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Palmer LTER: Dissolved silicic acid–nitrate relationships during austral autumn 1993

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The study of biogeochemical processes in representative antarctic marine ecosystems is a high-priority scientific objective of the U.S. Joint Global Ocean Flux Study (JGOFS) program (Anderson 1993). Carbon and bioelement (especially silica) fluxes in the southern oceans are significant on global scales but are, at present, poorly constrained due to undersampling. Consequently, we are unable to construct accurate coupled physical-biogeochemical models or to predict the response of the southern oceans to global environmental change.

The southern oceans ecosystem has traditionally been viewed as a macronutrient-saturated (that is, nitrate-, phosphate-, and silicic-acid–saturated) habitat (Holm-Hansen et al. 1977; Nelson and Treguer 1992). Substantial depletions in mixed-layer nutrients have been reported, however, in selected coastal and ice-edge ecosystems (Holm-Hansen et al. 1989; Karl, Tilbrook, and Tien 1991; Karl et al. 1992). Furthermore, the downward flux of biogenic particulate matter measured for selected habitats appears to be among the highest reported for any marine ecosystem (Honjo 1990; Karl et al. 1991), yet the export of particulate silica appears to be uniquely decoupled from the export of particulate carbon in the southern ocean (Anderson 1993). As one component of the austral autumn Palmer long-term ecological research (LTER) cruise aboard the R/V *Nathaniel B. Palmer*, we measured nutrient concentrations throughout the 1.8×10^5 square kilometer (km^2) LTER study area to help define the regional variability in water-mass distributions (Hofmann et al., *Antarctic Journal*, in this issue) and to map the patterns and magnitudes of the regional upper-ocean nutrient depletions resulting from biological activity. We focus here on the dissolved silicic acid–nitrate relationships which have been the subject of considerable discussion in recent years (Zentara and Kamykowski 1981; Le Jehan and Treguer 1983; Kamykowski and Zentara 1985; Nelson and Treguer 1992).

Vertical profiles of silicic acid concentrations along the 10 across-shelf LTER station transects (Waters and Smith 1992), exemplified by selected data for LTER line 800 (figure 1), displayed systematic patterns of nutrient depletion with increasing distance from shore (also see figure 2). Nitrate concentrations also revealed surface-water depletions but did not display the strong spatial coherence (figure 3) observed for silicic acid. Based on a model 2 linear regression analysis of water samples collected at all stations and water depths [that is, nitrate (in micromoles per liter)=17.61+0.161× silicic acid (in micromoles per liter); n=1,088], we conclude that the LTER study region exhibits a potential for "excess" nitrate at total silicic acid depletion. This contrasts sharply with data collected from the Ross Sea, data that exhibit a silicic acid excess (Kamykowski and Zentara 1985).

These regional distribution patterns were contrary to our expectations for at least two additional reasons. First, we had not expected to see significant upper water-column silicic acid or nitrate depletions—especially the large silicic acid depletions at selected offshore stations—in these waters in late austral autumn. Second, we did not anticipate the large implied silicon-to-nitrogen (Si:N) export ratio (6.2 by moles) for these waters.

We hypothesize that these two characteristic features could be the result of a late season production of diatom spores, which are characteristically more silicified than vegetative cells (French and Hargraves 1980). This could explain the high Si:N "uptake" ratios which we deduce from these data. The onshore-to-offshore gradient in surface-water silicic acid concentrations may be a direct result of deeper mixing offshore and corresponding effects on photosynthetically available radiation. Physiological processes, including light limitation, are known to induce spore formation in diatoms. Due to their increased sinking rates (Smayda and Boleyn 1966; Davis, Hollibaugh, and Seibert 1980) and high Si:N contents, the export of diatom spores from the euphotic zone could explain the distributional patterns observed during the austral autumn LTER cruise. One prediction of this hypothesis is a high Si:N ratio in particulate matter collected by sediment

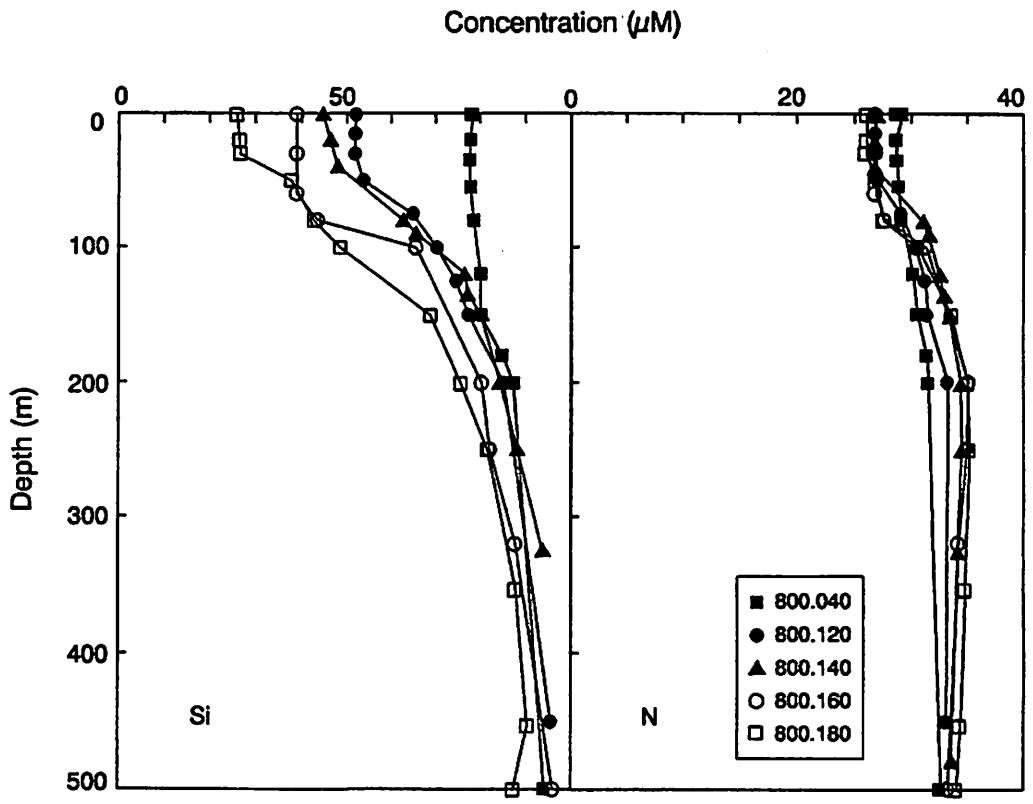

Figure 1. Selected data from the LTER line 800 transect sampled between 31 March and 6 April 1993. For clarity, only 5 of the 11 transect stations are shown here, but the full data set is displayed in figure 2. The decimal designation in the station number is the approximate distance, in kilometers, from the Antarctic Peninsula (see figure 2).

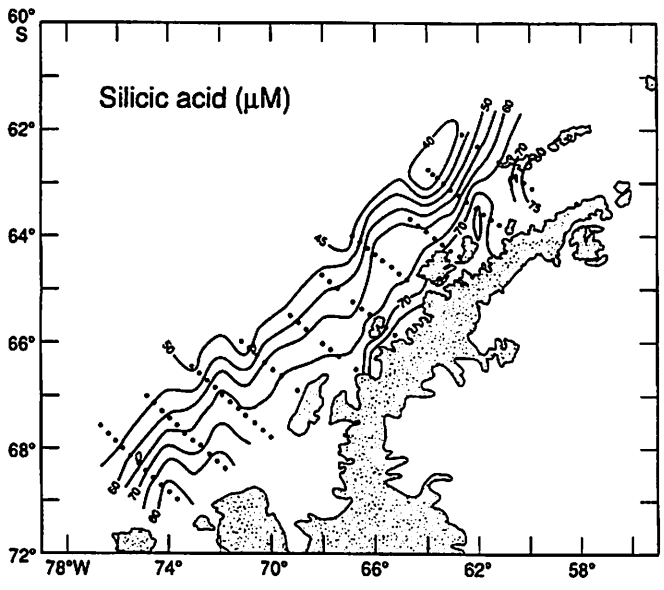

Figure 2. Surface-water contour plot for silicic acid concentrations (in micromoles per liter) for the LTER study region during the period from March through May 1993.

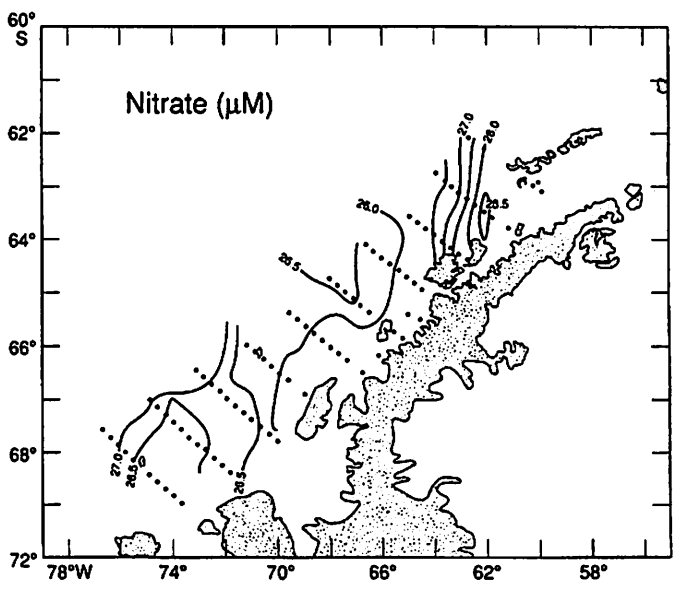

Figure 3. Surface-water contour plot for nitrate concentrations (in micromoles per liter) for the LTER study region during period from March through May 1993.

traps. The eventual analysis of samples recovered in April 1993 from a set of three bottom-moored, time-series sediment traps deployed for a 1-year period near LTER station 600.120 should test this diatom spore formation hypothesis.

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Palmer LTER: Bacterial exoprotease activity in the Antarctic Peninsula region during austral autumn 1993

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Extensive *in vivo* measurements of exoprotease (leucine aminopeptidase, or LAPase) activity of antarctic marine bacterioplankton were made on the austral autumn 1993 long-term ecological research (LTER) cruise of the R/V *Nathaniel B. Palmer*. The LTER grid consists of 10 transect lines running approximately perpendicular to the Antarctic Peninsula at 100-kilometer (km) intervals, extending from the coast to 200 km offshore. The lines are numbered 000 to 900 from south to north, and the stations are given numbers from 000 to 200 from inshore to offshore (Waters and Smith 1992).

LAPase activity was measured using the fluorescent substrate analog L-leucyl-beta-naphthylamine (LLBN; Somville and Billen 1983). LLBN is added to a 6-milliliter water sample to a final concentration of 1 millimole per liter. This ensures saturation of all available sites so that the measured activity represents an index of the amount of enzyme present in a sample. Samples are incubated for 24 hours at 0°C and the free beta-naphthylamine liberated is measured in a Perkin-Elmer LS-5B spectrofluorometer.

Average activity for each station is based on depth-integrated (trapezoid rule) activities from individual water samples. Integration is to 80 meters (m) or to the greatest sampling depth at a few shallow-water stations. Enzyme activity is expressed in nanomoles per liter per hour (depth-integrated activity divided by integration depth).

Onshore-offshore gradients are largely absent. Several lines show regions of elevated activity that may correspond to frontal zones (figure 1), but in general, activities are as great in the offshore waters of the Antarctic Circumpolar Current as in Bransfield Strait and near the coastal islands of the Palmer Archipelago. Activities are typically fairly constant from the surface to a depth of 80–120 m, where they decline sharply.

LAPase activity in the upper 80 m is not correlated with water depth, which ranges from less than 100 m to greater than 3,000 m (figure 2). LAPase activity is relatively constant from the 900 to the 400 line and then declines toward the southern end of the grid (figure 3). Because the cruise took place in the austral autumn and the southern stations were