Seeing the Past Through JGOFS Spectacles

T.F. Pedersen

University of Victoria

Collaborators:

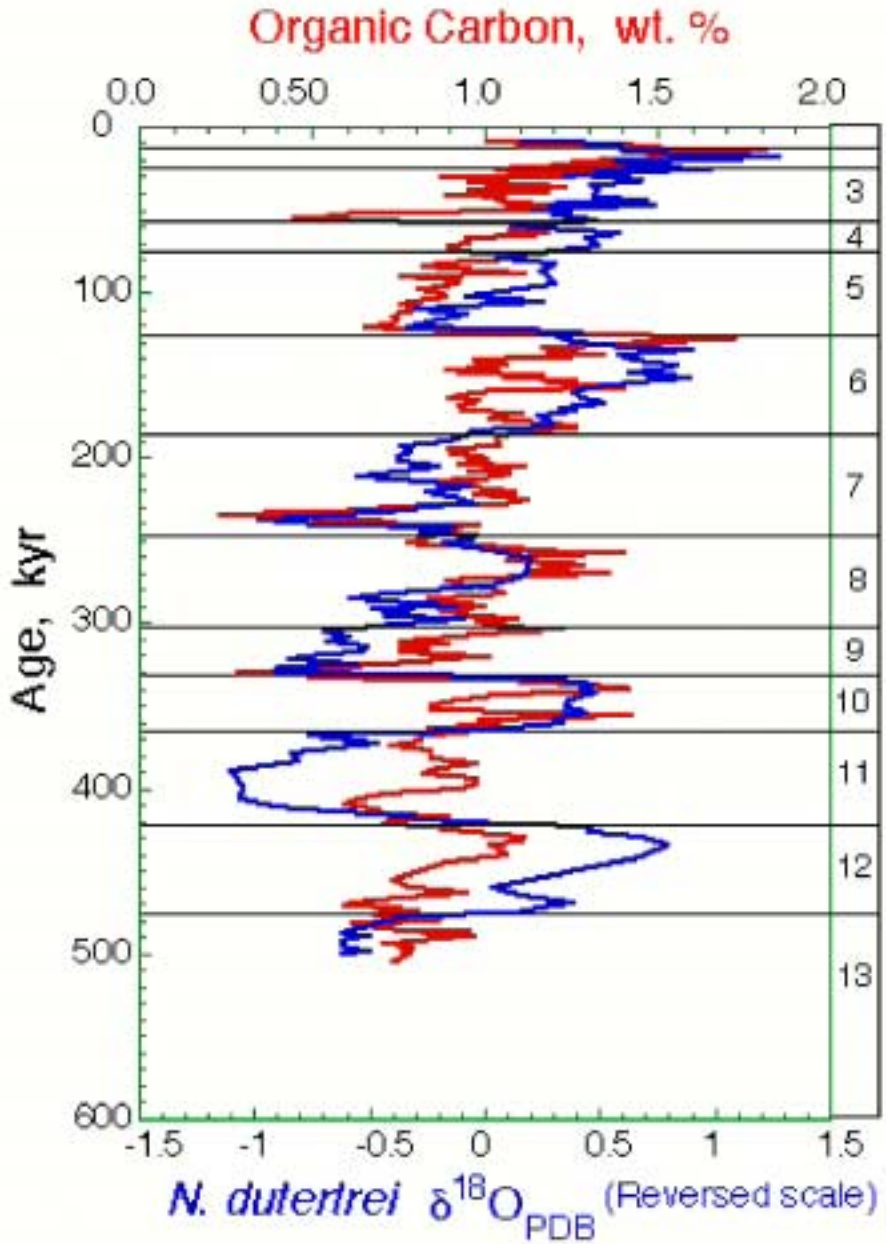
- **Jennifer McKay (UQAM)**
- **Raja Ganeshram (U. Edinburgh)**
- **Ingrid Hendy (U. Michigan)**
- **Stephanie Kienast (WHOI)**
- **Ryuji Tada (Tokyo)**
- **Jacqueline Flueckiger (Bern)**
- **Steve Calvert (UBC)**

The Original JGOFS Mission:

“To investigate the time-varying fluxes of carbon in the ocean”

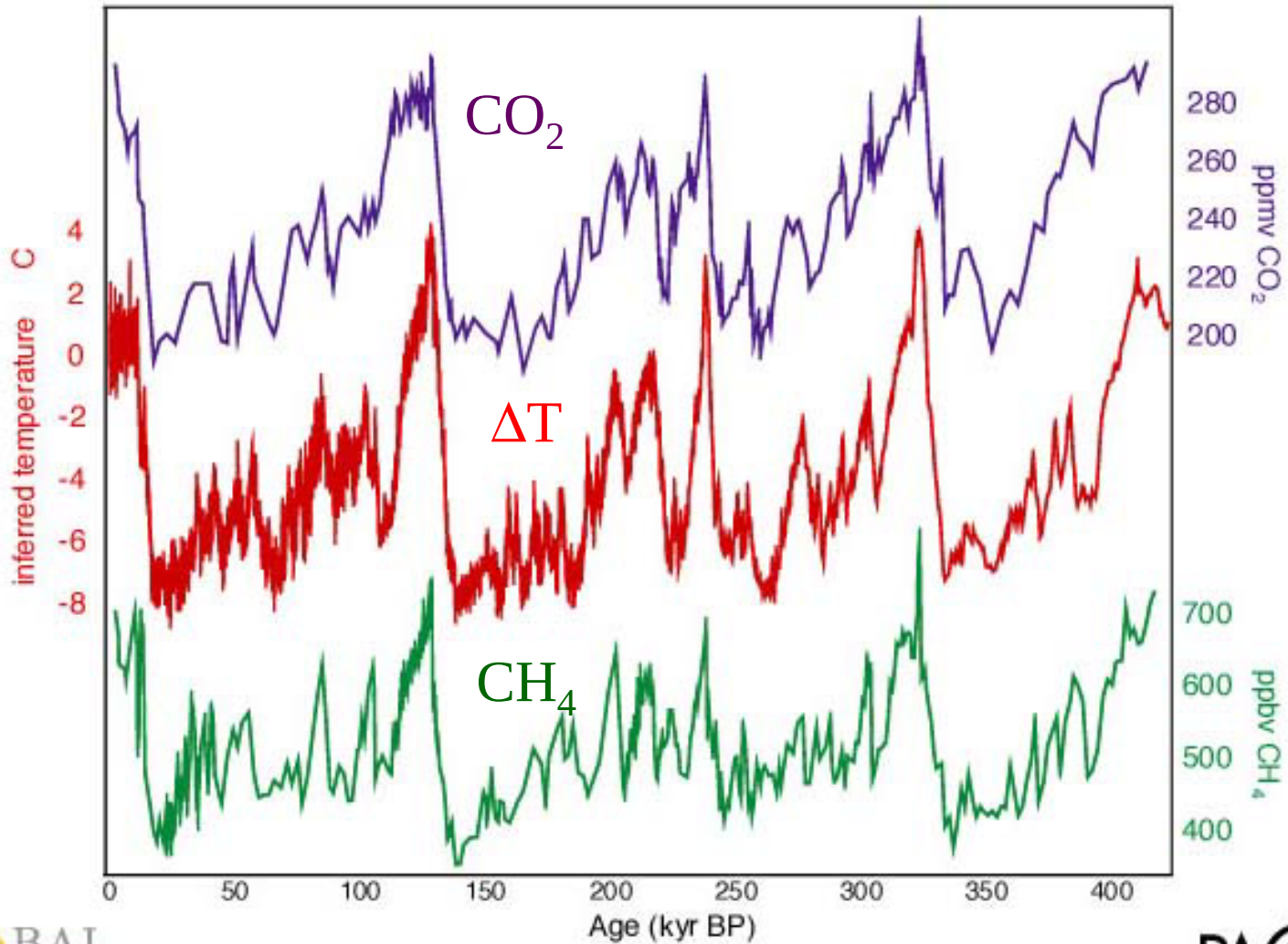
AII54-25PC
Central Panama Basin

500 kyr record of organic carbon abundance



Pedersen et al., 1991

4 glacial cycles recorded in the Vostok ice core



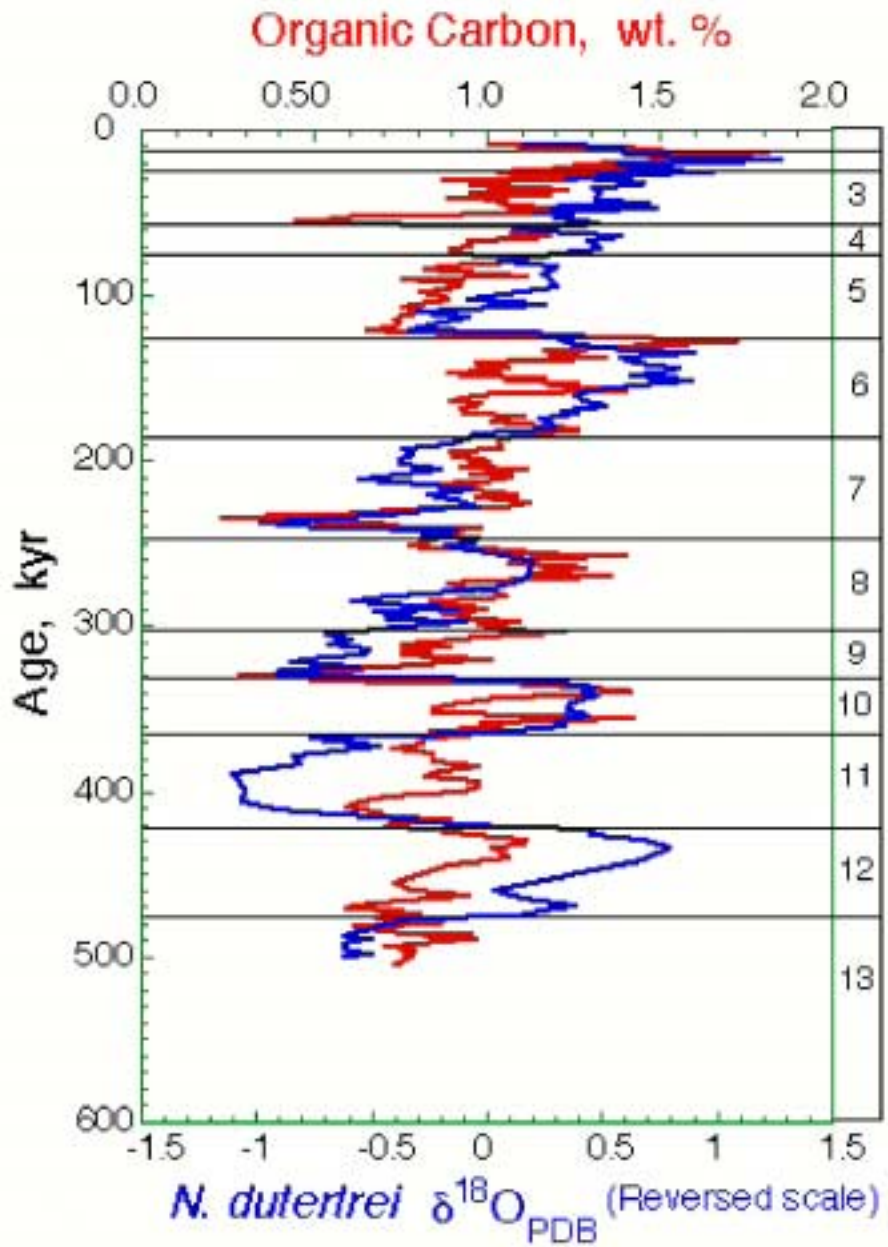
GLOBAL CHANGE IGBP

J.R. Petit et al., *Nature*, **399**, 429–36, 1999.

PAGES PAST GLOBAL CHANGES

AII54-25PC
Central Panama
Basin

500 kyr of Organic
Carbon Abundance



Nitrogen Isotopes As Paleotracers

- ***Relative Nutrient Utilization***

  Phytoplankton discriminate against ^{15}N (ε = ~5 ‰) when NO_3^- is abundant.

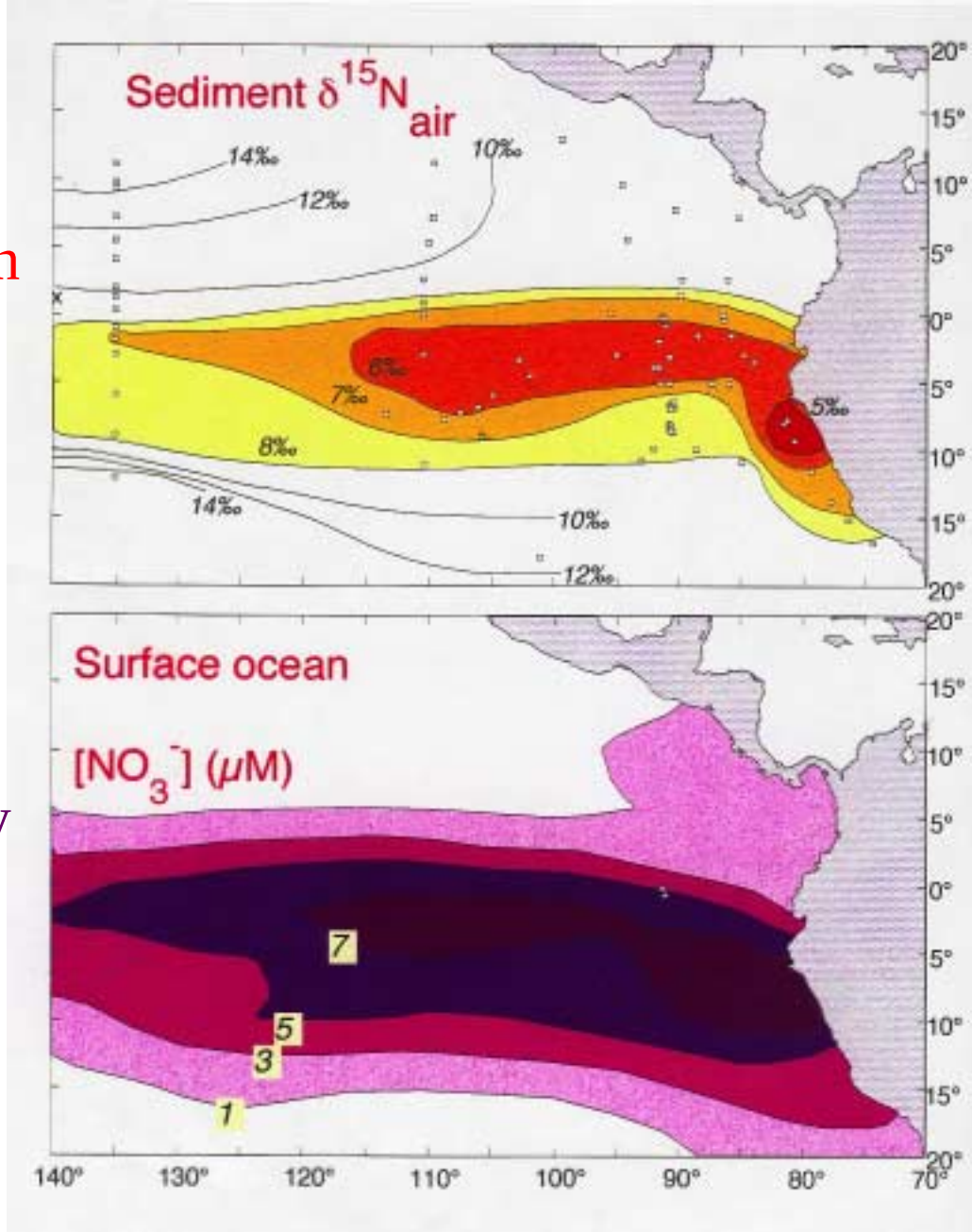
  As NO_3^- utilization proceeds with distance from the nitrate source, the product becomes isotopically heavier.
  Discrimination has little effect on $\delta^{15}N$ when NO_3^- is scarce.

- ***Denitrification***

Reduction of NO_3^- by denitrifying bacteria strongly fractionates the product N_2 (which is depleted in ^{15}N) from the substrate.
The residual NO_3^- becomes progressively enriched as denitrification proceeds and N_2 and N_2O are lost to the atmosphere.

Nitrogen Isotopes in Surface Sediments

Nitrate Climatology (Levitus)

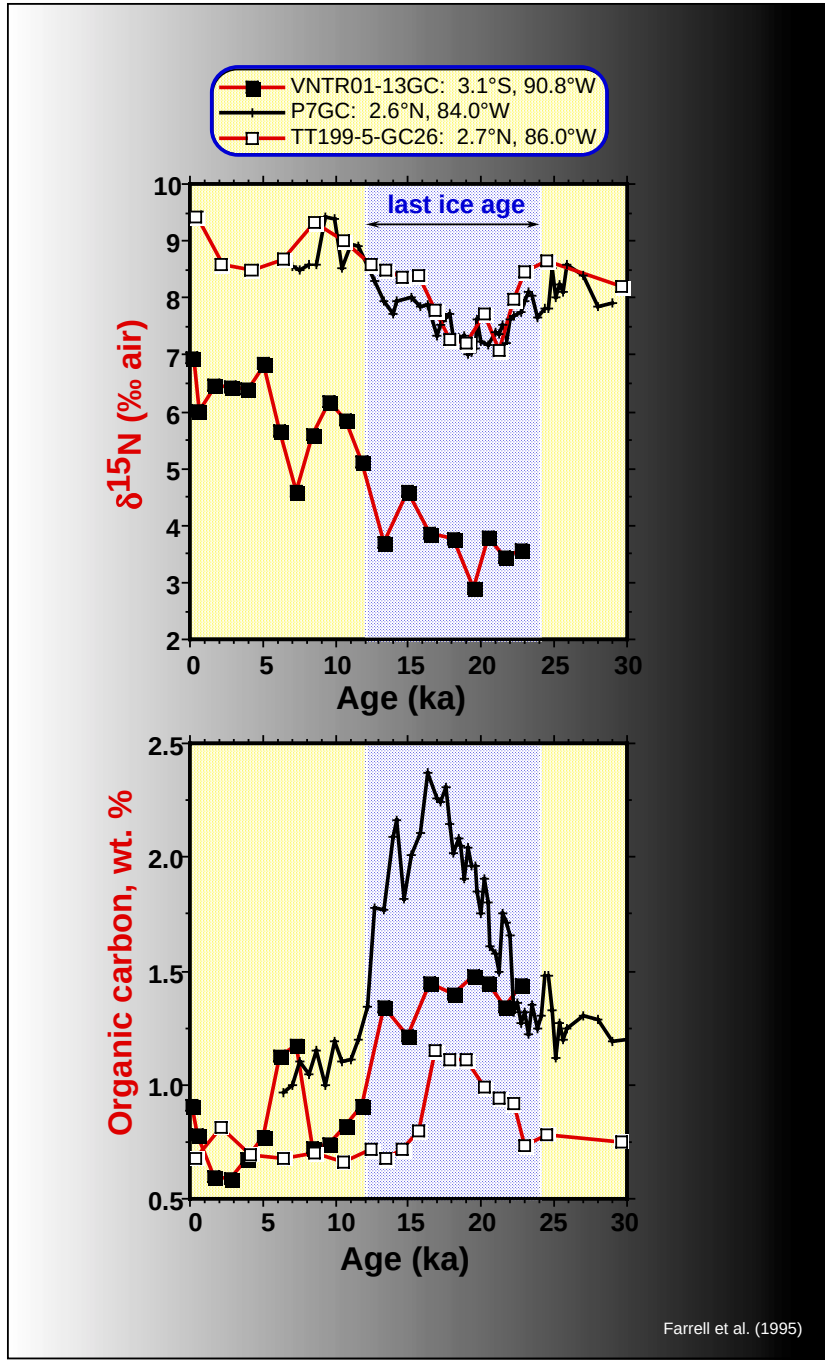


Farrell et al., 1995

Transect Across the Eastern Equatorial Pacific at ~90° W:

"Lighter" 15N during the LGM in conjunction with higher C_{org} % implies dominance of upwelling.

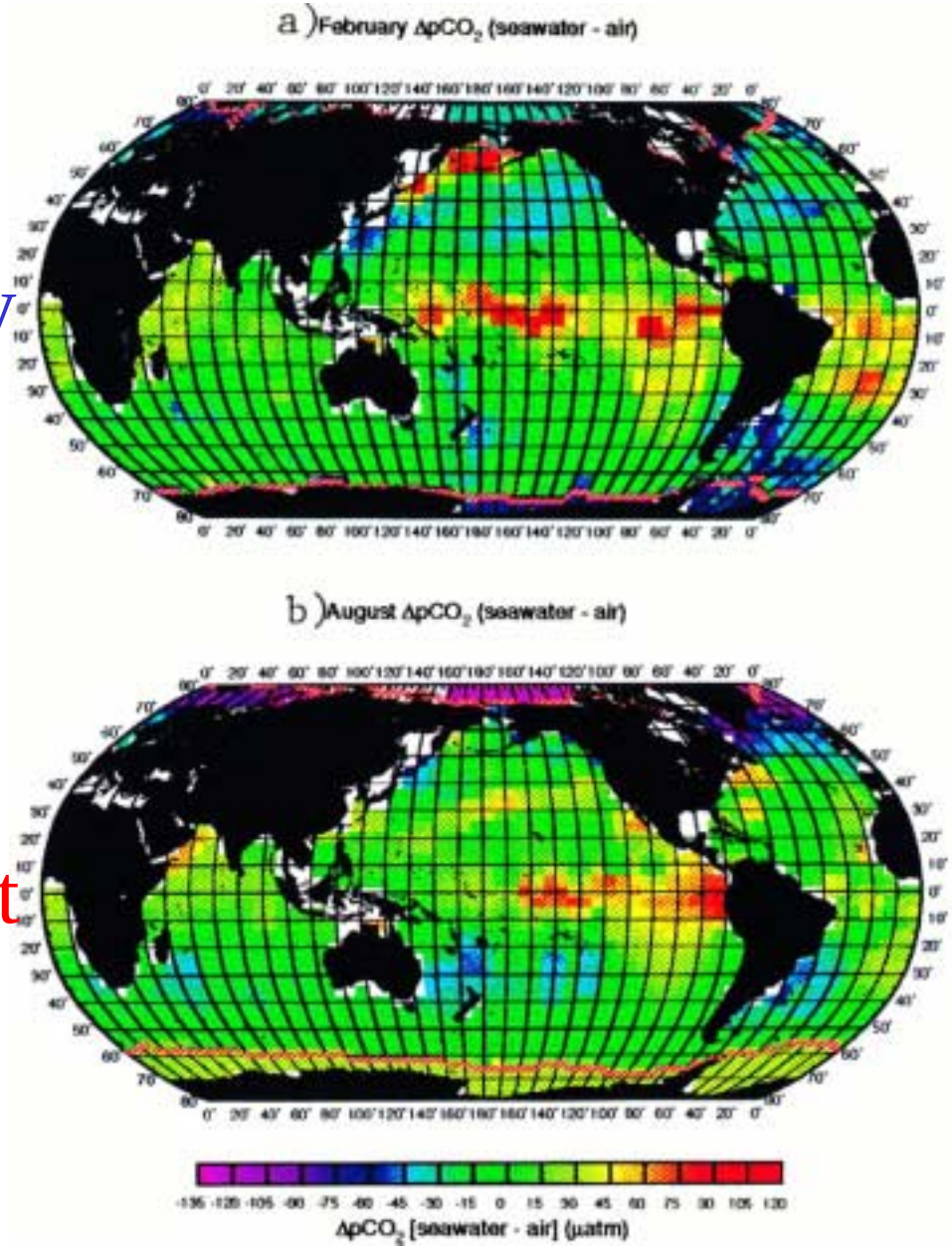
Farrell et al., 1995



Global ΔpCO_2, µatm

February

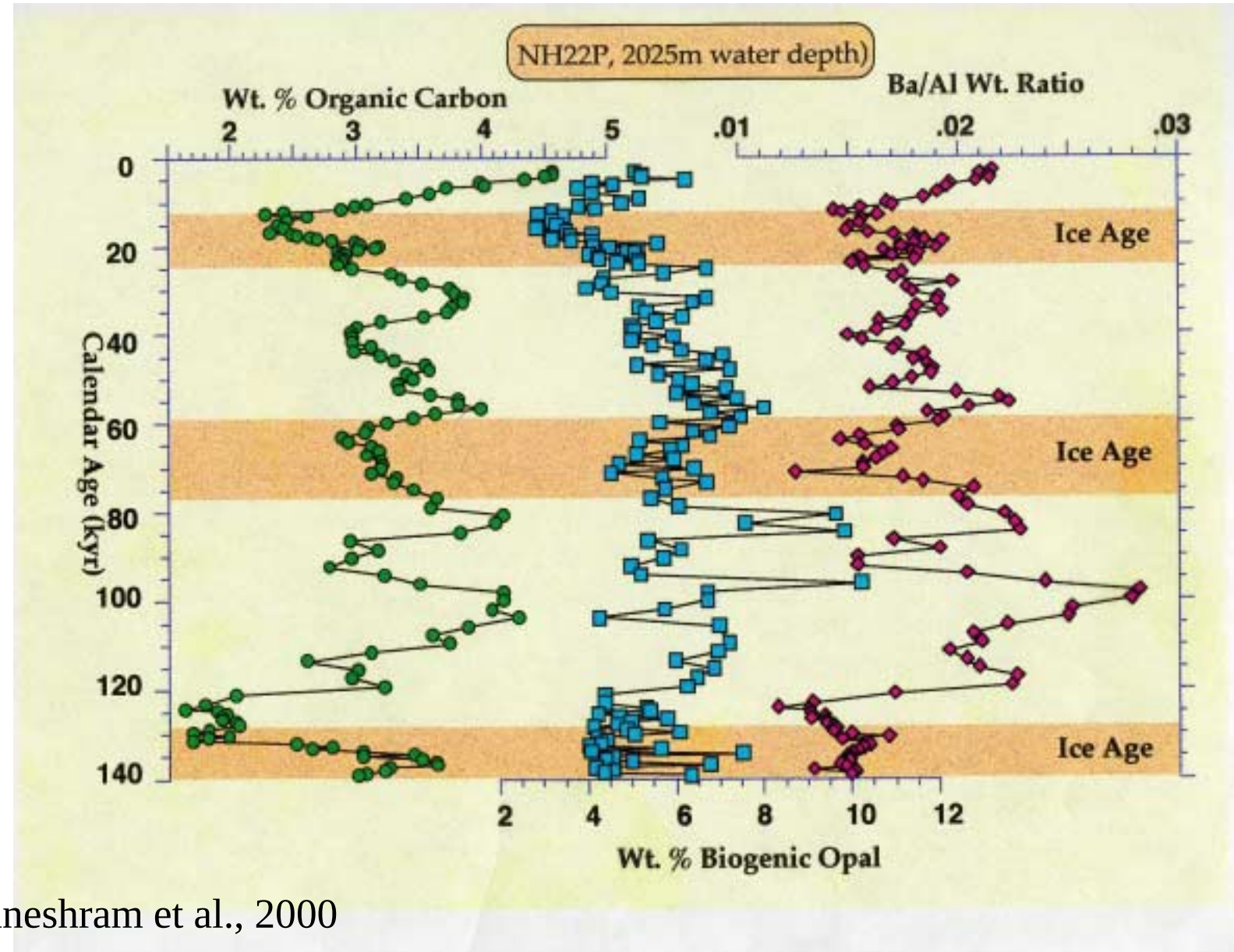
August



Takahashi et al.,
PNAS, 1997

But, when we moved from the open equatorial regions to the continental margins, a different picture emerged...

Paleoproductivity Indices, NW Mexican Margin, off Mazatlan



Ganeshram et al., 2000

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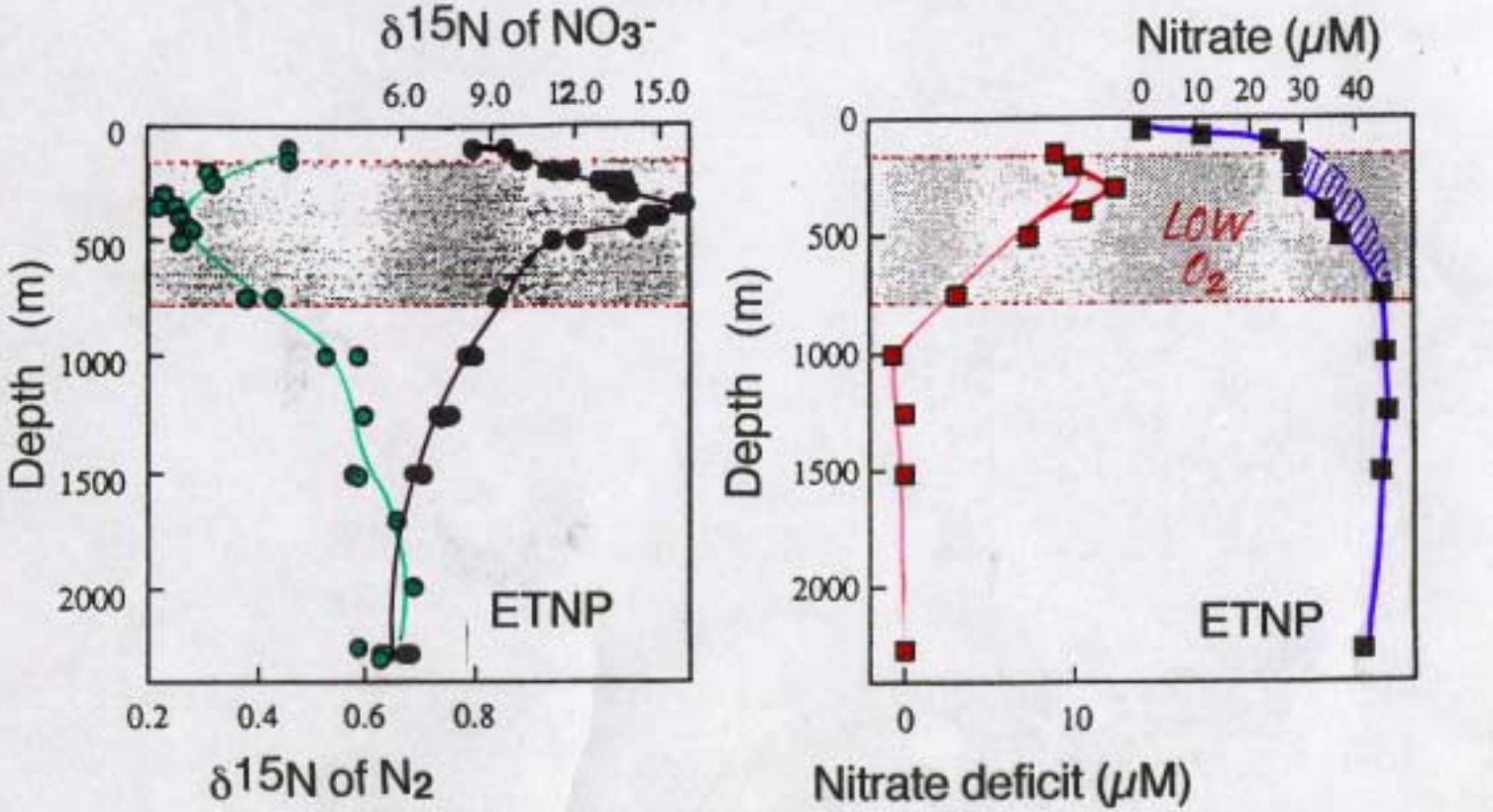
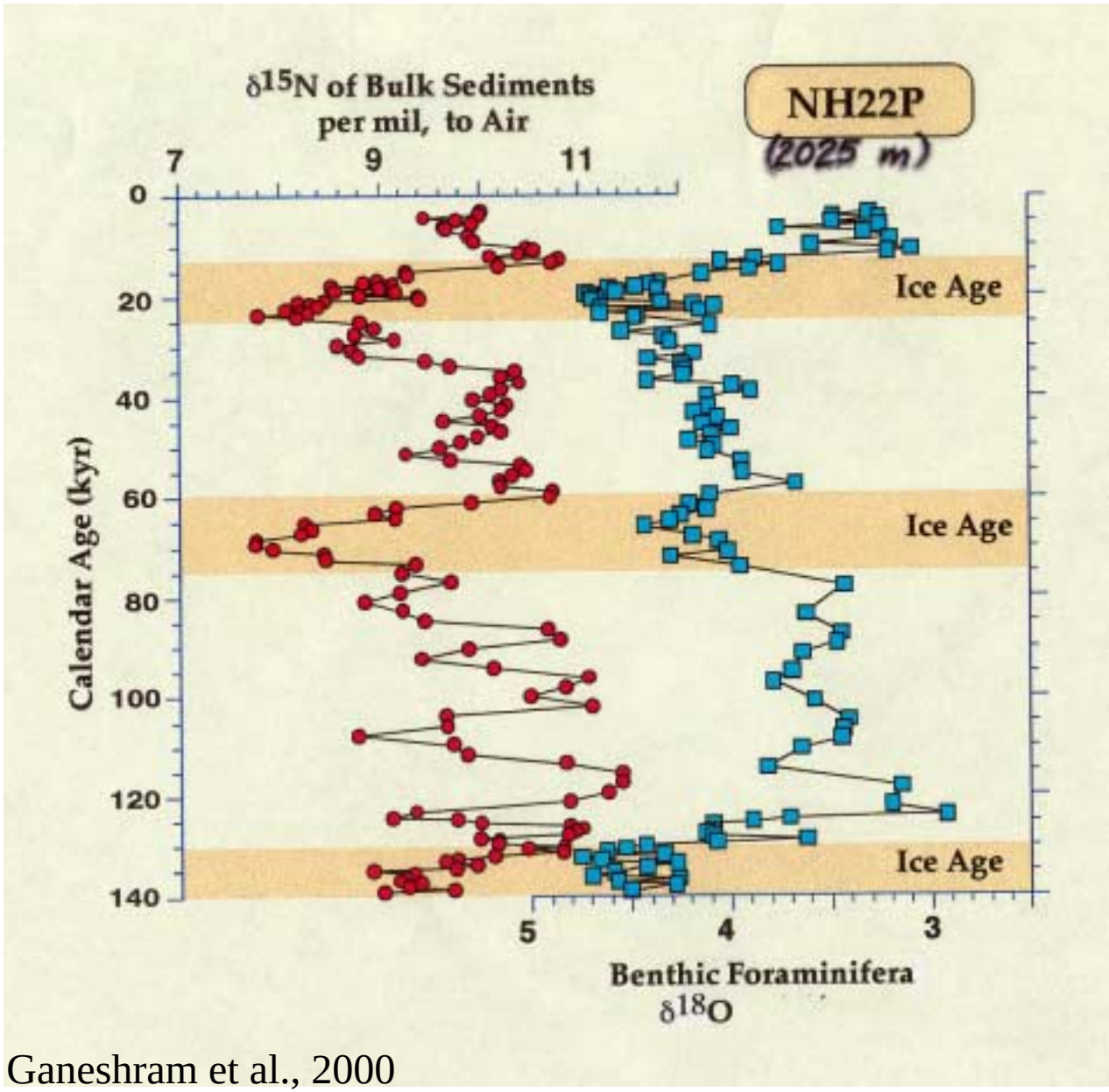
Nitrogen Species and Isotopic Composition in the Eastern Tropical North Pacific



Brandes et al., 1998, GBC

Proxy Denitrification History, NW Mexican Margin



Ganeshram et al., 2000

Dissolved Oxygen Concentration on the ~27.8 σ_T Surface

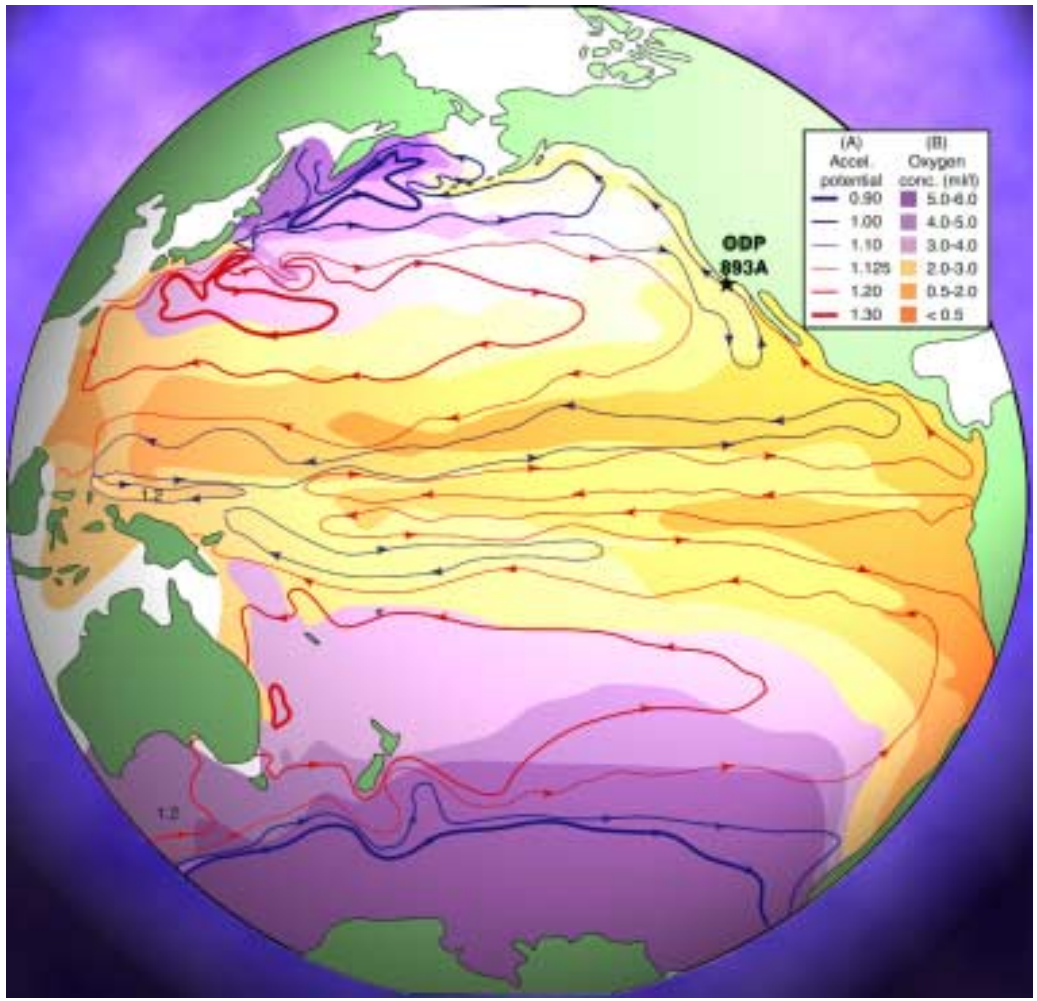
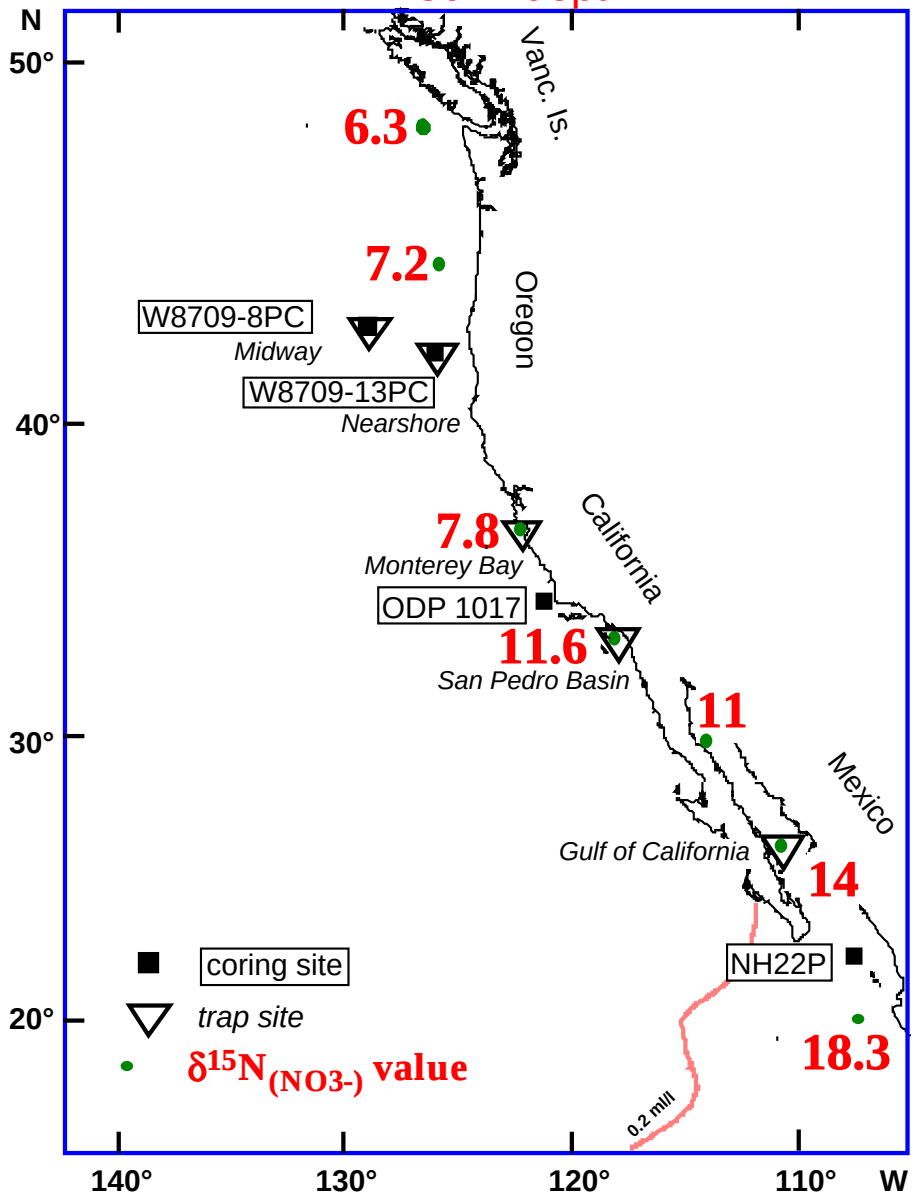
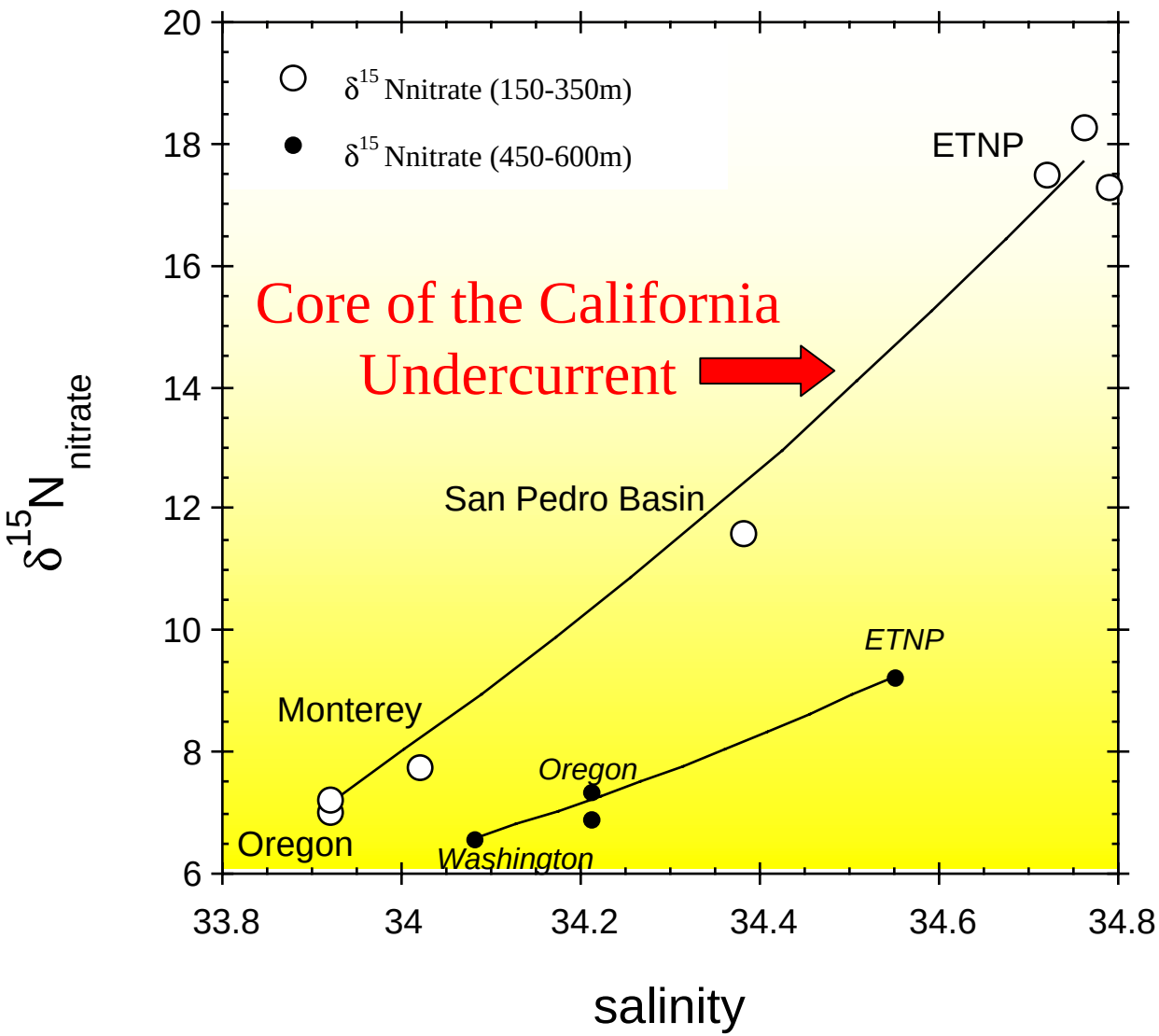


Illustration by Ingrid Hendy

Nitrate $\delta^{15}N$ in the California Undercurrent, ~250 m depth

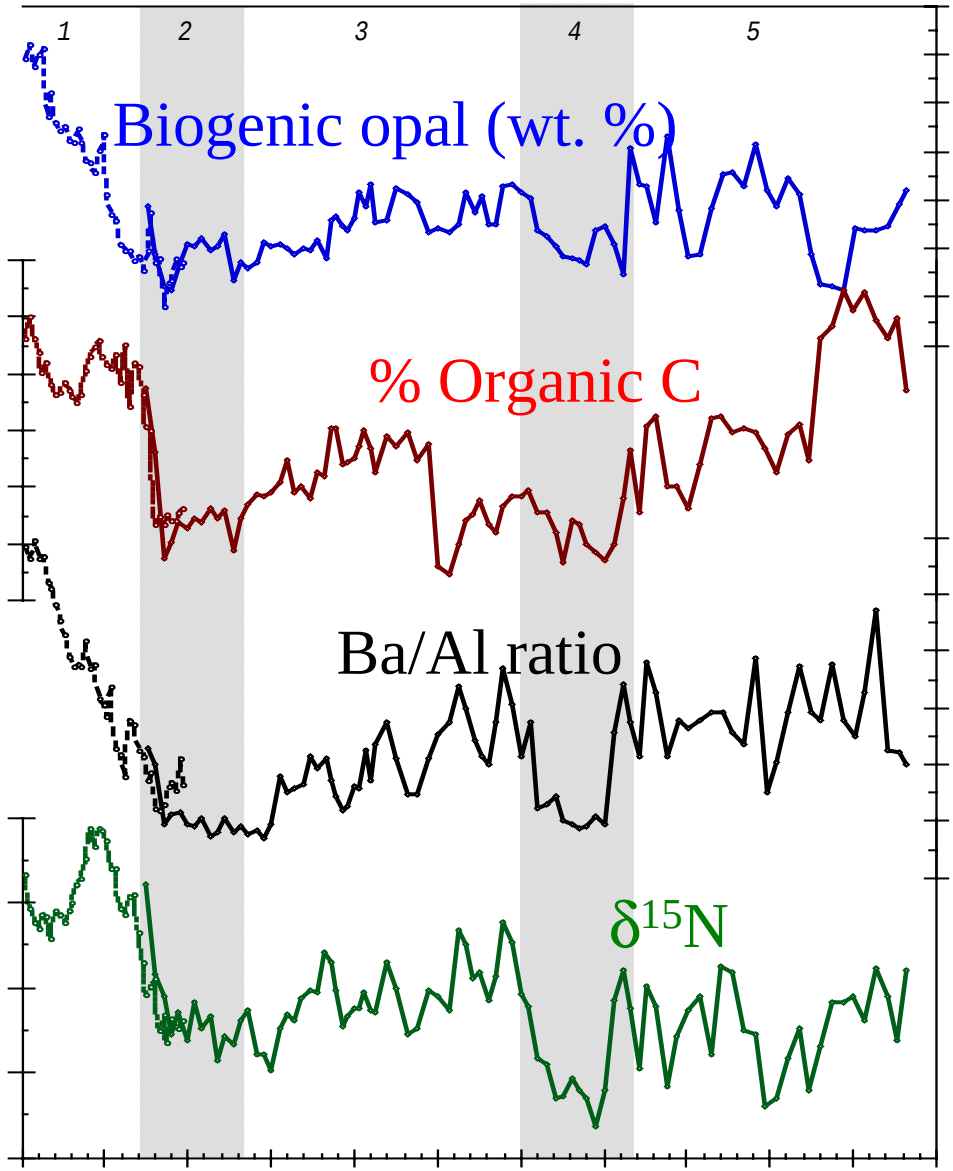


S. Kienast et al., 2002, Paleoceanography



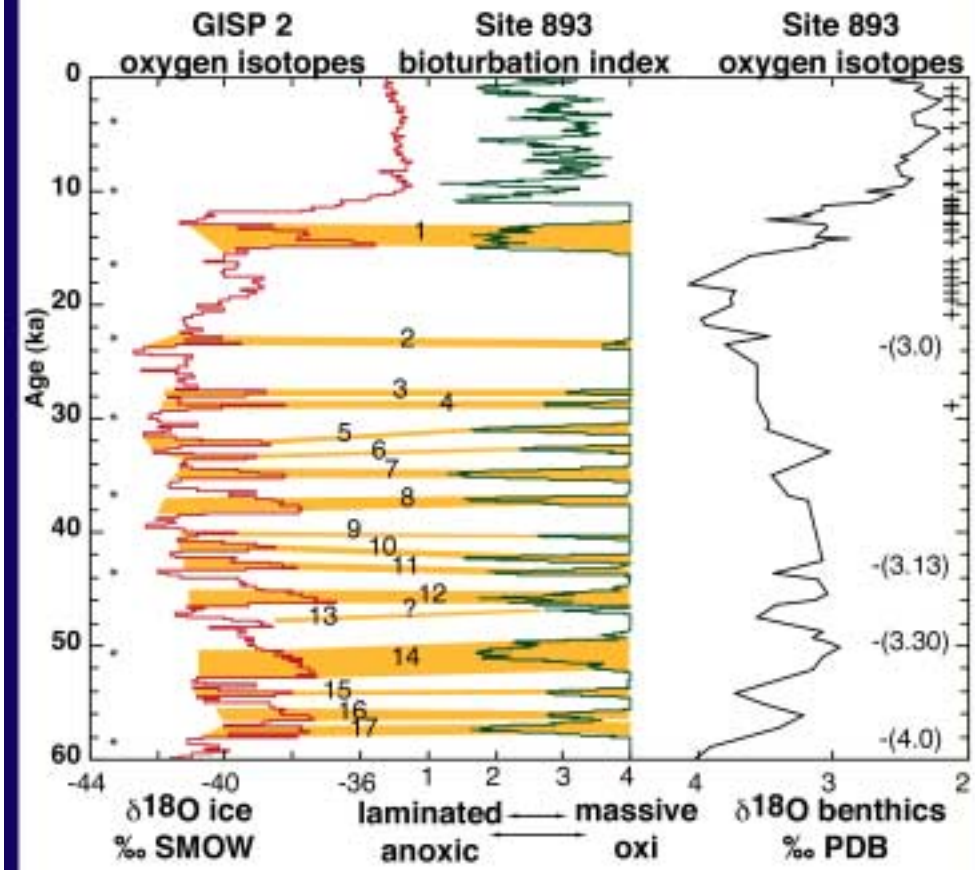
Kienast et al. 2002

Oregon Margin, 3111 m Water Depth



S. Kienast et al., 2002,
Paleoceanography

Stadial/Interstadial Transitions in the Santa Barbara Basin

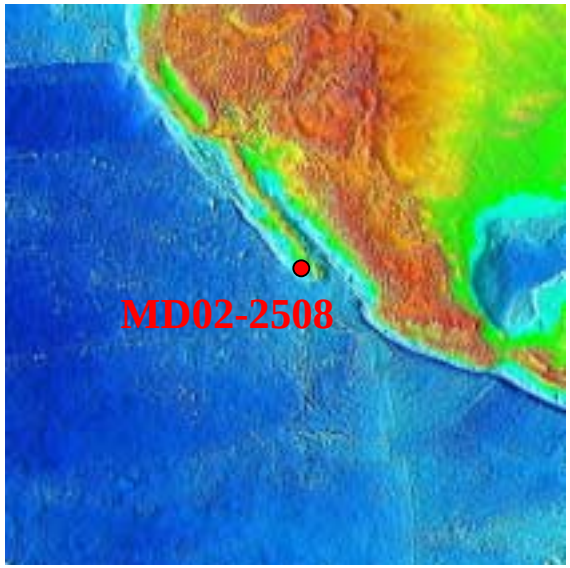


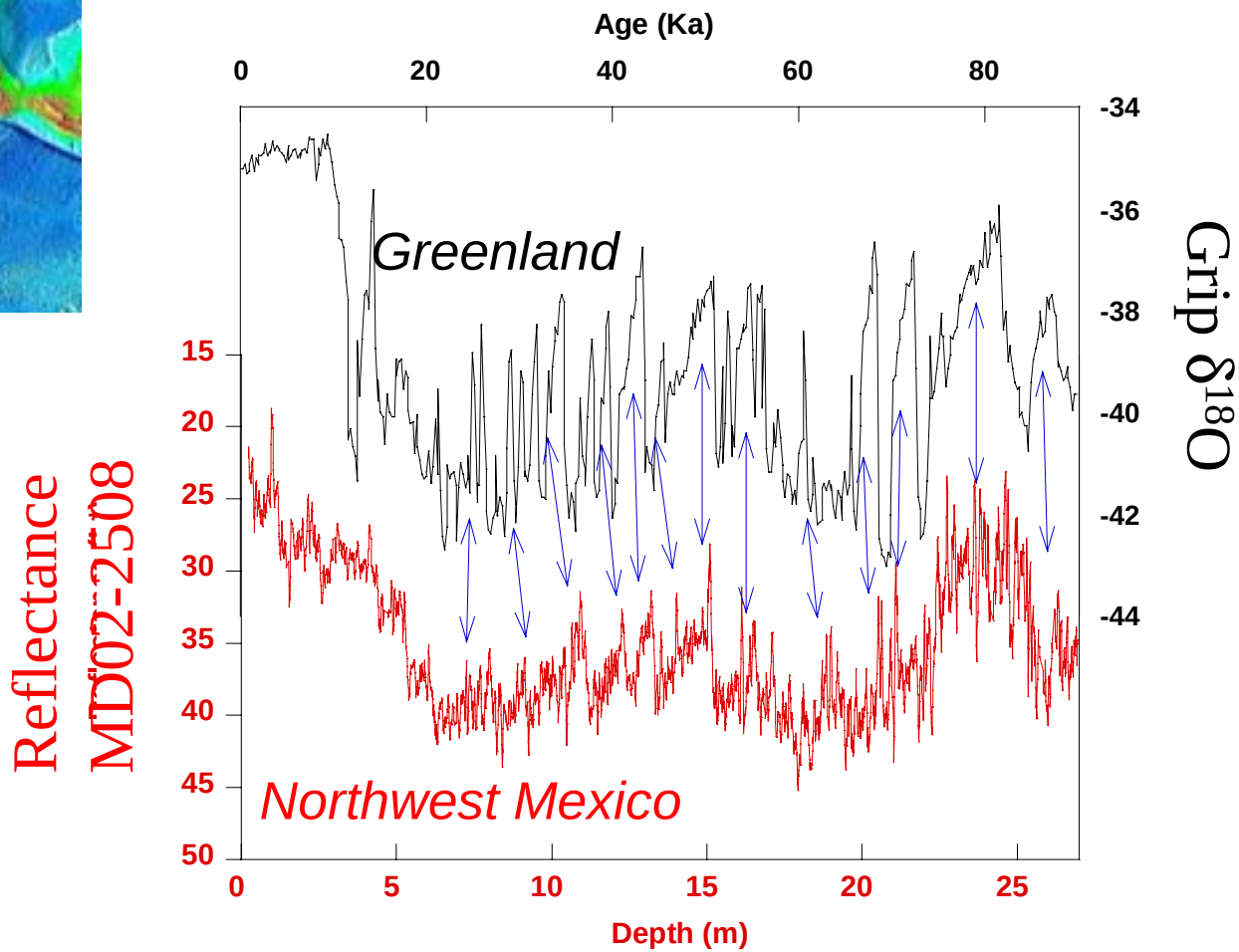
GLOBAL CHANGE
I G B P

Behl and Kennet (1996)
Nature, 379, 243-246.

PAGES
PAST GLOBAL CHANGES

Greenland-Baja Comparison

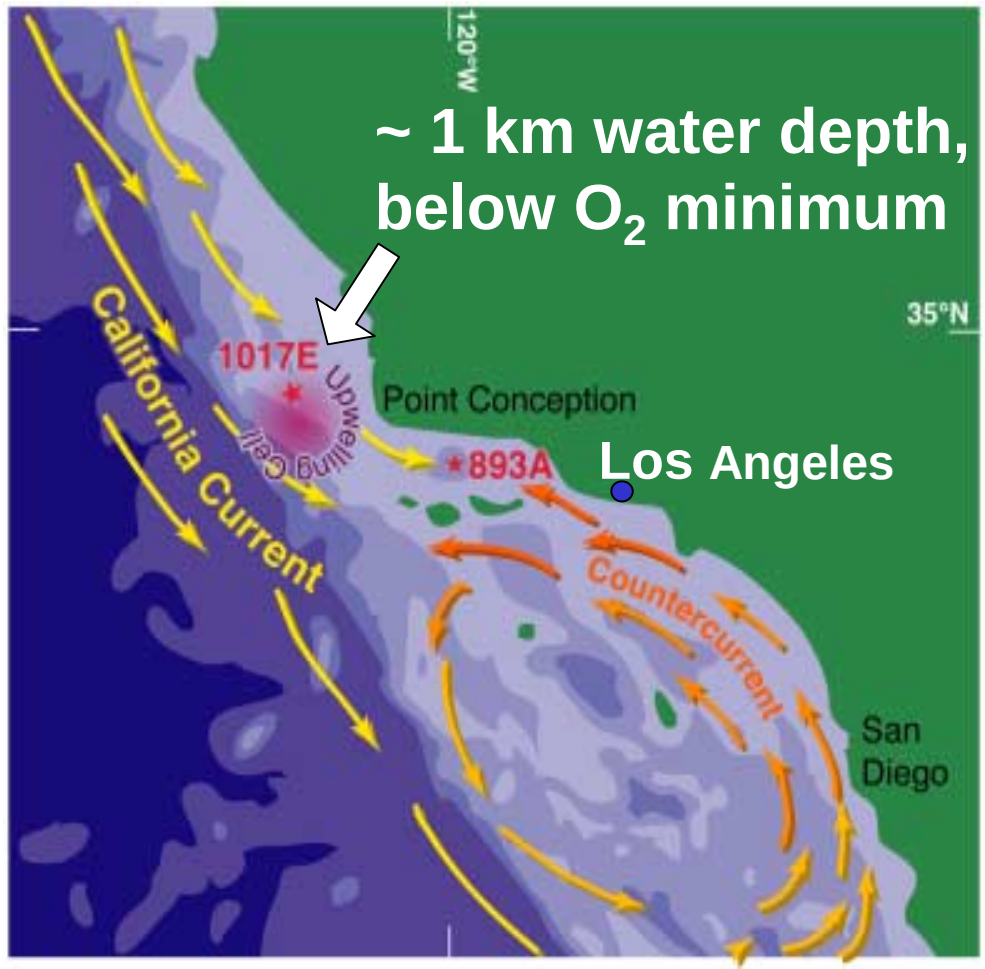




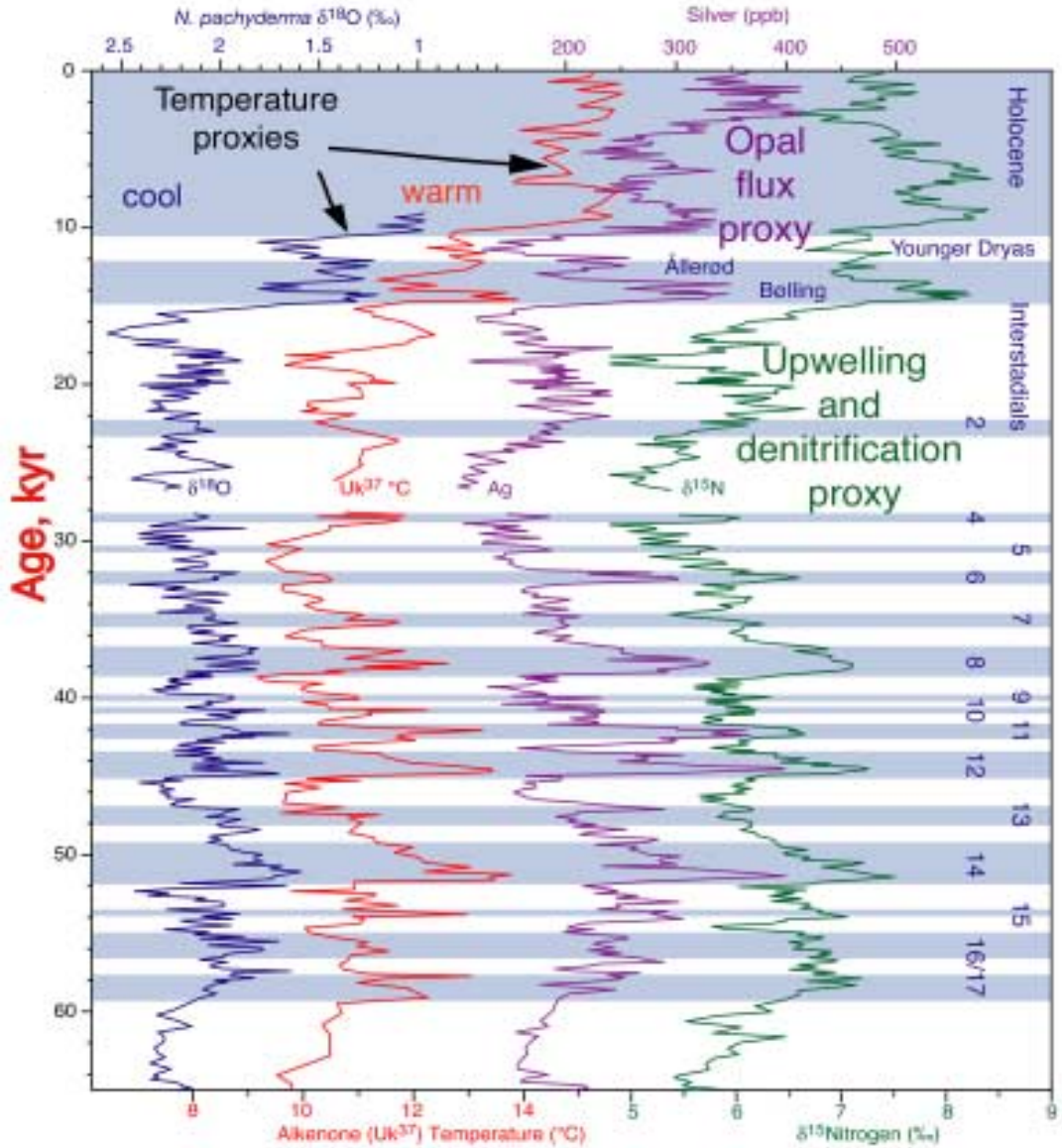
CORE MD02-2508 Cruise MONA-IMAGES VIII (June 2002)
Location : Western Margin of Baja California

MONA Shipboard Party, unpublished

Key Coring Sites and Surface Currents, Southern Californian Margin



ODP Hole 1017E, S. California Margin
1 km water depth



Hendy and Pedersen, in prep

Dissolved Oxygen Concentration on the ~27.8 σ_T Surface

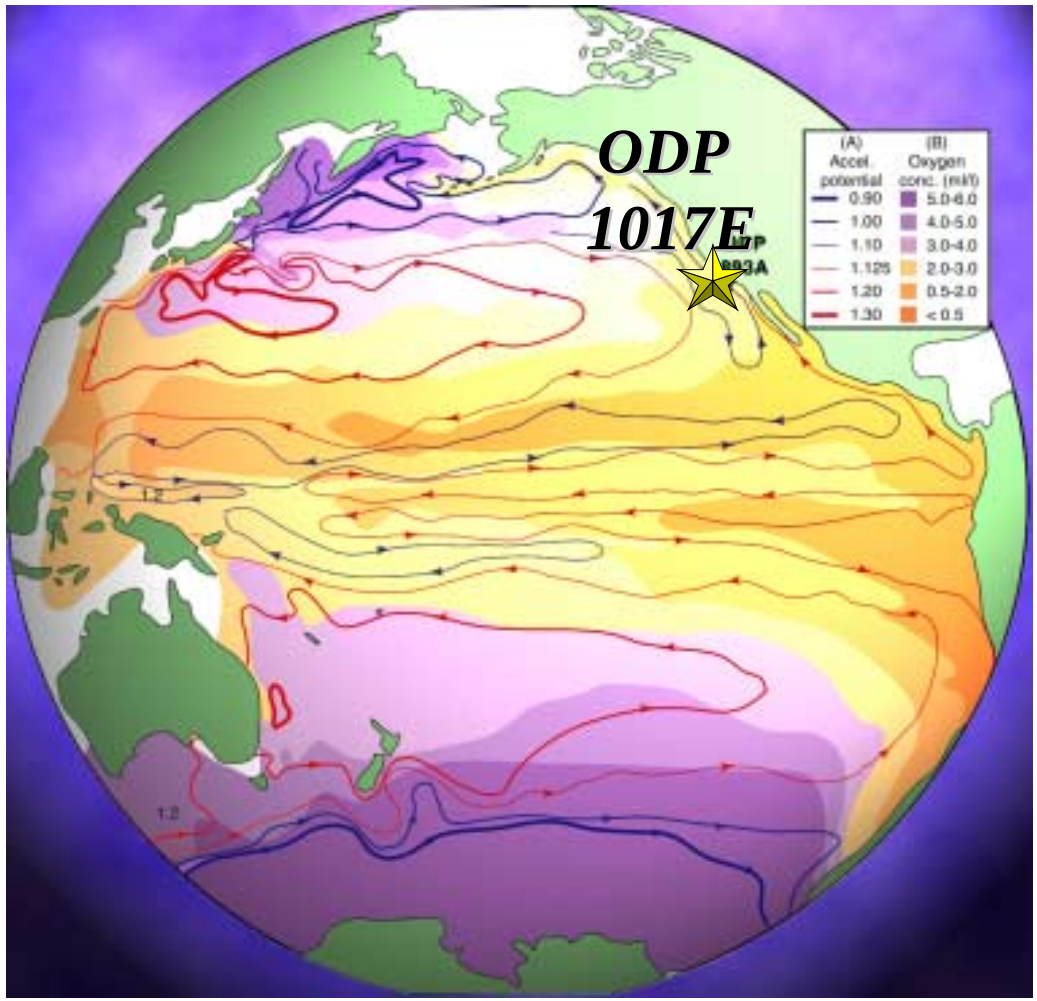


Illustration by Ingrid Hendy

ODP Hole 1017E, S. California Margin
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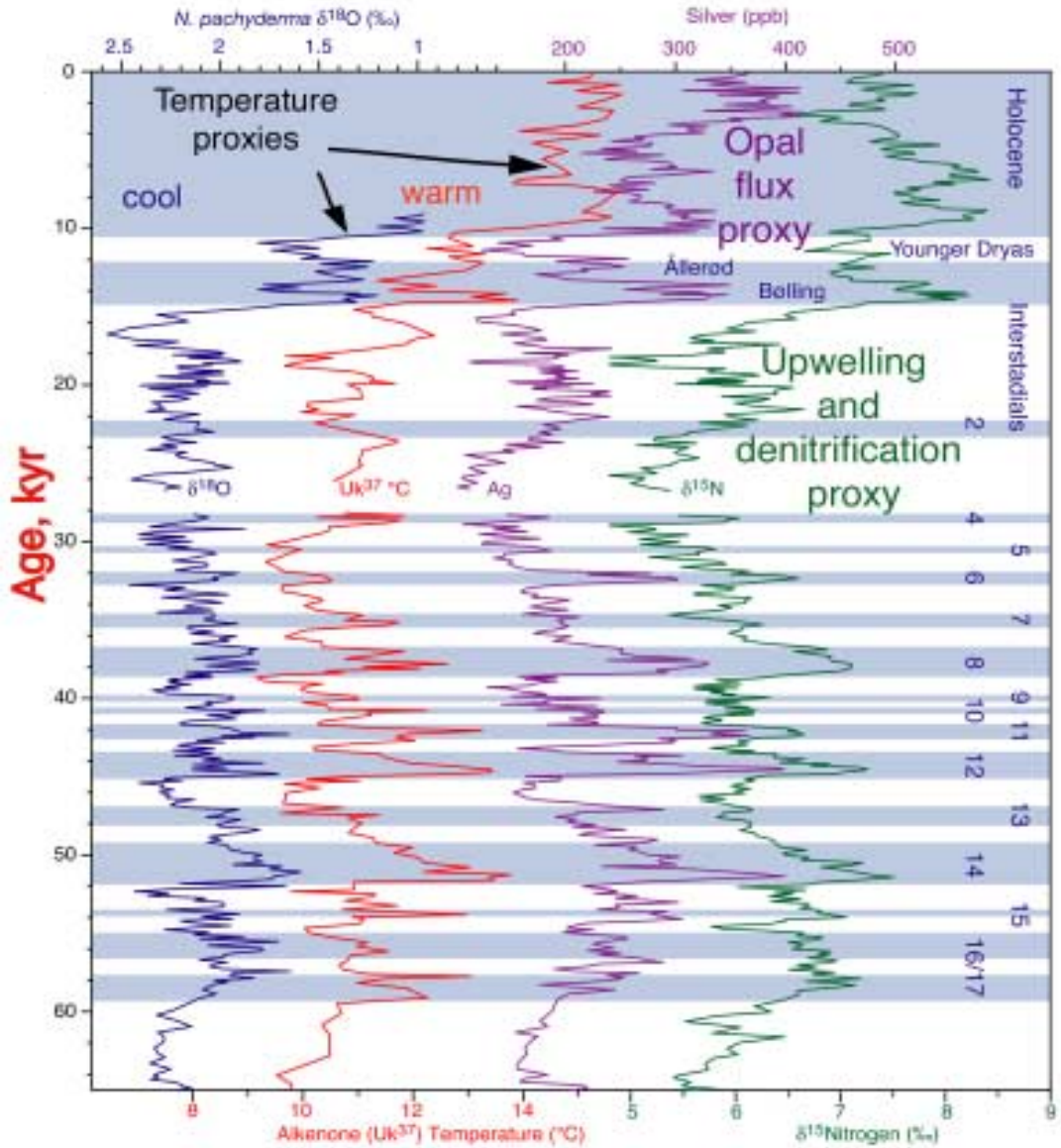
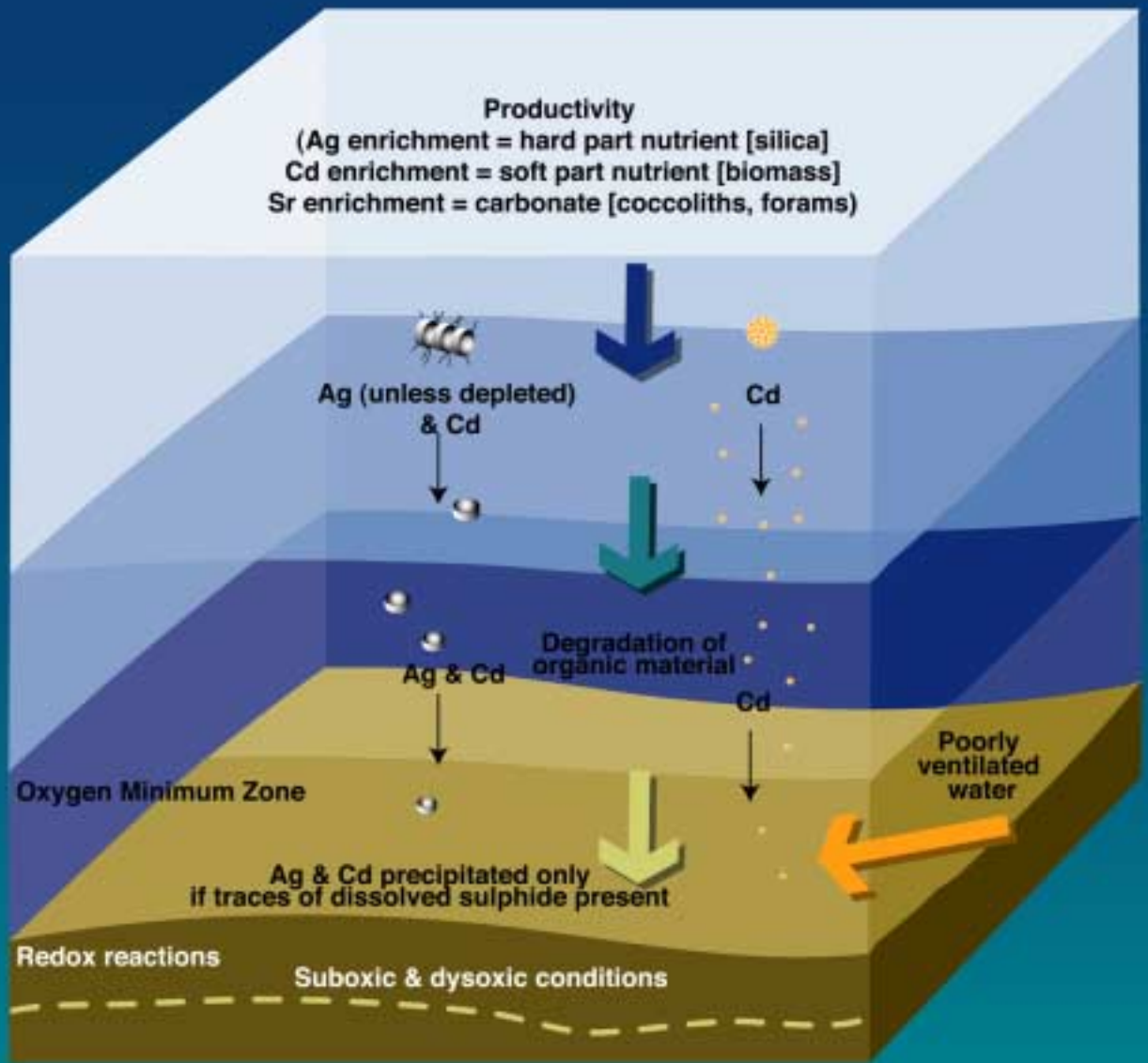


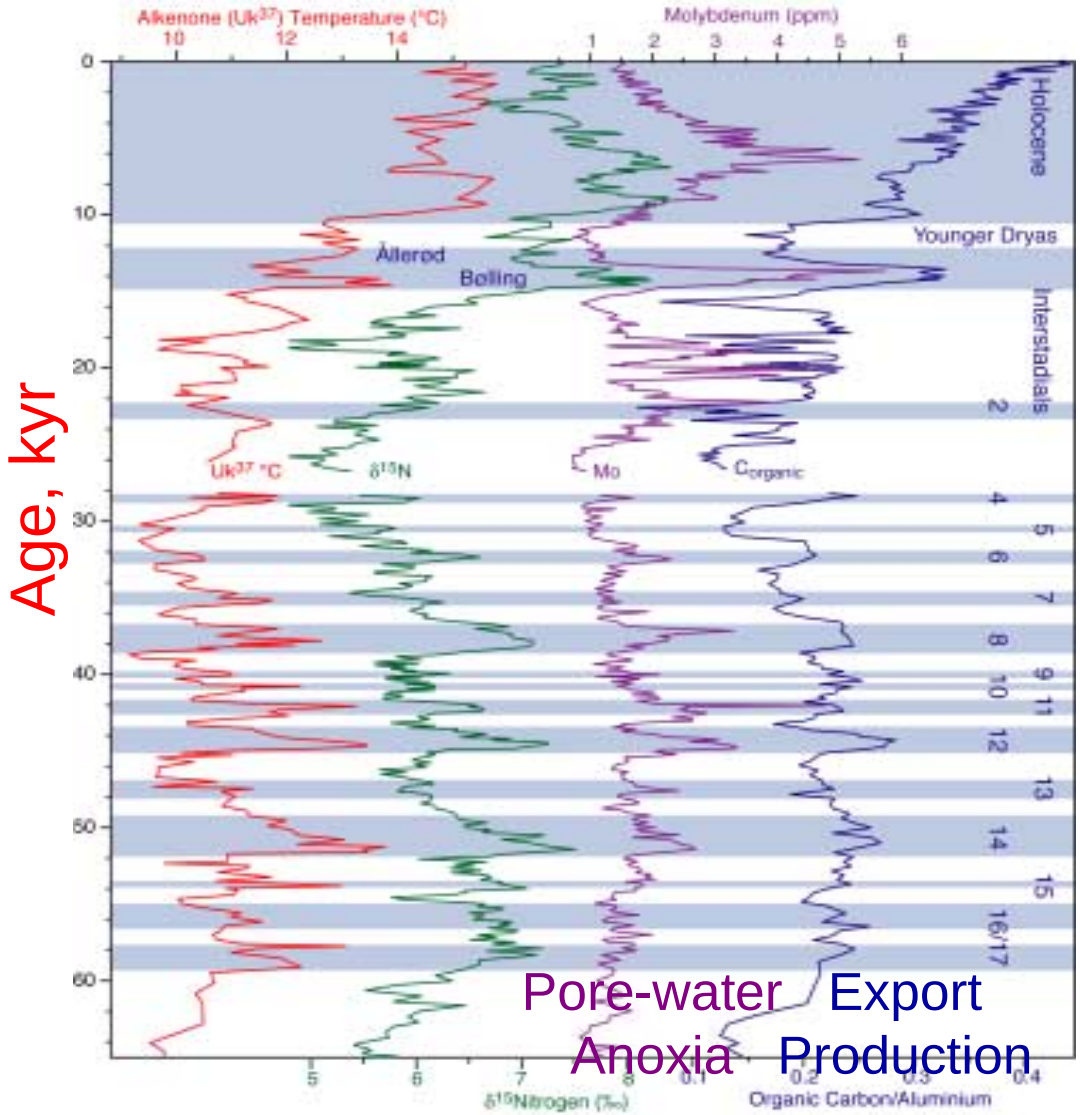
Hendy and Pedersen, in prep

Silver and Cadmium



The Ag/Cd ratio is thought to represent increases/decreases in diatom production relative to coccolithosphorids

ODP Hole 1017E, S. California Margin
1 km water depth



Hendy and Pedersen, in prep

Summary 1:

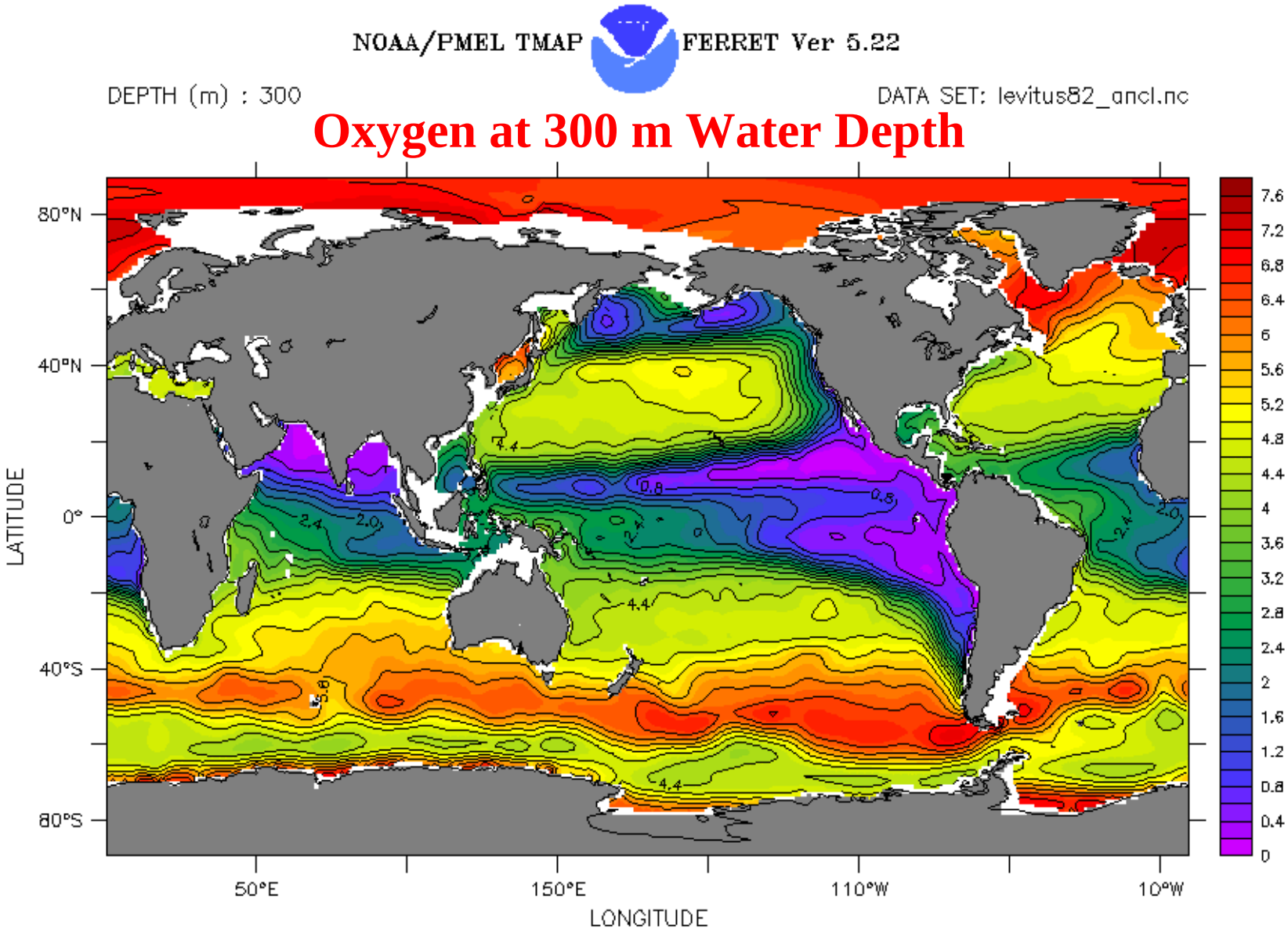
• Abrupt climate and hydrographic changes were common and possibly (probably?) synchronous in the North Atlantic and the NE Pacific during the Last Glacial.

• Off California, climate variations were accompanied by biological responses in surface waters ***and*** changes in oxygenation at 1 km water depth.

• The time-varying vertical flux of carbon (JGOFS!) was a (critical?) factor in modulating intensity of denitrification in the northeast subtropical Pacific.

A final question:

Are there implications for global climate bound up in variations in the intensity of denitrification in the NE tropical Pacific (and elsewhere)?


NOAA/PMEL TMAP
FERRET Ver 5.22
DEPTH (m) : 300
DATA SET: levitus82_ancl.nc
Oxygen at 300 m Water Depth
80°N
40°N
0°
40°S
80°S
LATITUDE
50°E
150°E
110°W
10°W
LONGITUDE
7.6
7.2
6.8
6.4
6
5.6
5.2
4.8
4.4
4
3.6
3.2
2.8
2.4
2
1.6
1.2
0.8
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0
DISSOLVED OXYGEN (ML/L)

Modern N cycle background:

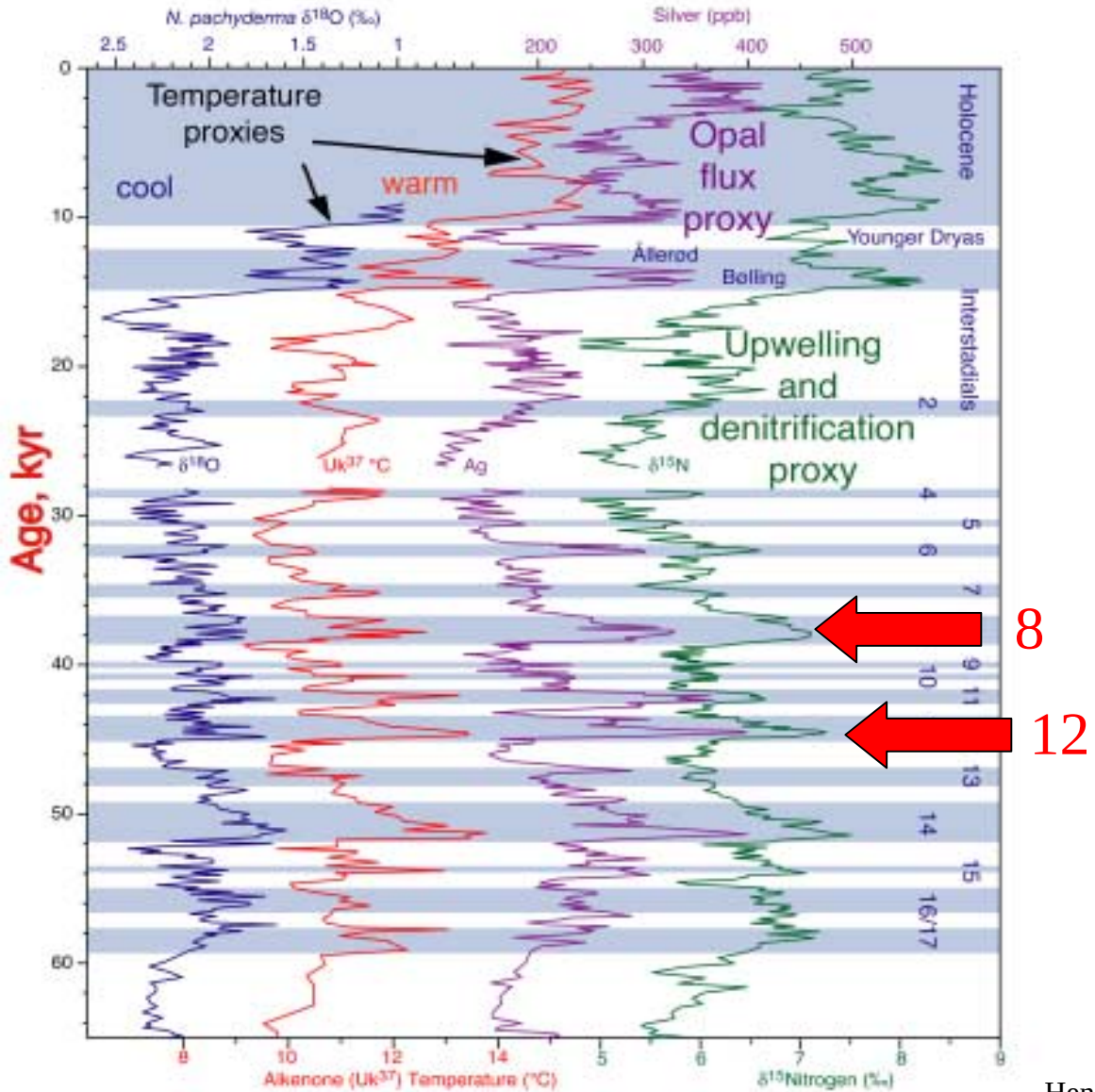
Fixed N supply to oceans is ~100-120 Tg yr^{-1}, but the loss is roughly 200 Tg yr^{-1}. ***Deficit: <100 Tg yr^{-1}***.

Imbalance is partly compensated by N_2 fixation, but the integrated contribution from this source is not well known.

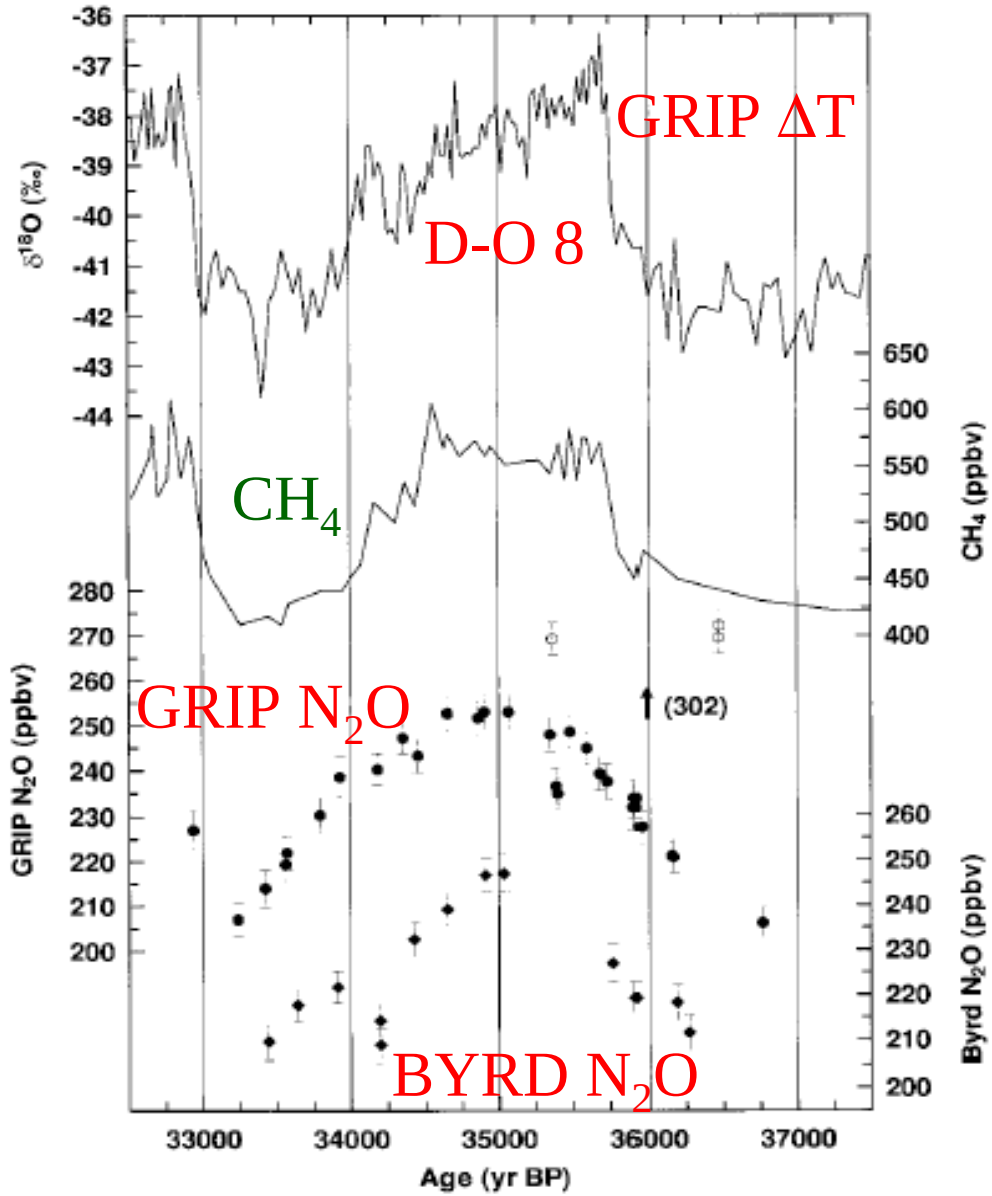
Implication:

The modern ocean is losing nitrogen. But if NO_3^- reduction was to be switched off, there would be a net gain of N, allowing "excess" P to be utilized and CO_2 to be drawn down.

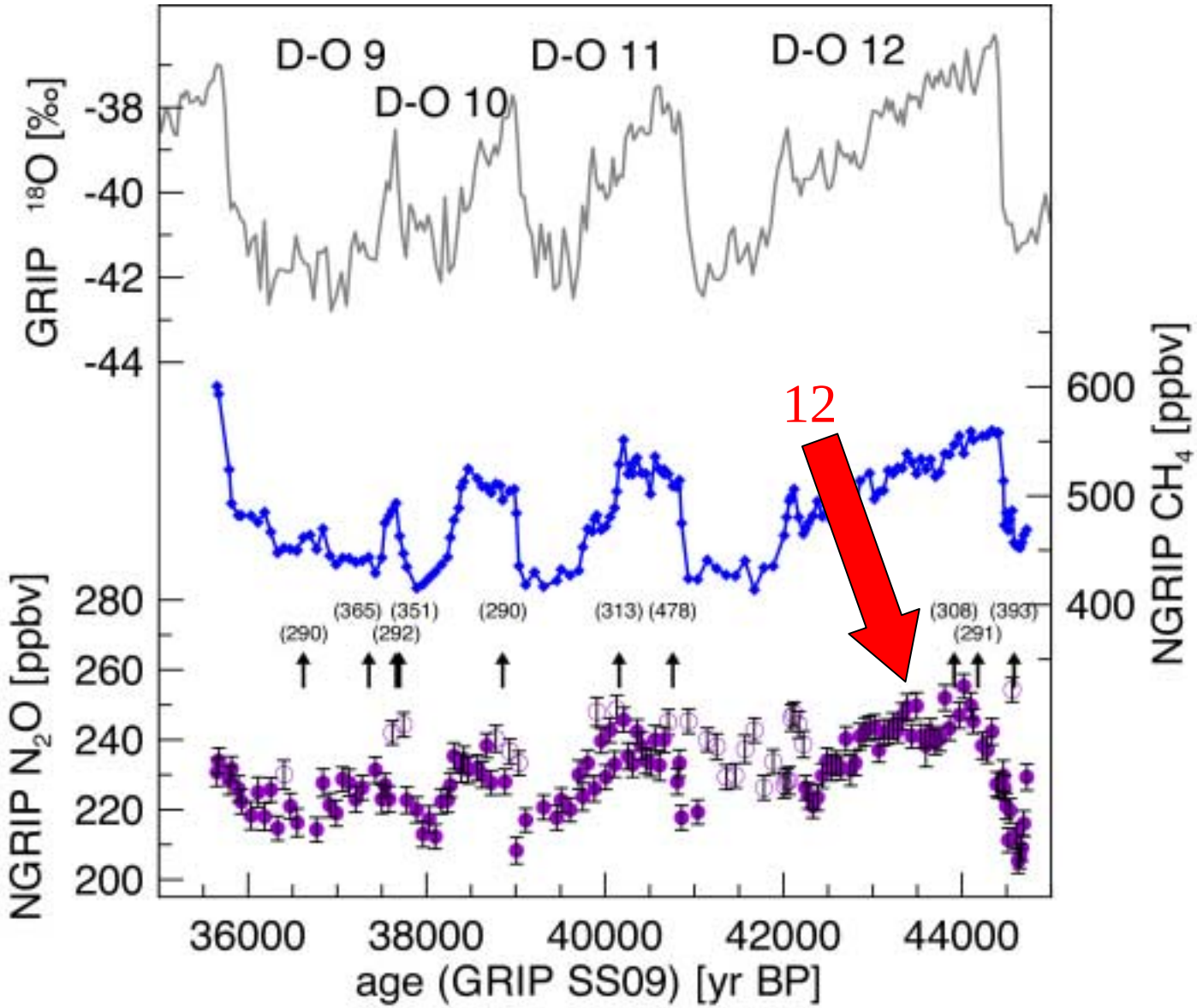
ODP Hole 1017E, S. California Margin
1 km water depth



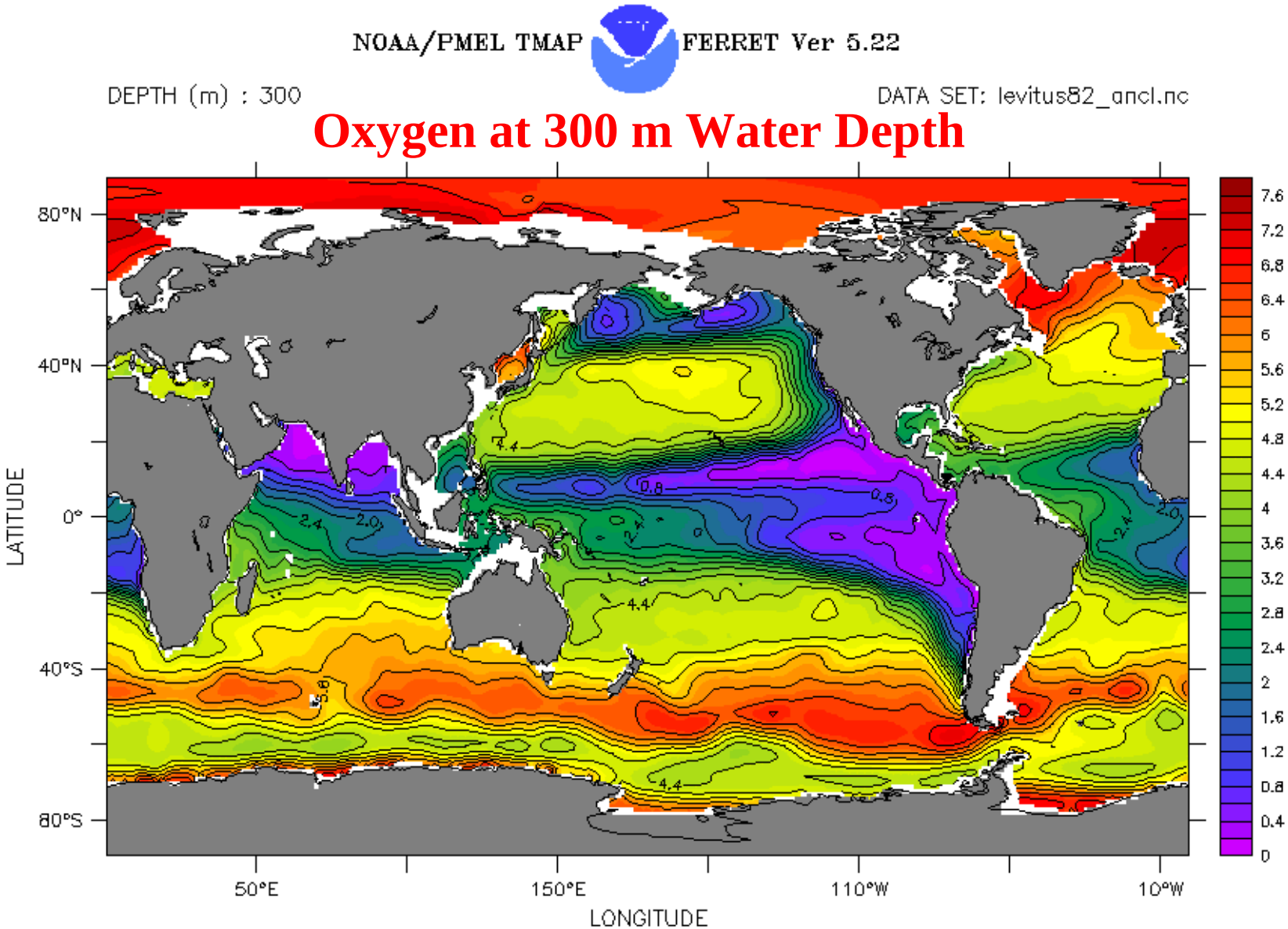
Hendy and Pedersen, in prep



Flueckiger et al., Science, 1999



Unpublished data, courtesy Jacqueline Flueckiger, University of Bern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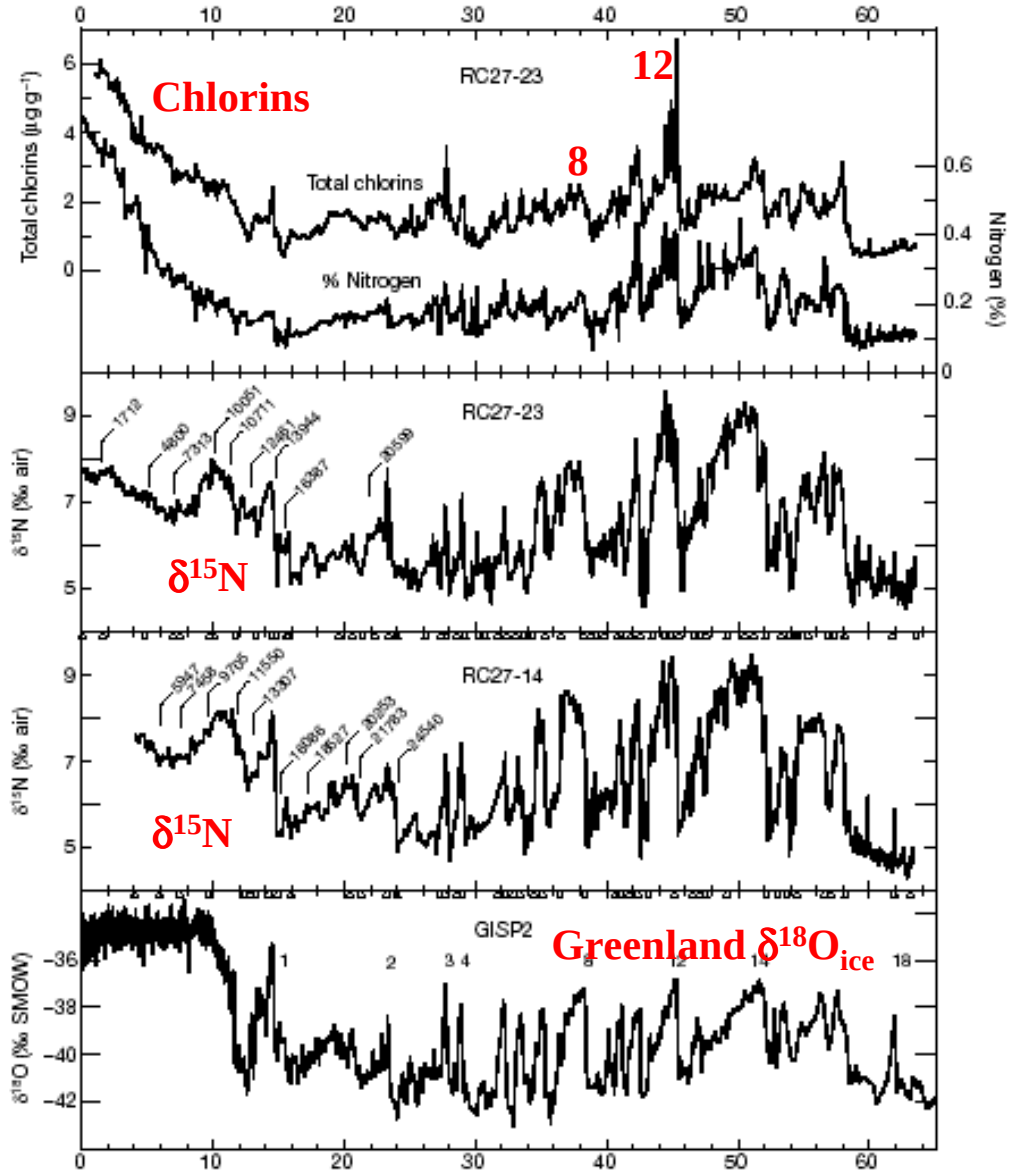
DISSOLVED OXYGEN (ML/L)

Oman Margin, Arabian Sea

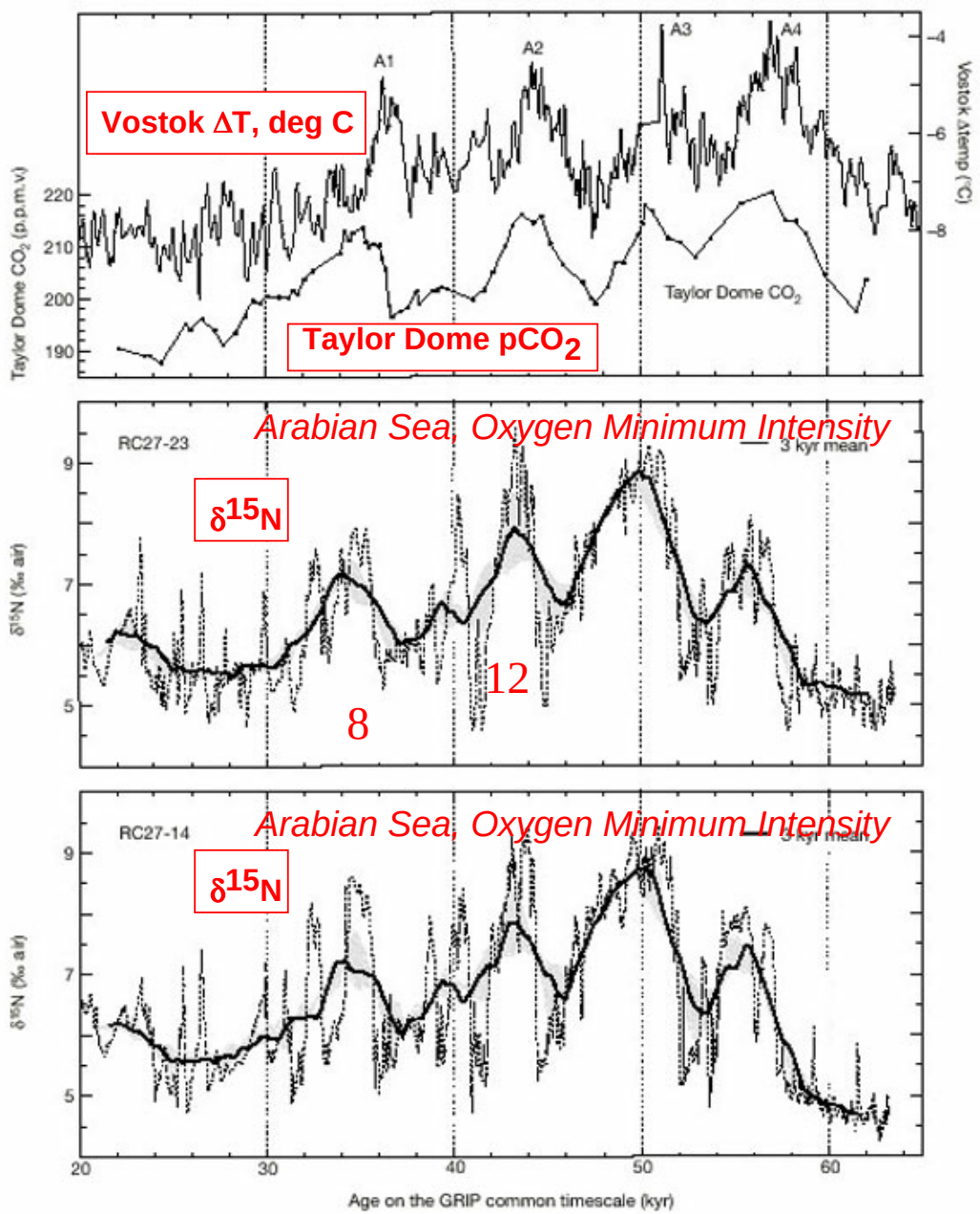
Altabet et al., 2002
Nature



High-frequency variability of denitrification intensity in the Arabian Sea

Altabet et al., 2002

NB: the timescale for the Arabian Sea cores is not independent, but was derived by correlation to GRIP. It is thus assumption dependent.



Altabet et al., 2002

Summary 2:

• The coupling of upwelling, export production and consequent denitrification in key oxygen minima may have had significant implications for climate but ***indirectly***, through the nutrient-abundance loop.

• Emerging pN_2O records support this inference.

• With respect to the impact of the time-varying fluxes of carbon on pCO_2, both quantification and attribution remain compelling problems.

Continuing Challenges or Needs: (PaleoJGOFS II?)

• More high-resolution paleogeochemical records from underexplored areas (e.g. the western coast of South America, the western Canadian margin, the Guatemalan margin).

• Continued refinement of interpretations based on empirical data with inferences from modelling (and vice versa). *Integration and interdisciplinarity remain key*.