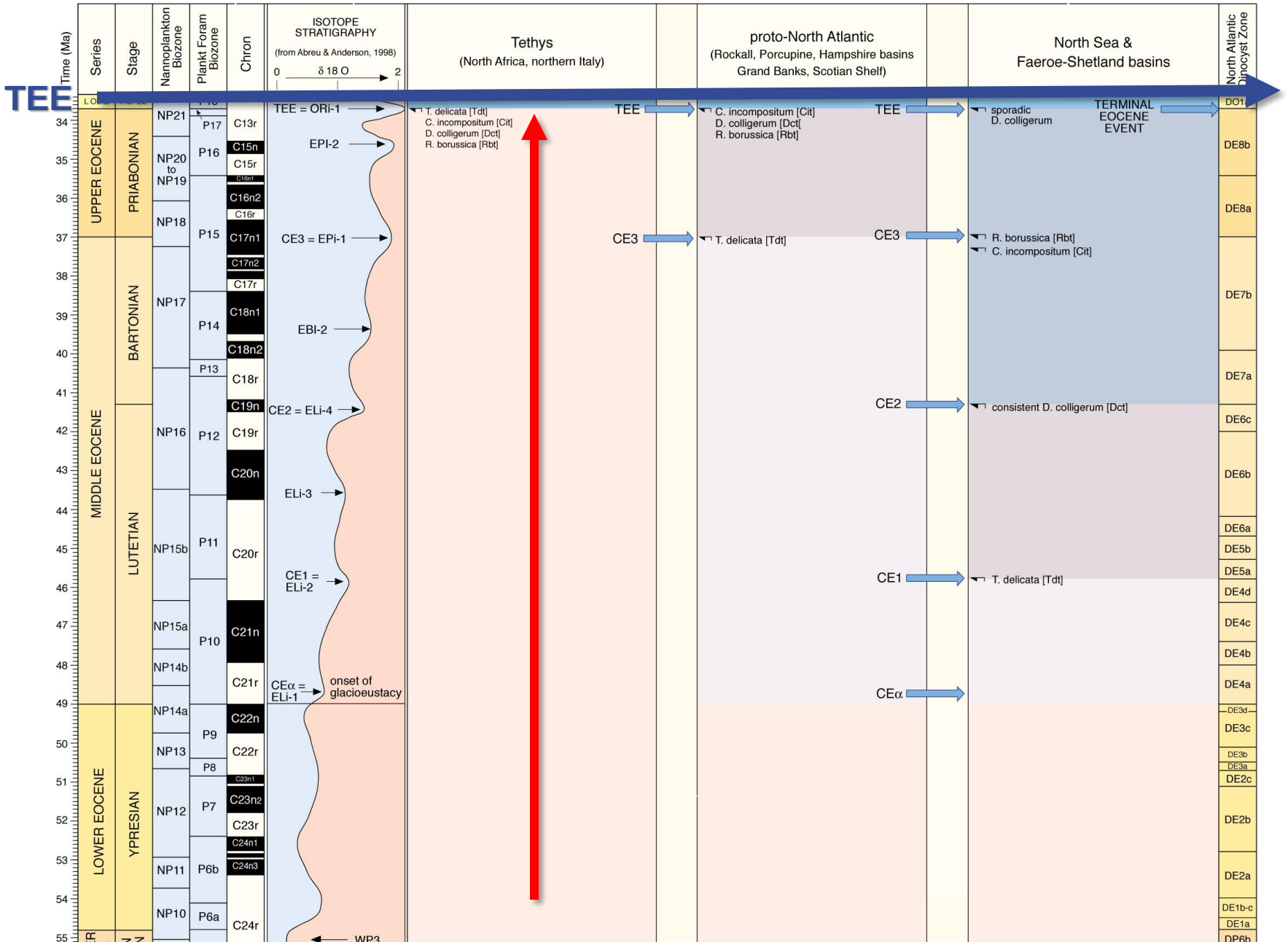
This indicates that the North Sea / N-G Sea system had a cooler SST than the North Atlantic System

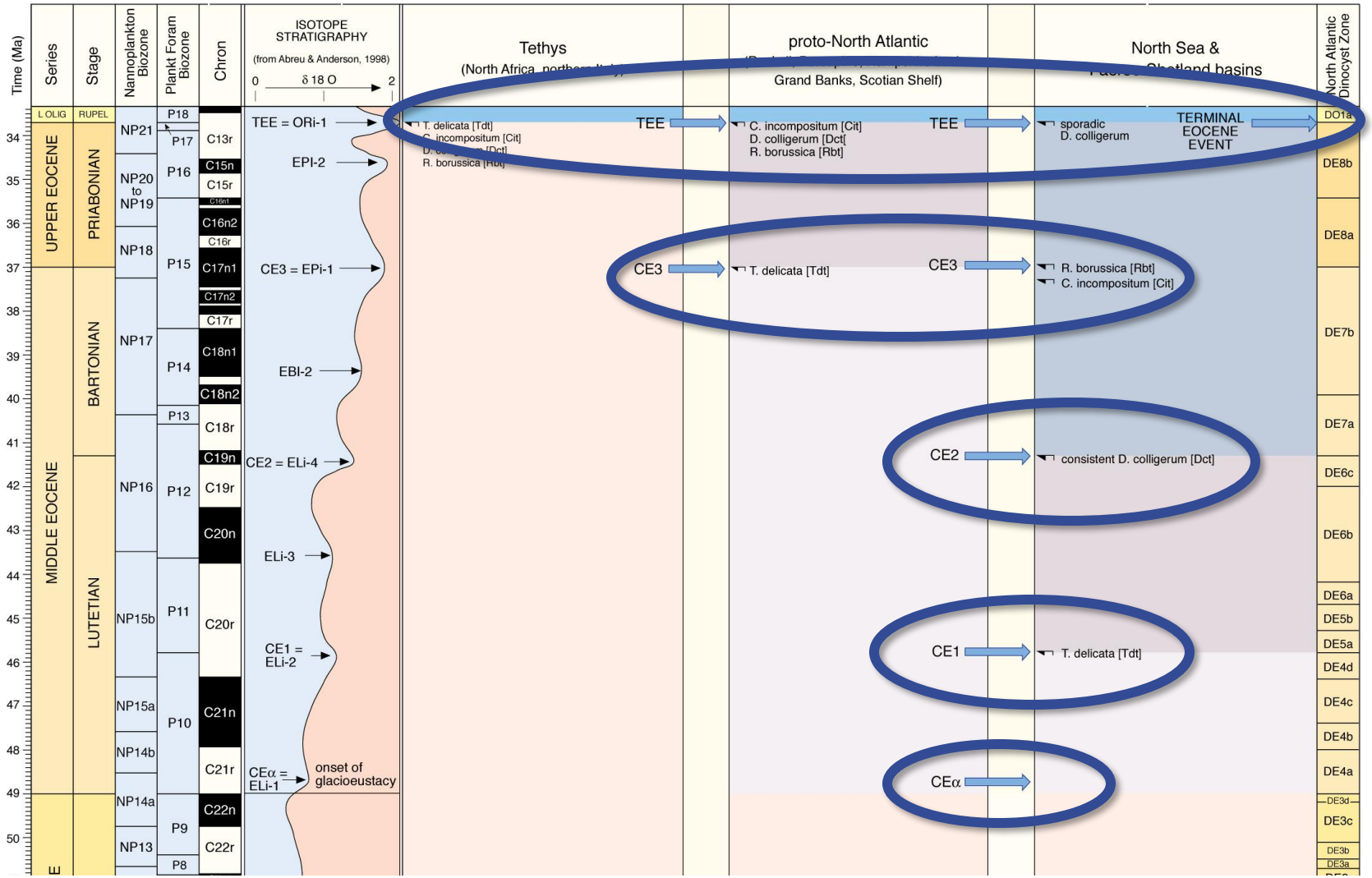


and that the North Atlantic was cooler than the Tethys (as we would expect)

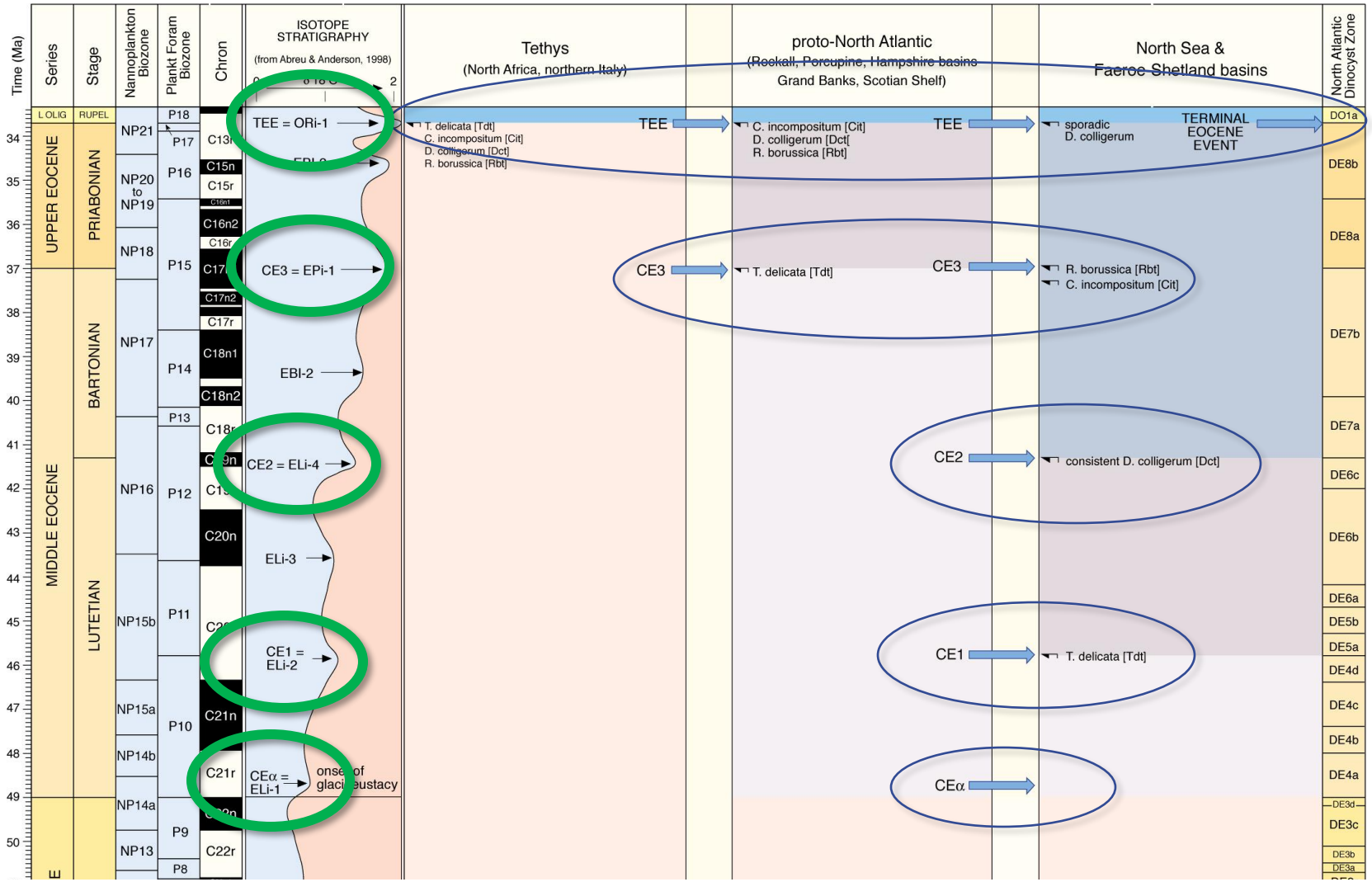


It also shows that cooling did not significantly affect the Tethyan region until the Terminal Eocene Event

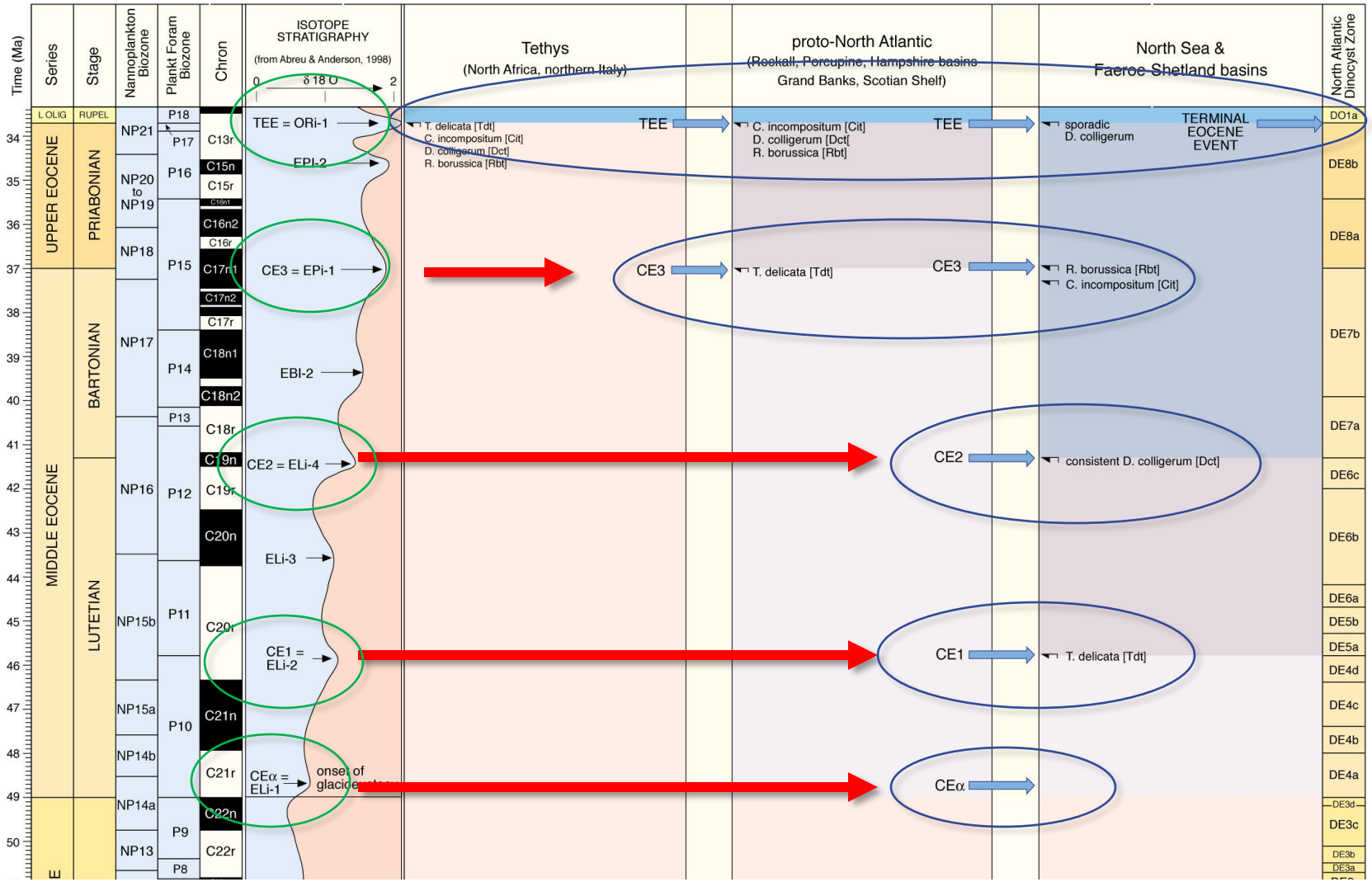




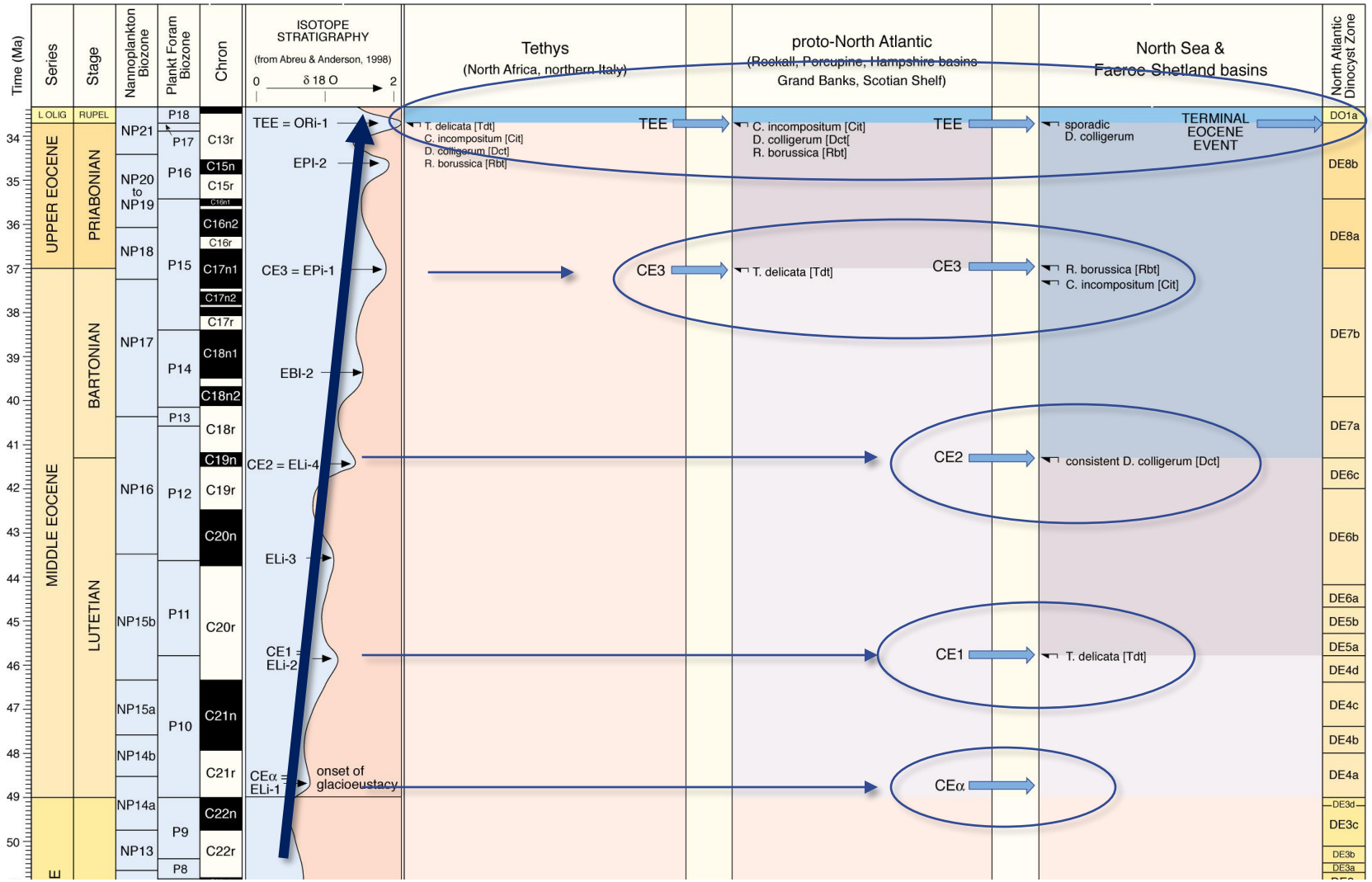
The succession of cooling steps is reflected by changes in sea-surface (dinocysts) and air temperatures (angiosperm pollen)



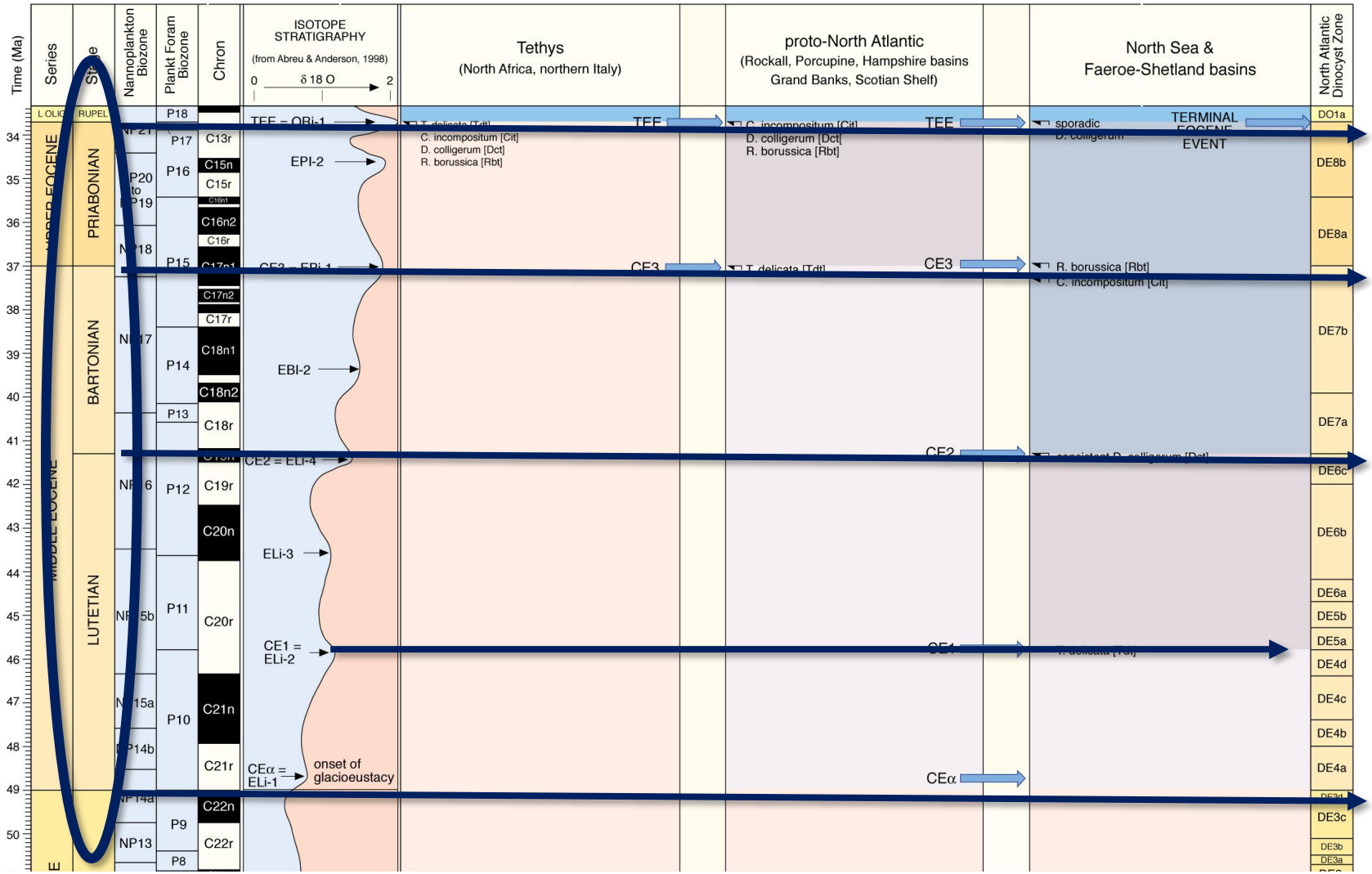
as well as the isotope record



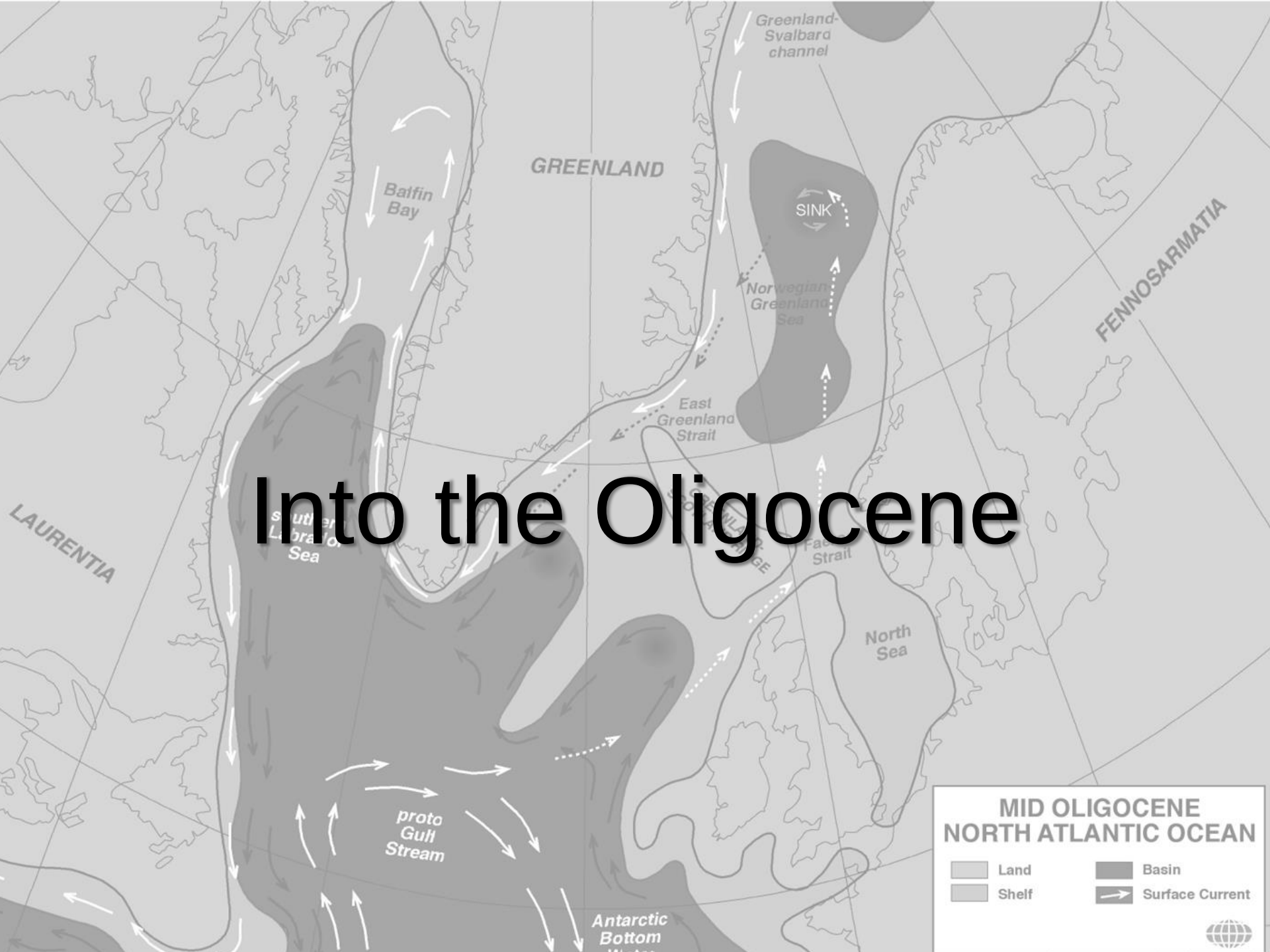
The close correlation of these events indicates that they do not reflect local facies changes



and that they were caused by a succession of Eocene cooling steps associated with the greenhouse to icehouse shift

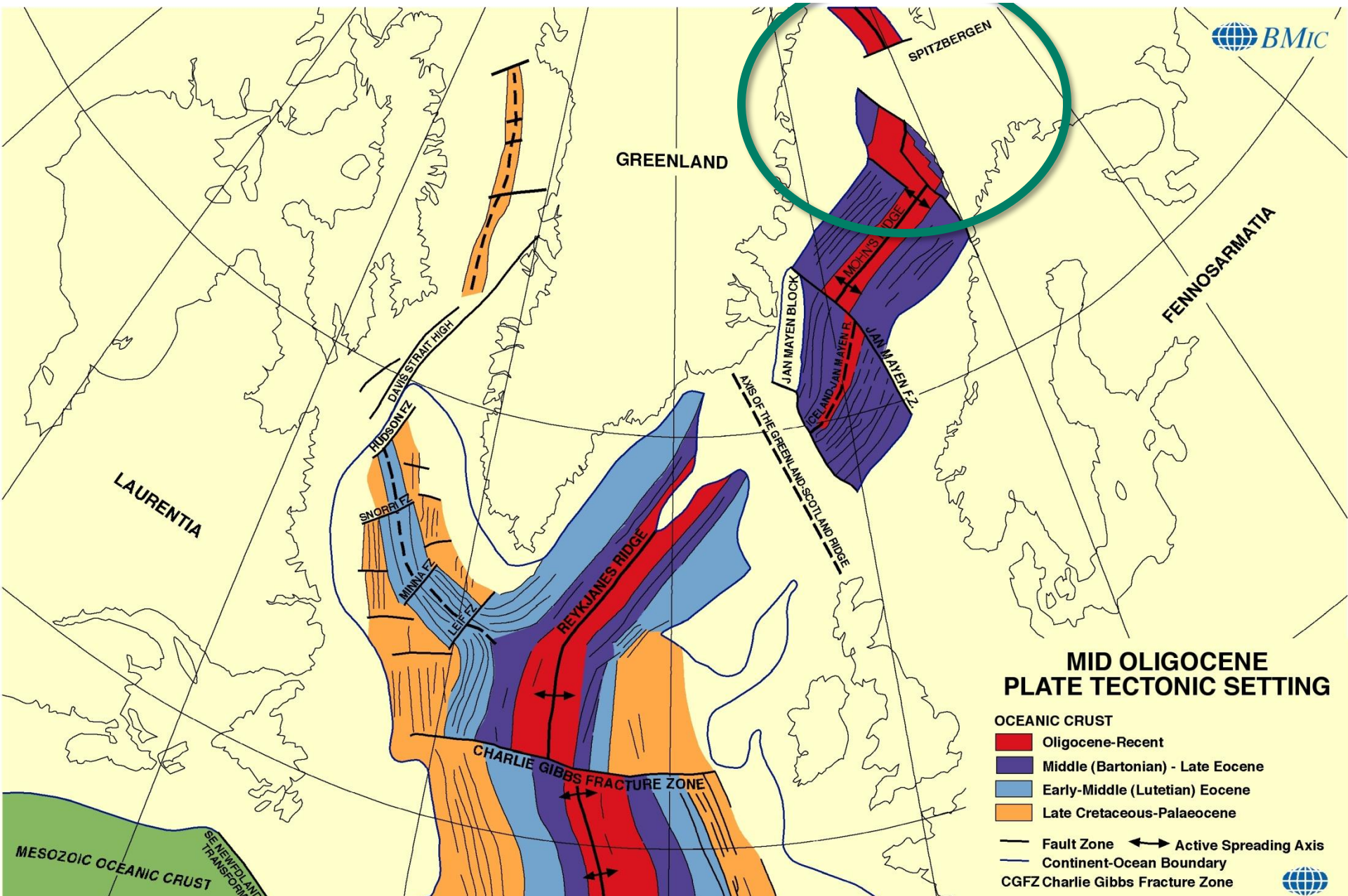


The cooling steps correspond to NW European stage or substage boundaries because the stages were originally defined on major changes observed in the North Sea / NE European basin system

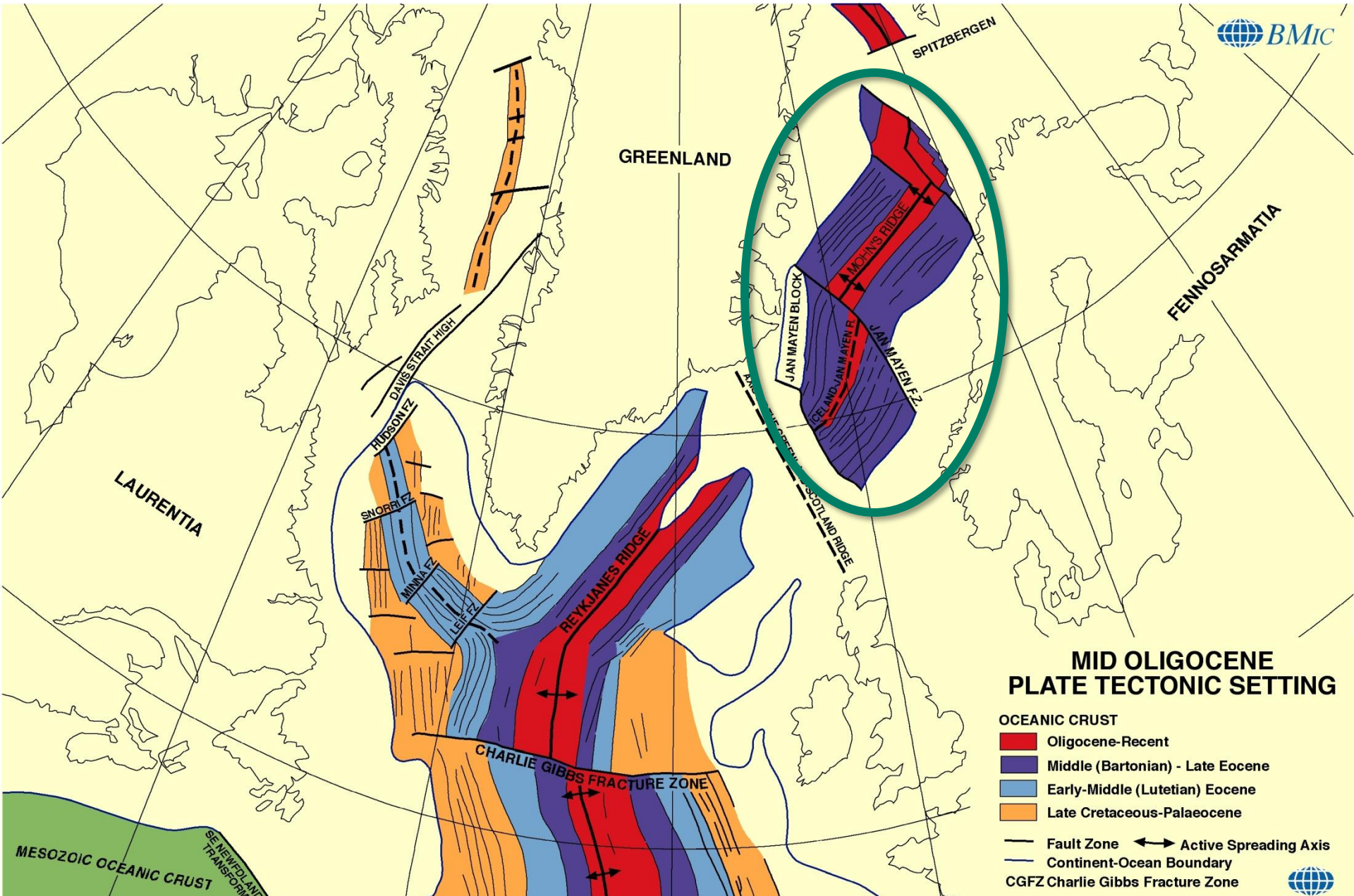


Into the Oligocene

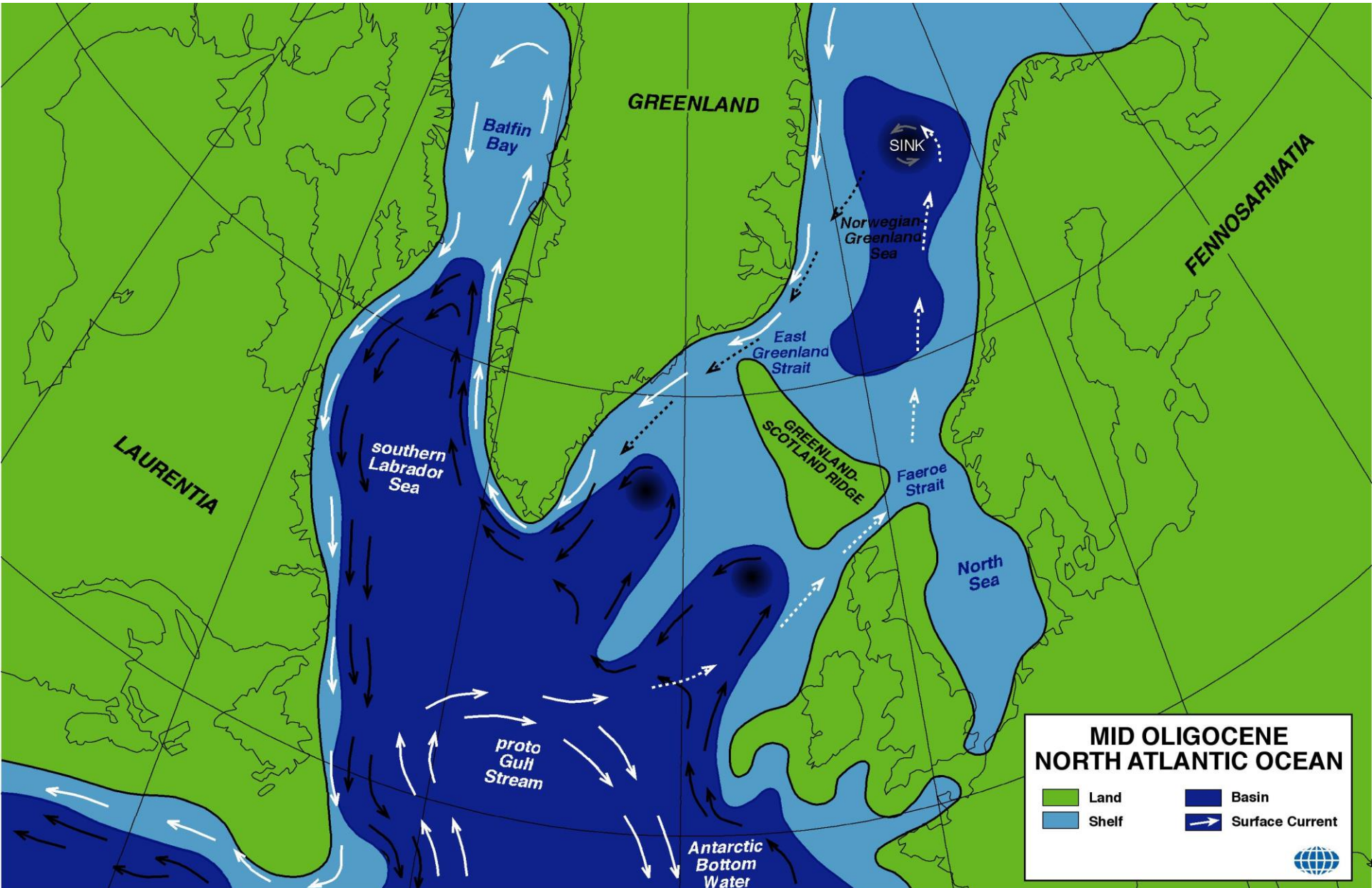
Plate tectonic spreading between Spitsbergen and Greenland opened a seaway deep enough for benthic forams to migrate into the Arctic…..



…..and it also deepened the Norwegian-Greenland Sea



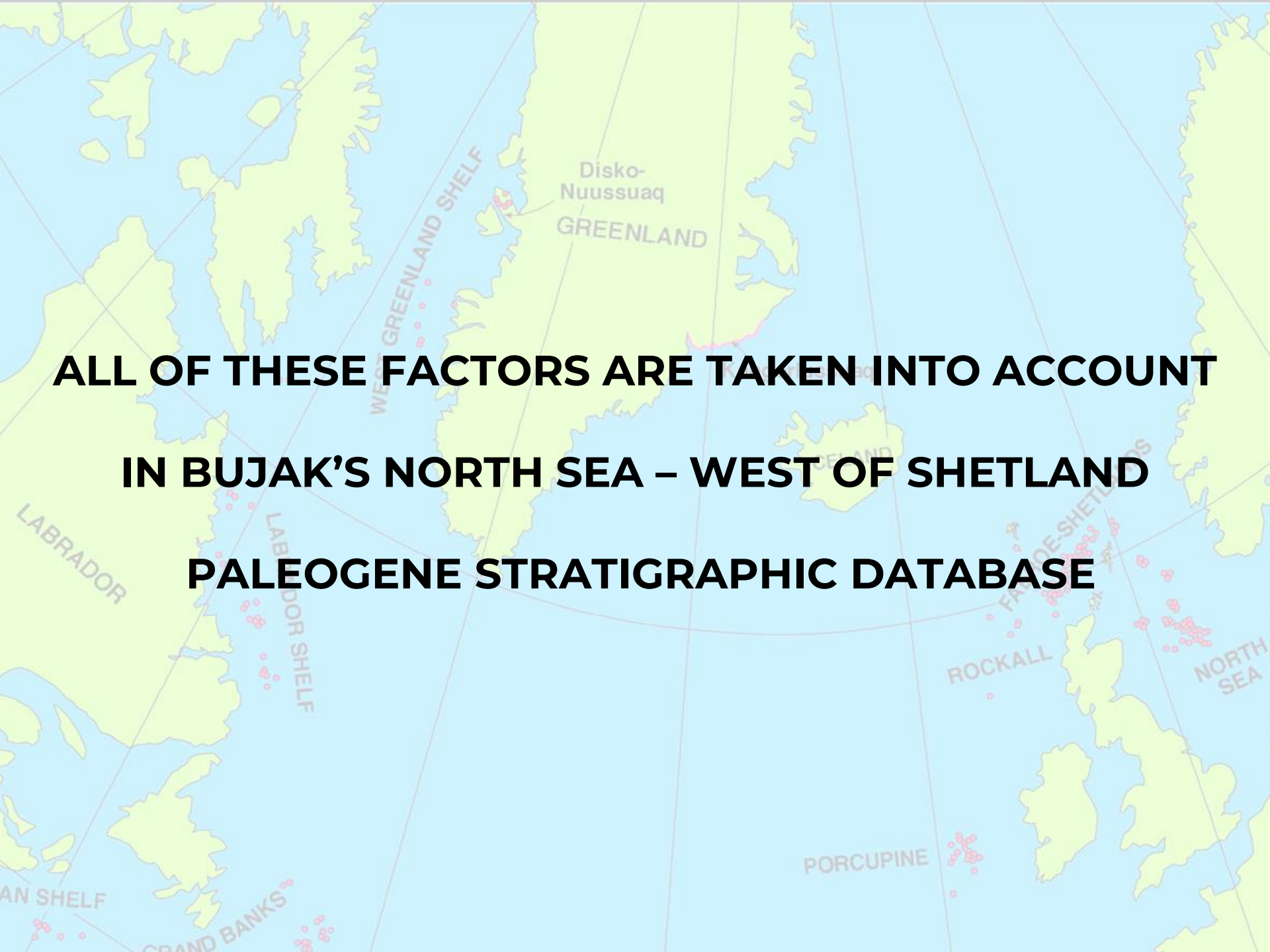
Initiating the proto-Gulf Stream and shifting circulation towards today's North Atlantic oceanographic system



With its icehouse climate and succession of glacial-interglacial cycles

Interglacial

Glacial



ALL OF THESE FACTORS ARE TAKEN INTO ACCOUNT

IN BUJAK'S NORTH SEA – WEST OF SHETLAND

PALEOGENE STRATIGRAPHIC DATABASE

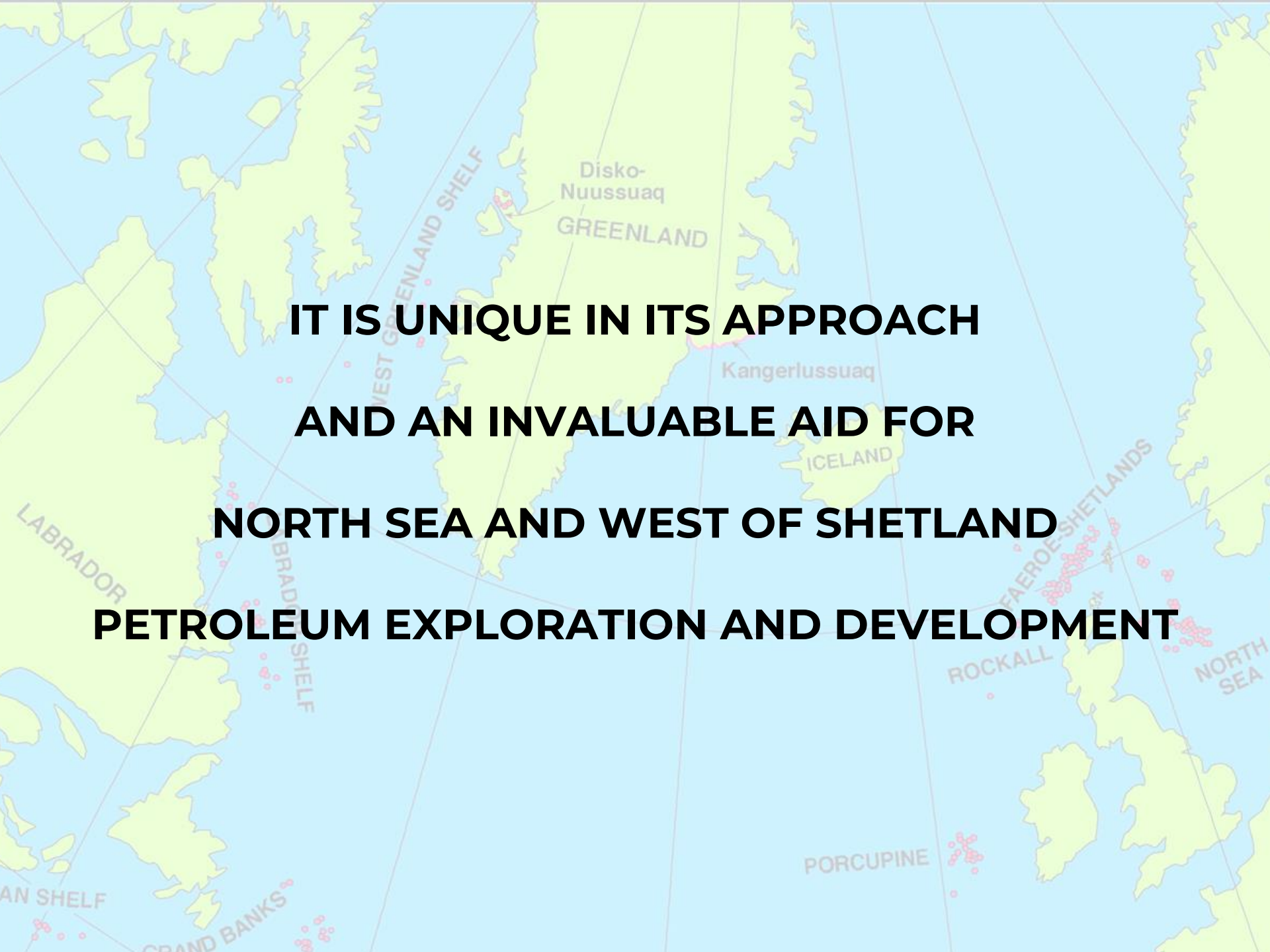
WHICH ALSO INTEGRATES THEM WITH

THE SEQUENCE STRAGRAPHIC FRAMEWORK

PUBLISHED IN A SERIES OF PAPERS

BY BUJAK, COPESTAKE AND MUDGE

THE BUJAK DATABASE DOCUMENTS THE SEQUENCE AND BIOSTRATIGRAPHY OF 1155 OFFSHORE WELLS TO PROVIDE CONSISTENT CORRELATIONS ACROSS THE NORTH SEA AND WEST OF SHETLAND REGION WITHIN THE COMPLEX OCEANOGRAPHIC AND CLIMATIC DEVELOPMENT OF THE NORTH ATLANTIC

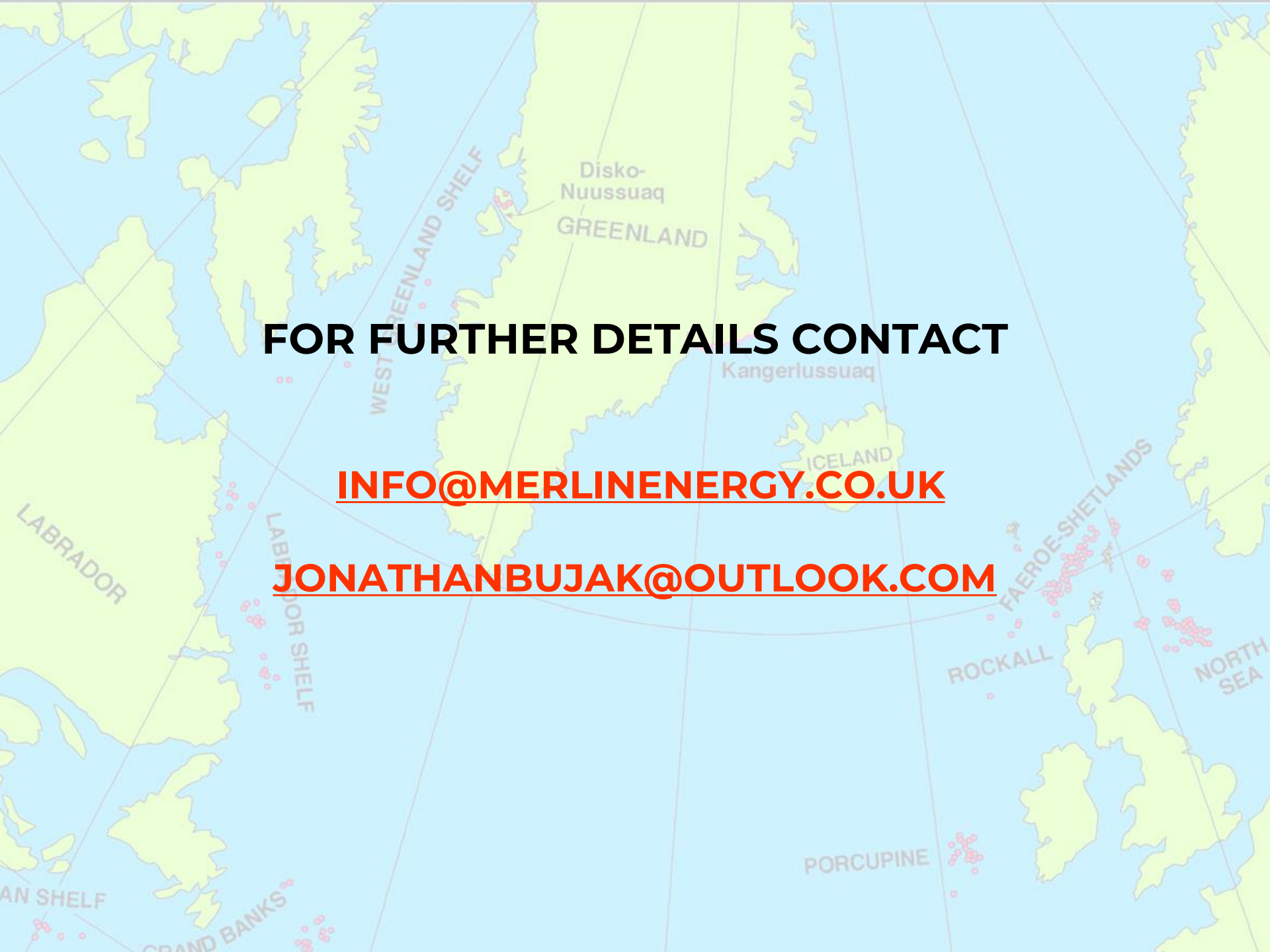


IT IS UNIQUE IN ITS APPROACH

AND AN INVALUABLE AID FOR

NORTH SEA AND WEST OF SHETLAND

PETROLEUM EXPLORATION AND DEVELOPMENT



FOR FURTHER DETAILS CONTACT

INFO@MERLINENERGY.CO.UK

JONATHANBUJAK@OUTLOOK.COM