Seeing the Past Through JGOFS Spectacles

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**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

\[ \text{CO}_2 \]

\[ \Delta T \]

\[ \text{CH}_4 \]

Age (kyr BP)


AII54-25PC
Central Panama Basin

500 kyr of Organic Carbon Abundance
Nitrogen Isotopes As Paleotracers

- **Relative Nutrient Utilization**
  Phytoplankton discriminate against $^{15}\text{N}$ ($\varepsilon = -5 \, ^\circ$) 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 $\delta^{15}\text{N}$ when NO$_3^-$ is scarce.

- **Denitrification**
  Reduction of NO$_3^-$ by denitrifying bacteria strongly fractionates the product N$_2$ (which is depleted in $^{15}\text{N}$) from the substrate.
  The residual NO$_3^-$ becomes progressively enriched as denitrification proceeds and N$_2$ and N$_2$O 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\textsubscript{org} % implies dominance of upwelling.

*Farrell et al., 1995*

**Global ∆pCO\textsubscript{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
Nitrogen Isotopes As Paleotracers

- **Relative Nutrient Utilization**
  Phytoplankton discriminate against $^{15}$N ($\varepsilon \approx 5\%_0$) 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$_2$O are lost to the atmosphere.

Brandes et al., 1998, GBC
Proxy Denitrification History, NW Mexican Margin

Dissolved Oxygen Concentration on the 
~27.8 $\sigma_T$ Surface

Illustration by Ingrid Hendy
Oregon Margin, 3111 m Water Depth

Biogenic opal (wt. %)

% Organic C

Ba/Al ratio

$\delta^{15}$N

S. Kienast et al., 2002, Paleoceanography

Stadial/Interstadial Transitions in the Santa Barbara Basin

Behl and Kennet (1994)
Greenland-Baja Comparison

Reflectance MD02-2508

Depth (m)

Reflectance MD02-2508

Grip δ18O

Age (Ka)

0 5 10 15 20 25

-44 -42 -40 -38 -36 -34

Greenland

Northwest Mexico

Key Coring Sites and Surface Currents, Southern Californian Margin

~ 1 km water depth, below O2 minimum
Dissolved Oxygen Concentration on the
\(~27.8~\sigma_T~Surface\)

Illustration by Ingrid Hendy
**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)?
**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 N₂ fixation, but the integrated contribution from this source is not well known.

**Implication:**

*The modern ocean is losing nitrogen. But if NO₃⁻ reduction was to be switched off, there would be a net gain of N, allowing “excess” P to be utilized and CO₂ to be drawn down.*

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*Hendy and Pedersen, in prep*
Flueckiger et al., Science, 1999

Unpublished data, courtesy Jacqueline Flueckiger, University of Bern
Oxygen at 300 m Water Depth

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.

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 pN2O records support this inference.
- With respect to the impact of the time-varying fluxes of carbon on pCO2, 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.*