Iron fertilization of the Subantarctic during the last ice age

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Vostok record of atmospheric CO$_2$

![Graph showing CO$_2$, δD, and ice volume](chart.png)

Petit et al. 1999
The major nutrients are not completely consumed in the polar ocean surface.
Rapid surface-deep exchange in the polar ocean releases deeply sequestered CO$_2$ to the atmosphere

Southern Ocean diatom productivity during the last ice age: Subantarctic vs. Antarctic

Mortlock et al. 1991
N isotopes in nature: \( ^{14}\text{N} = 99.64\% \)
\( ^{15}\text{N} = 0.36\% \)

\[ ^{15}\text{N} (\% \text{ vs. air}) = \frac{(^{15}\text{N}/^{14}\text{N})_{\text{sample}}}{(^{15}\text{N}/^{14}\text{N})_{\text{air}}} - 1 \times 1000 \]

Kinetic fractionation: \(^{14}\text{N}\)-bearing molecules preferentially undergo reaction, leaving the residual substrate (NO\(_3^-\)) enriched in \(^{15}\text{N}\)

Isotope effect = \( (\%\%) = ((^{14}k/^{15}k) - 1) \times 1000 \)

\[ \sim ^{15}\text{N}_{\text{substrate}} - ^{15}\text{N}_{\text{product(inst.)}} \]

assimilation
by phytoplankton: \( \text{NO}_3^- \quad \text{N}_{\text{org}} \)
Surface nitrate $^{15}$N/$^{14}$N records the degree of algal nitrate consumption.

Uncertainties in the nitrate utilization/nitrogen isotope link

- Nitrate supply
  (water column)

- Isotope effect of nitrate assimilation
  (water column, cultures)

- Alteration in the water column and sediments
  (microfossil-bound organic matter)
E 11-2 as a monitor of Subantarctic surface conditions

Satellite-derived Chlorophyll content

Subantarctic during the last ice age: higher nitrate consumption
Simulated dust deposition
iron fertilization in
the Subantarctic

Subantarctic nutrient drawdown would lower the nutrient content of the thermocline