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Hydrochemical conditions in Georges Bank Area in the Summer-Autumn period, 1971-1973

by

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INTRODUCTION

Since 1971, AtlantNIRO has been conducting the complex ecological surveys in the Georges Bank area. The studies on hydrochemical conditions considered as an environmental factor are a part of the survey programme.

MATERIAL AND METHODS

In June 1971 and June, August and October 1972 the studies were carried out on board the RV ARGUS, and in August and October 1973 on board the RTM BELOGORSK. A total of 249 stations have been made where dissolved oxygen, phosphates, nitrites, silicon, permanganate oxidation (in neutral environment) were determined.

Dissolved oxygen determinations (Winkler's method) and those of oxidation were made in 1971-1972. The determination of biogenous elements was made in 1972 on board the ship by the colorimetric method adopted in "A guide to marine hydrochemical studies, 1959". In 1971, 1973 the frozen samples for biogenous element determinations were landed to the shore and treated in photoelectronic colorimeters by a group of hydrochemists according to "The modern methods in marine hydrochemical studies in view of fisheries investigations, 1973".

RESULTS OF OBSERVATIONS

a) Dissolved oxygen

In June 1971 the oxygen content fluctuated between 5.3 and 7.4 ml/l at the surface (fig. 1a) with higher values in the north and lower ones in the south and between 4.2 and 7.1 ml/l in pre-bottom layer (fig.1 b): 6-7 ml/l in the shallow regions where intensive mixing of the waters occurred and 3.2-4.3 ml/l in the regions with greater depths where the pycnocline impeded a complete water mixing.

The percentage of oxygen saturation in the waters all over the area was over 100% in the upper 20 m, reaching 110% in some places and decreased to 67-75 % in the pre-bottom layer.

A similar pattern of distribution of the oxygen content in the area was observed in June and August 1972 (fig.c).

In October 1972 the oxygen content within the whole water column in the area grew higher and more uniform (5.2 - 6.6 ml/l or 82-105% of saturation accordingly). The highest percentage of oxygen saturation was characteristic of the upper 20 m (110-115%) along the coast of Nova Scotia and in the north-eastern Georges Bank.

An increase in the oxygen content observed in October occurred as a result of lowered water temperature (the increase in oxygen solubility) and frequent storms during that period which contributed to water mixing. As far as Nova Scotia is concerned, the increase in oxygen content occurred there due to predominant oxygen production which followed the intensive phytoplankton development in the fall (Riley, 1941).

In vertical oxygen distribution the reduction in oxygen content taking place from the surface to the bottom with the maximum values in the layer corresponding approximately to the upper boundary of the pycnocline is typical for all the stations. The layer satiated with oxygen (100%) and lowering sometimes to 30-50 m can be well seen (fig.2). The depth of the lower boundary of this layer depends upon the zones of lifting and sinking of the water (Sigaev, in press). Beginning from 200-500 m, an increase in oxygen content was recorded caused by the influence of the ocean intermediate water mass of Arctic origin.

b) Oxidation

In June 1971 the oxidation values fluctuated within the range of 0.3-0.6 ml O₂/l. Maximum values were observed in the surface layer of the American shelf (1.6 ml O₂/l), in the south-western Gulf of Maine (5.7 ml O₂/l) and on the eastern slopes of the Georges Bank (9.2 ml O₂/l).

In June 1972 the higher oxidation values were observed (0.8-1.3 ml O₂/l). however, the maximum values in the surface layer appeared to be lower in the south-western Gulf of Maine (2.5 ml O₂/l), on the north-western Georges Bank (1.9 ml O₂/l), in pre-bottom layer around Cape-Cod and Long Island (1.7 ml O₂/l), as well as in the Eastern Channel (4.3 ml O₂/l) at the depth of 30 m and in Hudson Canjon (3.6 ml O₂/l) at the depth of 50 m.

In August the oxidation values on the surface were everywhere lower than in June by 0.2-0.5 ml O₂/l and by 0.5-0.8 ml O₂/l in the pre-bottom layer. The distribution pattern of oxygen remained the same, however, the maximum values did not exceed 1.2 - 1.6 ml O₂/l.

In October 1972 a reduction in oxidation to 0.06 - 0.25 ml O₂/l took place pre-bottom layers of the Eastern Channel, and to 0.25 ml O₂/l in the south-western Gulf of Maine; no changes were observed in other areas.

Recently the maximum oxidation values were recorded in the surface layers of the south-west Gulf of Maine, around Cape Cod, Korsör Canyon and Browns Bank - the junction areas of differently oriented currents (Bigelow, 1927; Sigaev ...). In the remaining areas the maximum oxidation values were observed in the layer of photosynthesis.

c) Phosphates

In June 1971 the phosphate contents on the surface (fig.3a) averaged 0.3 g - at/l with the exception of the American Shelf where the mean value reached about 0.1 g - at/l and the south eastern Long Island where only the traces of phosphates were observed (0.01 g-at/l).

In the pre-bottom layer (fig. 3b) the concentration of phosphates exceeded 0.5 g-at/l with the exception of the American Shelf off the Cape Cod and the centre of Georges Bank where the concentration fluctuated around 0.4 g-at/l. The largest concentration of phosphates was recorded at the depths of 250-300 m (1.7 g-at/l) on the southern slopes of the Georges Bank.

From the data obtained on board the RV ARGUS in June 1971, an inverse relationship between the phytoplankton biomass and concentration of phosphates is evident: the larger the biomass, the smaller the concentration of phosphates, and vice versa.

In June 1971 the concentration of phosphates on the surface was 0.1-0.3 g-at/l to the west of 68°W (fig. 3c) and 0.6-1.4 g-at/l to the east, while in the western and eastern parts of the pre-bottom layer it was 0.4-1.0 g-at/l and 0.9-1.9 g-at/l, accordingly. The higher values of the phosphates to the east of 68°W can be evidently attributed to the fact that the peak of the spring phytoplankton growth had already occurred in the western part of the area, while in the eastern part, where no peak has been yet observed the winter maximum of phosphates maintained. A lag in the phytoplankton growth might have been caused by an insufficient illumination in June 1972 compared with June 1971 (the cloudiness over 9 grades and the fogs in June 1971 were 18%, while in 1972 they were 83%). The largest values of phosphates (2.6-2.9 g-at/l) were found in the layer of 400-500 m.

In August the concentration of phosphates decreased almost everywhere: to 0.1 g-at/l on the surface (fig. 3d) off Cape Cod and to 0.2 - 0.3 g-at/l in the remaining area with the exception of the Eastern Channel zone where the concentration of phosphates fluctuated between 0.4 and 0.5 g-at/l. In the pre-bottom layer the concentration decreased to 0.2 g-at/l southward of Cape Cod and to 0.3-0.6 g-at/l in the remaining area. The Browns Bank area where high concentrations (0.8-1.2 g-at/l)

maintained was an exception. The phosphate maximum (2.4-2.8 g-at/1) shifted from 400-500 m to 200-300.

In October the pattern of phosphate distribution had little changed (fig.3e, f) with the exception of the Browns Bank area where the concentration of phosphates decreased to 0.4-0.6 g-at/1 through the whole water column. This can probably be attributed to an intensive phytoplankton growth in the fall in that part of the area (Riley, 1941).

In August 1973 the phosphate content on the surface ranged from 0.5 to 1.0 g-at/1 on the Georges Bank and from 0.2-to 0.5 g-at/1 on the American Shelf (fig. 4b), and in the layer between 200 m and the bottom it fluctuated from 1.0 to 1.4 g-at/1, from 0.8 to 1.0 g-at/1 along the Southern Channel (fig. 4d); the maximum values of phosphates (2.0-2.2 g-at/1) were observed in the layer of 300-400 m.

In October the phosphate content decreased on the surface to 0.2 g-at/1 on the northern slopes of the Georges Bank and American Shelf; only in the Gulf of Maine and in the regions of Korsör and Lydonia Canyons it was 0.5 g-at/1 (fig.4f). In the layer from 200 m to the bottom the phosphate distribution did not change considerably, however, the higher concentration values decreased as a result of lowering the maximum phosphates (2.0-2.2 g-at/1) to a 400-500 m layer.

An increase in the phosphate content from the surface to the bottom with large gradients in the pycnocline is characteristic of vertical distribution (fig. 5a, 6).

d) Nitrites

In June 1971 the nitrite content was at the level of analytical zero in the upper 30 m almost all over the area. In the pre-bottom layer its concentration did not exceed 0.3 g-at/1. The maximum values (1.0-1.8 g-at/1) were observed in the layer of 30-75 m in the southern and eastern Channel zones and were, evidently, connected with the process of carrying the died plankton out of those areas by the currents (Bigelow, 1927; Sigaev, in press).

In June 1972 the nitrite content was higher almost all over the area (fig. 3g). The concentration of nitrites on the surface was 0.2 g-at/l southward of Cape Cod, 2.0 g-at/l in the Southern Channel and 0.3-1.7 g-at/l on the Georges Bank on the side of the Eastern Channel.

In vertical distribution of nitrites the maximum was recorded in 20-50 m layer in the shallow regions and in 50-100 m layer in deep-water regions. The largest nitrite values (2.2-2.5 g-at/l) were observed northward of Korskör Canyon, on the north slopes of the Georges Bank and in the Hudson Canyon (4.5 g-at/l) in the 50-80 m layer. On the American Shelf the nitrites were not seen anywhere except for the Cape Cod region.

In August in the surface and pre-bottom layers the nitrites were not observed anywhere except for the central Georges Bank (0.8 g-at/l) and Browns Bank (1.7 g-at/l). Maximum concentrations were found in the layer from 50 m to the bottom (fig. 3 h) with the maximum values between 4.4 and 8.7 g-at/l. This indicates the past intensive plankton growth. The nitrites were not observed at the offshore stations and at those in the Eastern Channel zone.

In October the nitrite content increased compared with August to 1.0-3.0 and 0.7 - 2.9 g-at/l on the Georges Bank and in the Gulf of Maine along the Nova Scotia coastline accordingly. In an anticyclonic gyre the nitrites having the concentration of 1.0-1.4 g-at/l maintained on the Georges Bank. No nitrites were observed in other regions. Such a distribution of nitrites indicates the peak of plankton growth in the northern part of the area under study which occurred in fall.

In August 1973 the concentration of nitrites was equivalent to the analytical zero on the surface with the exception of Browns Bank where it reached 0.2-1.0 g-at/l. Maximum value was observed between 20 and 50 m, the concentration of nitrites being 0.2-0.4 g-at/l. The nitrites were not found in the Gulf of Maine or at the offshore stations covering the region from Lydonia Canyon to Browns Bank.

On the Browns Bank their concentration was increasing from 0.2-1.0 g-at/l on the surface to 4.8-9.0 g-at/l at the bottom.

In October the concentration of 0.2-0.3 g-at/l was observed all over the surface eastward of 68°W, besides, the nitrites could be traced to the depth of 75-100 m with the maximum values of 0.6-0.8 g-at/l at the levels of 20-50 m. In October no such high concentration of nitrites was observed on the Browns Bank as in August.

The distribution of nitrites in the area reflects seasonal character of plankton growth described by Riley (Riley, 1941). The results of our observations coincide with those of Rakestraw (Rakestraw, 1936), namely, the nitrites were seldom found on the surface, however, their substantial concentrations were observed below 30 m or in pre-bottom layer at lesser depths. At the deep-water stations the zone of maximum nitrite values along the shelf edge is deeper as compared with the shelf. This fact can be explained by the influence of adjacent oceanic water in which the zone of nitrite maximum values lies invariably deeper than at the shelf stations.

e) Nitrates

In August 1973 the nitrate content on the surface was 2-3 g-at/l in the Southern Channel decreasing to 0.2-0.5 g-at/l on the American Shelf around Cape Cod and on Georges Bank eastward of 68°W (fig. 4a). The nitrate concentrations of 9 g-at/l and 10-15 g-at/l contained in deep waters of the Gulf of Maine and on the eastern Shelf slopes accordingly, were traced to enter the layer between 200 m and the bottom (fig.4b). The concentration of nitrates was 2-5 g-at/l on Browns Bank, the maximum values reaching 7-9 g-at/l.

In October the concentration of nitrates on the surface was mainly 0.5-1.0 g-at/1 decreasing to an analytical zero at the offshore stations around the Lydonia and Korsör Canyons and increasing to 1-2 g-at/1 westward of Browns Bank and to 2-3 g-at/1 on the ocean side along 69°W (fig.4e). Between 200 m and the bottom the concentration of nitrates was everywhere 0.6-4.8 g-at/1 with lesser values in the centre of Georges Bank which increase to 9-17 g-at/1 and 6.0-18.6 g-at/1 on the western and eastern slopes of the Bank accordingly.

A vertical structure of nitrates distribution on the American Shelf is simple: the content of nitrates is increased from the surface to the bottom. Their distribution is more complex around Georges Bank (fig.5b) which can be correlated with a two-layer structure of vertical circulation of the water around the Bank, as if it were an island (Loitzanski, 1970), divided by the layer of maximum stability of the water masses.

From the pattern of isolines it is seen that the nitrate distribution is similar to vertical distribution of water temperature, however, no quantitative relation was observed between them.

f) silicon

In June 1971 the silicon content on the surface (fig.1d) fluctuated mainly from 7.1 to 8.9 g-at/1. In the prebottom layer it was 12.5-19.6 g-at/1 and 8.9 g-at/1

on the south-west and north-west Georges Bank. A pattern of silicon distribution, particularly in pre-bottom layer, is inversely proportional to that of diatom algae biomass: the larger the biomass of diatoms, the lesser the silicon concentration and vice versa.

In June 1972 lower concentration of silicon like that of phosphates, was observed westward of 68°W and higher concentration eastward of that position, i.e. 2.5-3.3 g-at/1 accordingly on the surface, and 3.9-8.9 g-at/1 and 10.7-21.4 g-at/1 in pre-bottom layer. In the following months such high concentrations of silicon were not seen

eastward of 68°W. In all probability, it was spent for development of diatom algae which represented the bulk of phytoplankton in spring (Bigelow, 1926; Riley, 1941), and was not recovered till the end of October.

In August the silicon concentration decreased all over the area. It was 1.8-2.8 g-at/l on the surface (fig.1f), 2.5-3.2 g-at/l in the pre-bottom layer (fig.1g) of Georges Bank at the depth of 100 m, 7.1 g-at/l at the depth of 100-200 m and increased to 12.8-15.3 g-at/l at 200 m and deeper.

In October the silicon concentration was not changed (fig. 1h).

In August 1973 the silicon content on the surface (fig. 4h) was 4-7 g-at/l on the north-east Georges Bank and 5 g-at/l around Long Island decreasing to 2 g-at/l on the eastern slopes of the Bank.

The silicon content was 4-8 g-at/l between 200 m and the bottom; it increased to 11-13 g-at/l on the western slopes and to 10-12 g-at/l on the eastern ones. Maximum concentrations of 16-18 g-at/l were observed in the layer of 400-500 m.

In October the concentration of silicon on the surface decreased by 1-2 g-at/l all over the area (fig. 4g). In the pre-bottom layer its content decreased by 2-4 g-at/l on the Georges Bank remaining unvariable in other areas.

The biogenous elements appear on the Georges Bank as a result of advection of the deep water and under the influence of atmospheric circulation. Fig.6 clearly demonstrates the movement of the maximum silicon concentration from 400-500 m to 40-60 m and simultaneously its shift in the southward direction from the station 118 to 125 which is caused by horizontal anticyclonic circulation around Georges Bank.

The phosphates are seen to enter Georges Bank together with the deep water of the Gulf of Maine under the influence of the northern wind of 13.7 m/sec in force and of the waves of 5.5 m in height.

CONCLUSIONS

1. The content of dissolved oxygen in the photic layer was 5,5 ml/l or more (85-90% saturation). No considerable differences were revealed in oxygen content in June 1971-1972.
2. The oxidation ranged from 0.3 to 0.6 ml O_2 /l all over the area reaching the maximum values of 1.6-5.7 ml O_2 /l.
3. The content of phosphates in Cape Cod area fluctuated from 0.1 to 0.2 g-at/l in the period of observations reaching 0.01 g-at/l in June 1971. The maximum values of 1.8-2.3 g-at/l were observed in the layer of 300-500 m. The phosphate content in the photic layer was 0.01-0.3 g-at/l in 1971, 0.3-0.7 g-at/l in 1972 and 0.2-0.5 g-at/l in 1973.
4. The nitrite content on the surface well agreed with the values obtained analytically. The maximum values of nitrites were observed in the layer of 30-50 m, their concentration in the regions of intensive plankton growth being 2-4 g-at/l with the maximum values of 7-9 g-at/l.
5. The concentration of nitrites in 1973 fluctuated within the range of 0.2-3.0 g-at/l on the surface, 0.6-5.0 g-at/l between 200 m and the bottom reaching the maximum values of 18-20 g-at/l in the layer of 200-400 m.
6. The silicon content changed according to that of phosphates. In 1971 the silicon content was 4.3-7.1 g-at/l on the surface and 16.0-19.6 g-at/l in the pre-bottom layer; in 1972 it was 2.8-4.6 g-at/l and 14.2-17.8 g-at/l accordingly and in 1973 - 4-7 g-at/l and 8-12 g-at/l. The maximum silicon concentrations of 16.-20 g-at/l were observed in the layer of 300-500 m.

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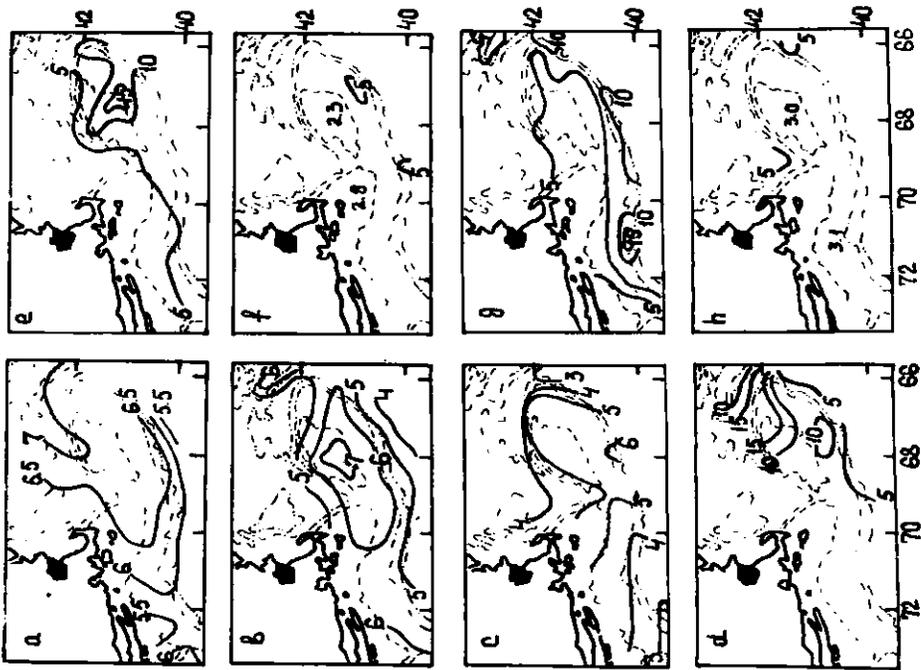


Fig. 1. The distribution of hydrochemical elements in space.

- a) 0.2ml/l, surface, June 1971
- b) 0.2ml/l, 200 m - bottom, June 1971
- c) 0.2ml/l, 200 m - bottom, June 1972
- d) SI g-at/l, surface, June 1971
- e) SI g-at/l, surface, June 1972
- f) SI g-at/l, surface, August 1972
- g) SI g-at/l, 200 m - bottom, August 1972
- h) SI g-at/l, surface, October 1972

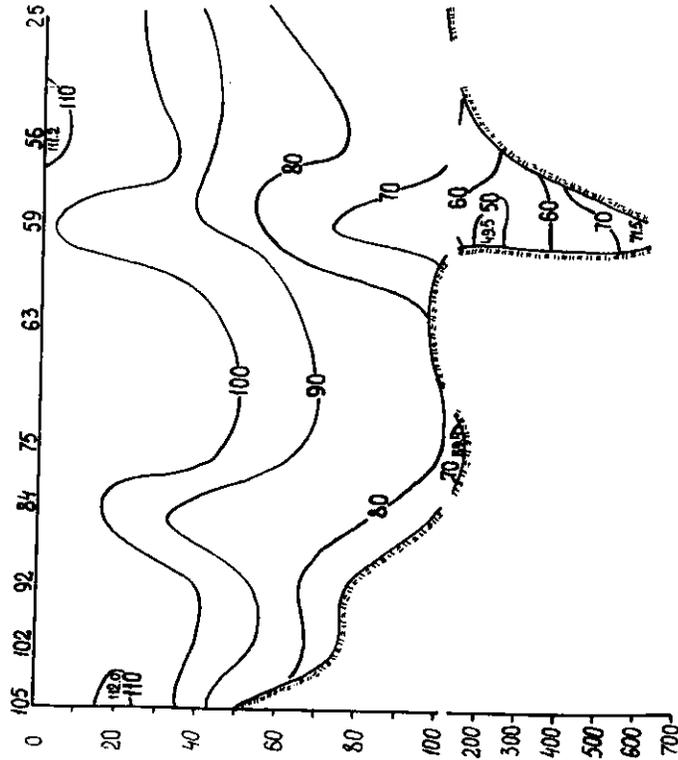


Fig. 2. The saturation of the water by oxygen, %, June 1971.



Fig. 3. The distribution of hydrochemical elements in space.

- a) PO₄ g-at/l, surface, June 1971
- b) PO₄ g-at/l, 200 m - bottom, June 1971
- c) PO₄ g-at/l, surface, June 1972
- d) PO₄ g-at/l, surface, August 1972
- e) PO₄ g-at/l, surface, October 1972
- f) PO₄ g-at/l, 200 m - bottom, October 1972
- g) NO₂ g-at/l, 50 m - bottom, June 1972
- h) NO₂ g-at/l, 50 m - bottom, August 1972



Fig. 4. The distribution of hydrochemical elements in space.

- a) NO₃ g-at/l, surface, August 1973
- b) NO₃ g-at/l, 200 m - bottom, August 1973
- c) PO₄ g-at/l, surface, August 1973
- d) PO₄ g-at/l, 200 m, bottom, August 1973
- e) NO₃ g-at/l, surface, October 1973
- f) PO₄ g-at/l, surface, October 1973
- g) Si g-at/l, surface, October 1973
- h) Si g-at/l, surface, August 1973

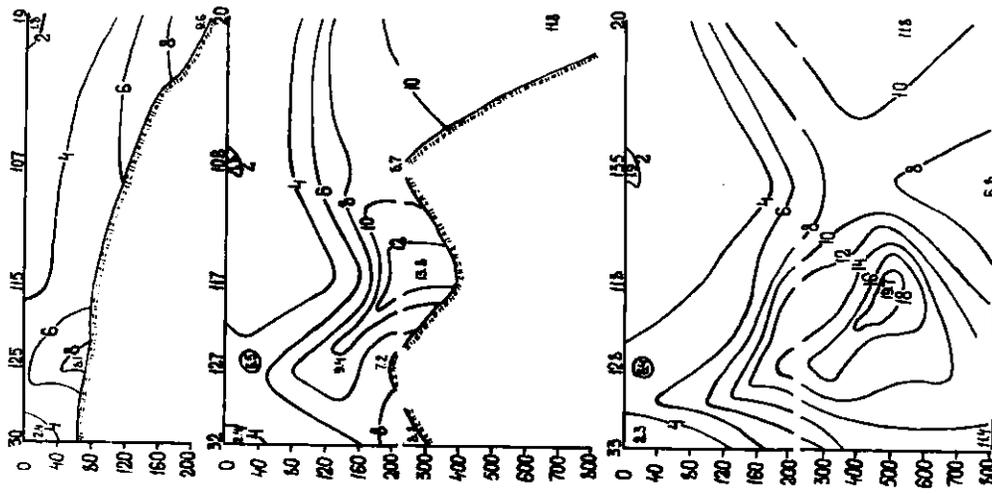


Fig. 6. The distribution of silicon along the sections made parallel to the ocean slopes of Georges Bank. August 1972.

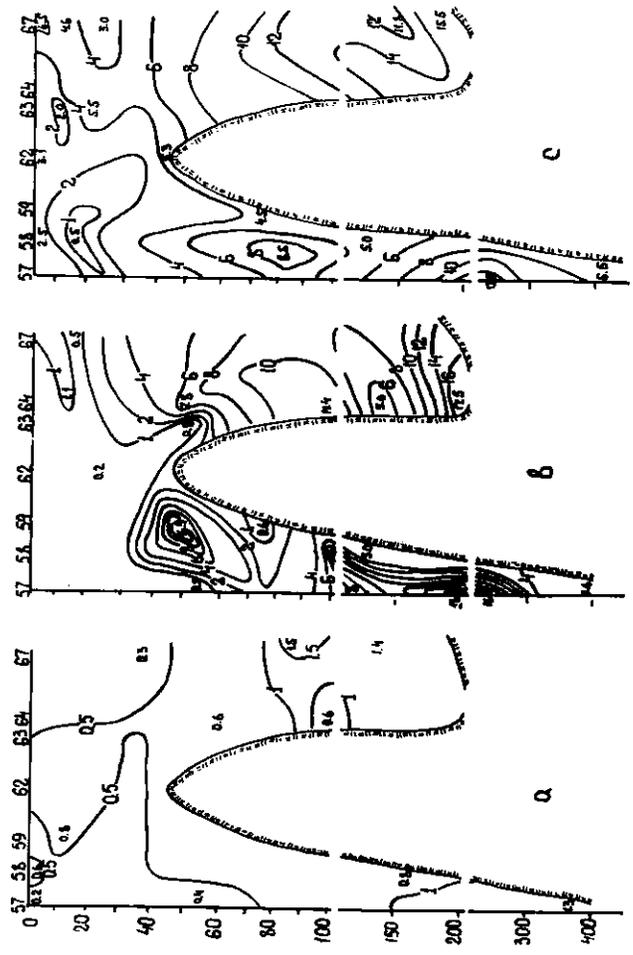


Fig. 5. The vertical distribution of biogenous elements on Georges Bank:

- a) phosphates
- b) nitrates
- c) silicon

October 1973.

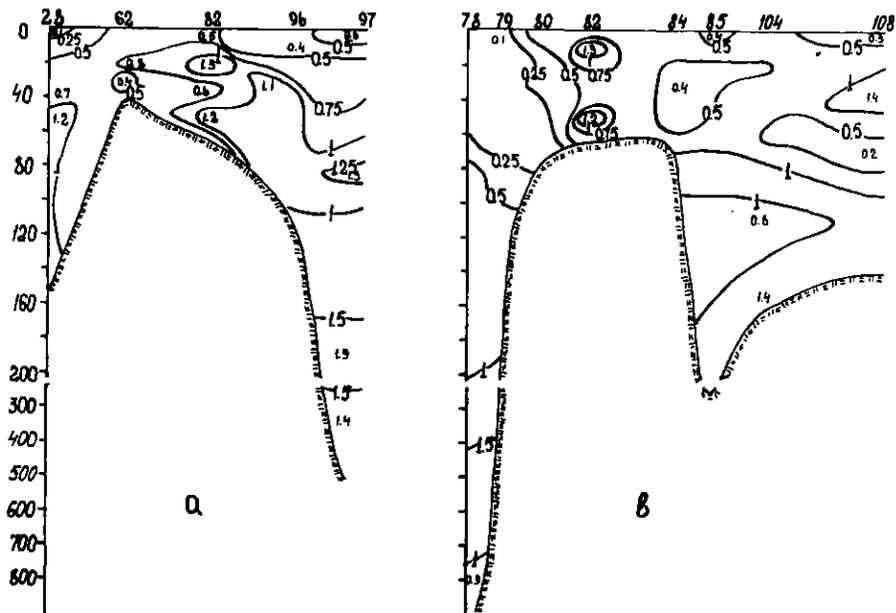


Fig. 7. The distribution of phosphates.

- a) the section along 67°W
- b) the section along the axis of Georges Bank, SW-NE.

October 1973.

