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## Transport of Nutrients from Deeper Waters in the North Pacific Subarctic Sea

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### Abstract

Transport of nitrate, phosphate and silicate from deeper waters to surface waters is described. The ratio of  $\text{NO}_3/\text{PO}_4$  for both  $180^\circ$  and  $155^\circ$  W longitude is about 16 throughout observed water columns which is in good agreement with that of phytoplankton. The ratio of  $\text{SiO}_2/\text{PO}_4$  at a depth of less than 200 m on both of these lines is approximately 30, however, at greater than 200 m the ratio is more than 30. This indicates that opal or silicate minerals from the atmosphere appear to dissolve in deeper waters. Deep waters having a high  $\text{SiO}_2/\text{PO}_4$  ratio play an important role in the high productivity of diatoms.

### Introduction

It is well known that the North Pacific Subarctic Sea has high primary productivity. Chemical substances, especially nutrients, as well as physical conditions are very important factors concerning any increase in primary productivity. Deep waters in the North Pacific Ocean move upward with a velocity of  $4\text{--}5\text{ m/y}^{1)}$ . Deep waters of the North Pacific Ocean have higher nutrient concentrations than those of the Atlantic Ocean.

Vertical sections of nutrients for the North Pacific Ocean have been reported 20 years ago<sup>2)</sup>, however, accurate analytical methods for determining nutrient concentrations had not yet been established and there has also been no discussion relevant to ratios of  $\text{NO}_3/\text{PO}_4$  and  $\text{SiO}_2/\text{PO}_4$ . In terms of oceanographic structure in the northern part of the North Pacific, it was reported that the North Pacific is more suitable for primary production than the South Pacific<sup>3)</sup>.

Herin the transport of nutrients from deeper waters to surface waters and the ratios of  $\text{SiO}_2/\text{PO}_4$  and  $\text{NO}_3/\text{PO}_4$  are discussed.

### Methods

Water samples were taken with roset samplers from the stations shown in Fig. 1 during a period from June to August, 1984. All samples were frozen immediately on board and subsequently analyzed in the laboratory. Nitrate, nitrite, phosphate and silicate were determined by an autoanalyzer. Nitrite will not be further

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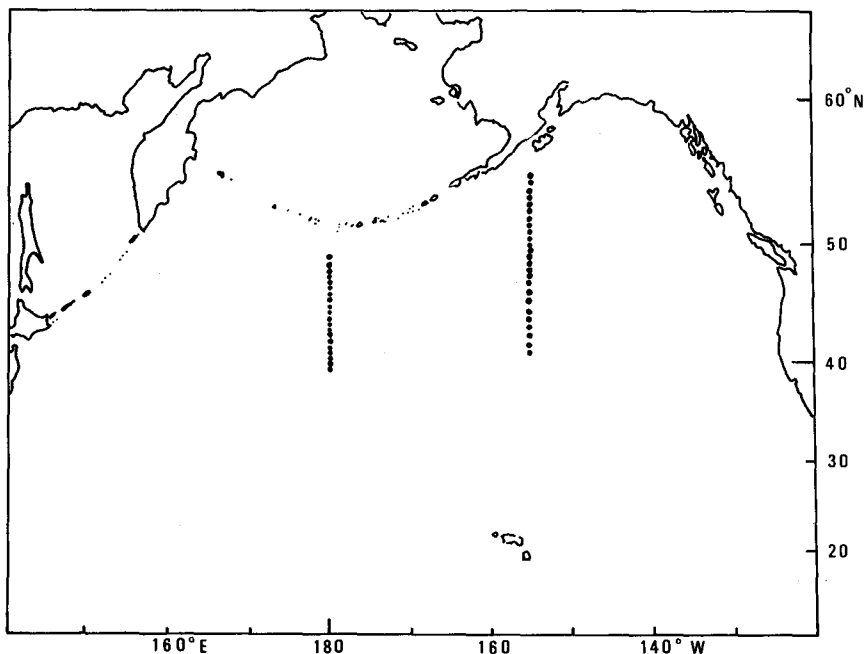


Fig. 1. Sampling stations.

discussed because the nitrite concentrations were negligible, less than  $1 \mu\text{M}$ , and also, nitrite is an intermediate product of nitrification of ammonia or denitrification of nitrate.

### Results and discussion

The vertical sections of salinity, nitrate, phosphate, silicate and  $\sigma_t$  at both  $180^\circ$  and  $155^\circ$  W longitude lines are shown in Figs. 2-4 respectively. Water of the same salinity and  $\sigma_t$  becomes shallower from south to north. This is particularly obvious at  $155^\circ$  W longitude. At  $40^\circ$  N on  $180^\circ$  longitude, water containing  $20 \mu\text{M}$  of nitrate,  $2 \mu\text{M}$  of phosphate and  $40 \mu\text{M}$  of silicate at a depth of 400 m is transported to a depth of about 100 m at  $49^\circ$  N. Also,  $155^\circ$  W longitude has nearly the same vertical profiles as  $180^\circ$  longitude. These results show that nutrients are transported from deeper waters to surface layers.

The vertical distributions of silicate at some stations on both lines are shown in Fig. 5. Comparison of silicate concentrations at an equal depth near  $40^\circ$  and  $50^\circ$  N shows that silicate at near  $40^\circ$  N is less concentrated than that at near  $50^\circ$  N.

The silicate and nitrate concentrations are plotted against phosphate as shown in Figs. 6 and 7 at  $45\text{--}55^\circ$  N on  $180^\circ$  and  $155^\circ$  W longitude respectively because at these latitudes there is a considerable transport of nutrients. In Figs. 6 and 7, the data at a depth of greater than 200 m are plotted with open circles. The nitrate plots against phosphate both show nearly straight lines. The ratio of  $\text{NO}_3/\text{PO}_4$  for both lines is about 16 which is in good agreement with the ratio for phytoplankton.

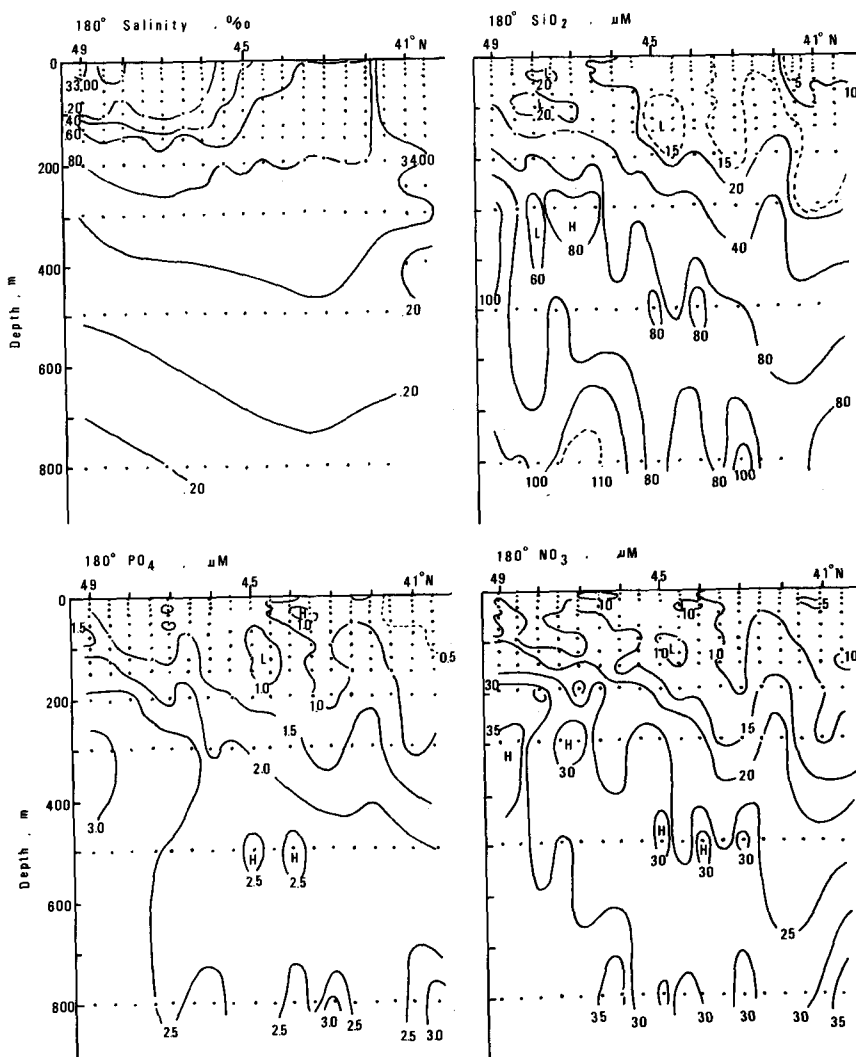


Fig. 2. Vertical sections of salinity, nitrate, phosphate and silicate on 180° longitude line.

The silicate plots against phosphate at a depth of greater than 200 m, however, are above the straight lines which are drawn with plots for a depth of less than 200 m. The ratio of  $\text{SiO}_2/\text{PO}_4$  at a depth of greater than 200 m for both lines is about 30.

Nitrate plots against phosphate are on the lines. Thus, nitrate does not appear to be added to deeper waters. Silicate plots against phosphate at a depth of greater than 200 m depth, however, are above the lines (Fig. 6). This implies that silicate is added to deeper waters. It is well known that the dissolution rate of particulate silicate is very slow. Thus, opal or silicate minerals from the atmosphere would dissolve as they sink into deeper waters.

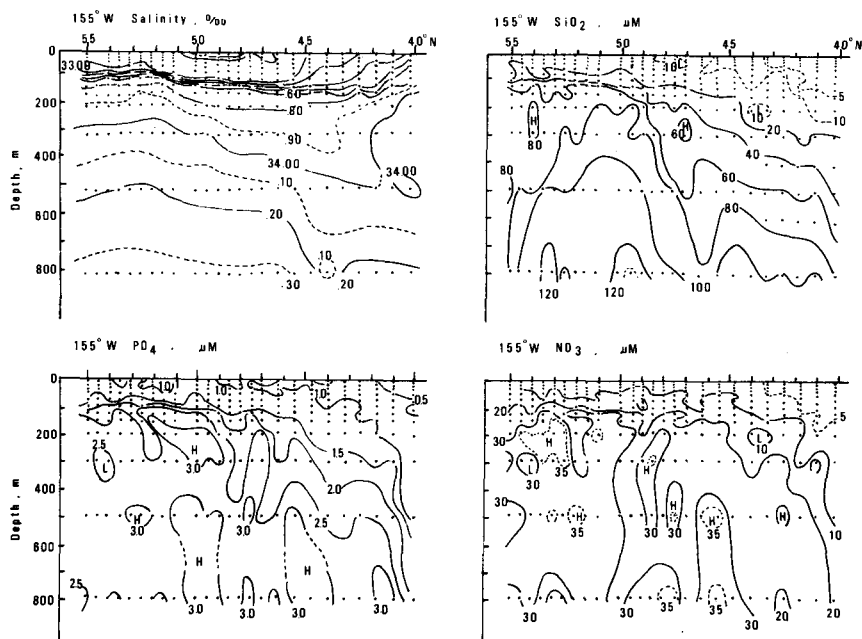


Fig. 3. Vertical sections of salinity, nitrate, phosphate and silicate on 155°W longitude line.

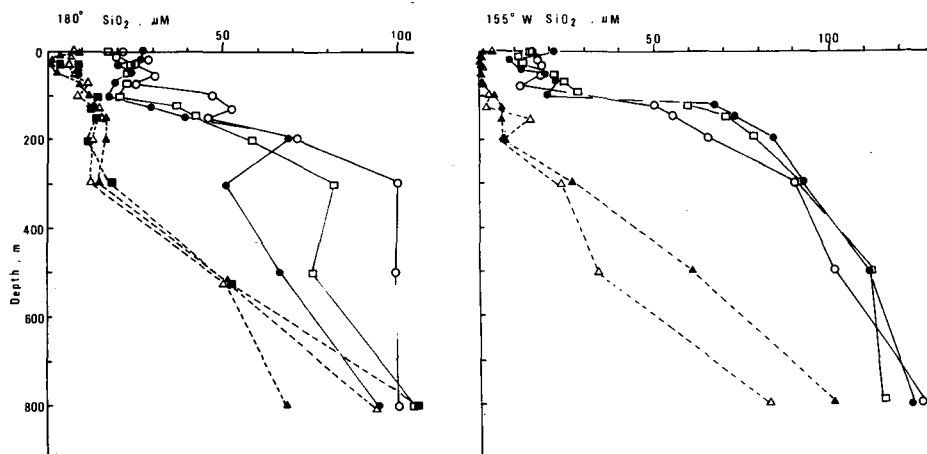


Fig. 5. Vertical distributions of silicate on 180° and 155°W longitude lines.

● : 49°-00; □ : 48°-30; ○ : 48°-00; ▲ : 41°-30; △ : 40°-57; ■ : 40°-30 N on 180° line  
 ● : 51°-00; □ : 50°-00; ○ : 49°-00; ▲ : 40°-59; △ : 40°-07 N on 155°W line

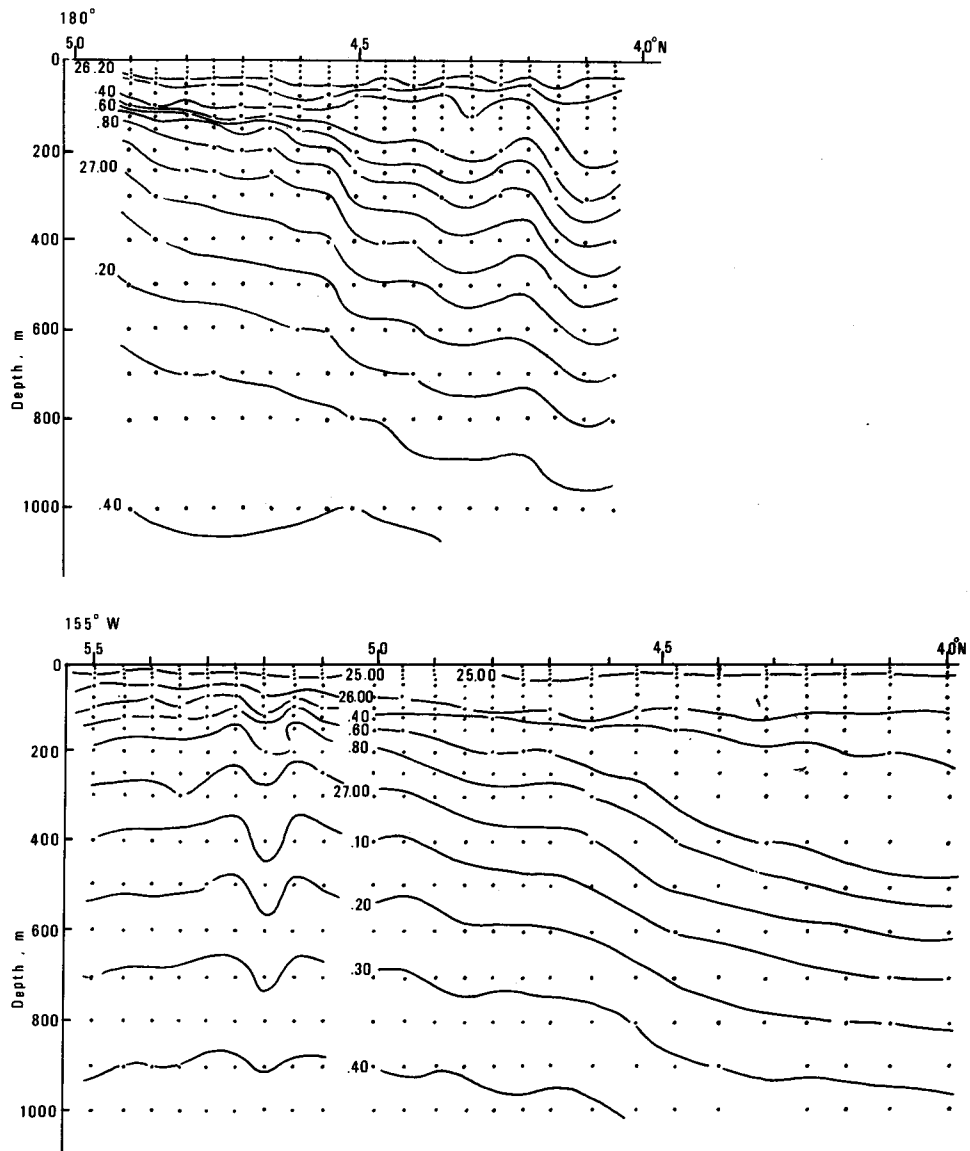


Fig. 4. Vertical sections of  $\sigma_t$  on 180° and 155°W longitude lines.

Although both nitrate and silicate content in surface waters is low when compared to phosphate (Fig. 6 and 7), deeper waters having high  $\text{SiO}_2/\text{PO}_4$  ratios supply silicate to surface waters. Thus, the North Pacific Subarctic Sea has a high silicate concentration which yields a high diatom content.

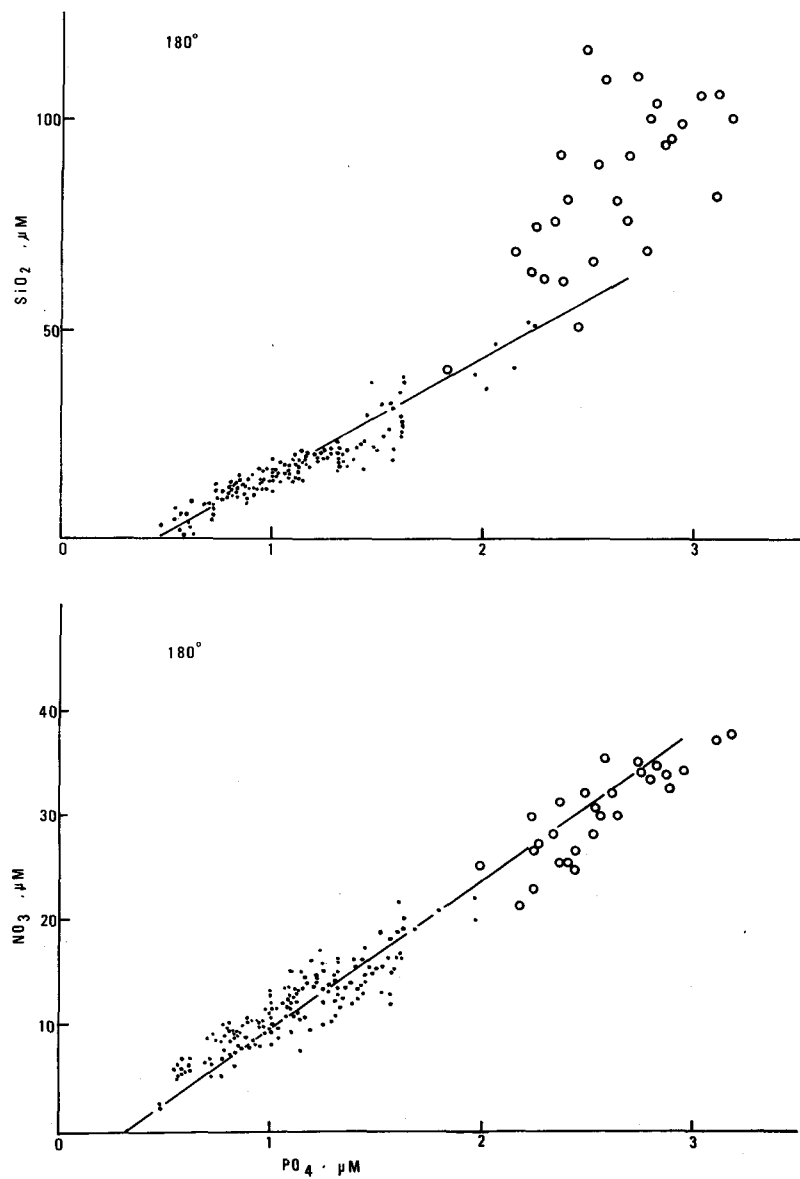


Fig. 6. Plots of silicate and nitrate against phosphate on 180° longitude line  
 ○ : below 200 m

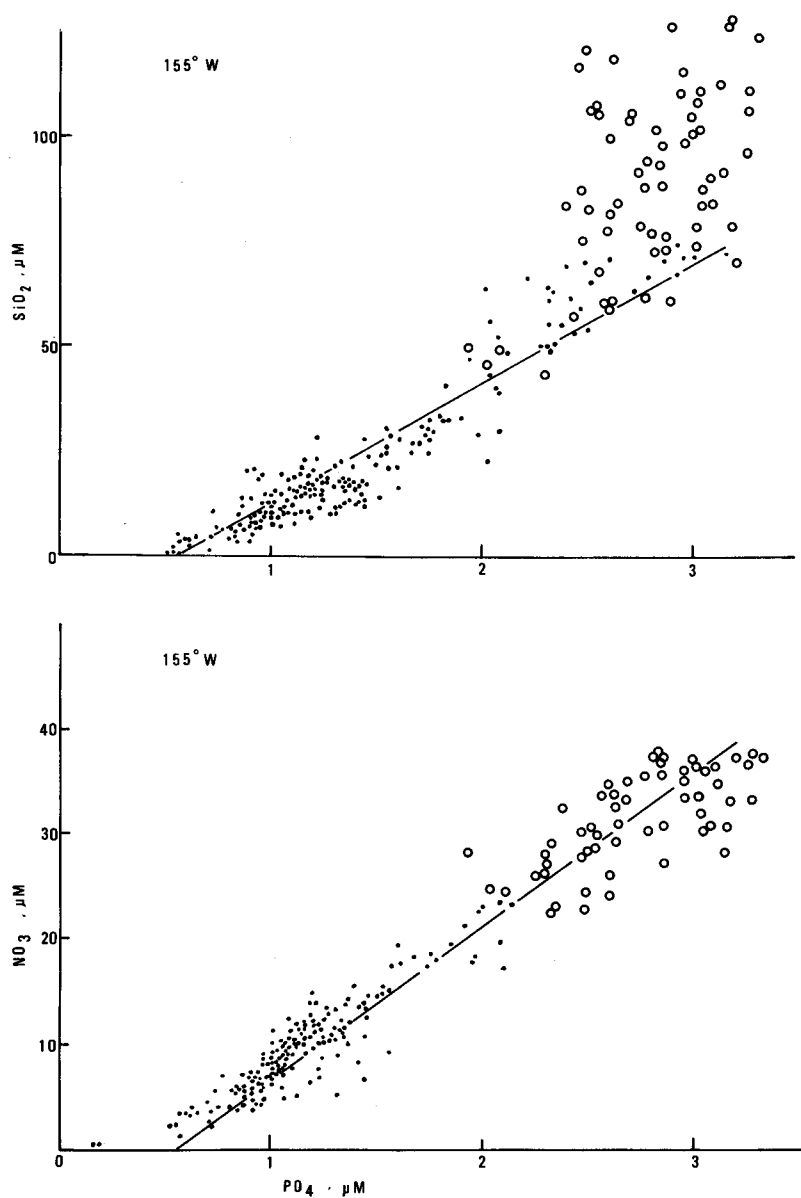


Fig. 7. Plots of silicate and nitrate against phosphate on 155°W longitude line  
○ : below 200 m

### Acknowledgements

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### References

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