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CONTENTS OF OXYGEN AND NUTRIENTS IN THE FRONTAL ZONE OF THE BRAZIL AND FALKLAND CURRENTS

Contents: 1. Introduction, 2. Experimental, 3. Results and discussion, 4. Conclusions; Streszczenie, References.

1. INTRODUCTION

Biogenic salts, i.e., inorganic salts of nitrogen, phosphorus and silicon, are the compounds essential for the productivity of a marine ecosystem. Adequate amounts and appropriate mutual proportions of these salts form the basis for the development of life in the sea. Intensive increase in primary production can lead to loss of balance in biogenic salt concentrations and frequently to their total depletion [8]. The concentration of nutrients in the photic layer of the ocean depends on the intensity of primary production, as well as the possibility of transport of the salts from deeper layers. The euphotic layer of the ocean contains soluble salts of phosphorus, nitrogen and silicon within the concentration range of several microgram-atoms of the basic element per cubic decimeter. Phosphorus can participate in the process of photosynthesis in the form of dissolved orthophosphates or complex ions containing magnesium and calcium [7]. Suspended forms of phosphorus-containing organic compounds do not take part in photosynthesis directly. Of the nitrogen compounds, nitrates, nitrites and ammonia salts and, to a small extent, simple amino acids and urea are biochemically active [2, 6]. A small amount of nitrogen can be introduced to the marine environment directly from the atmosphere by some algae (blue-green algae).

The third group of biogenic salts consists of dissolved silicon compounds. Silicon occurs in sea water mainly as a weak orthosilicic acid $Si(OH)_4$ [3]. The majority of silicon compounds is assimilated by the diatoms, thus being converted from the dissolved form to sparingly soluble suspensions and further to precipitates.

A characteristic of the region in which investigations were carried out in May 1978 was the higher contents of biogenic salts as well as the wider range of their concentrations than the data published in literature suggested. Exemplary concentration distribution of individual nutrients in sea water with respect to temperature and salinity according to J. L. Reid et al. [6] is shown in Fig. 1. Data for this diagram were collected in the Argentine Basin.

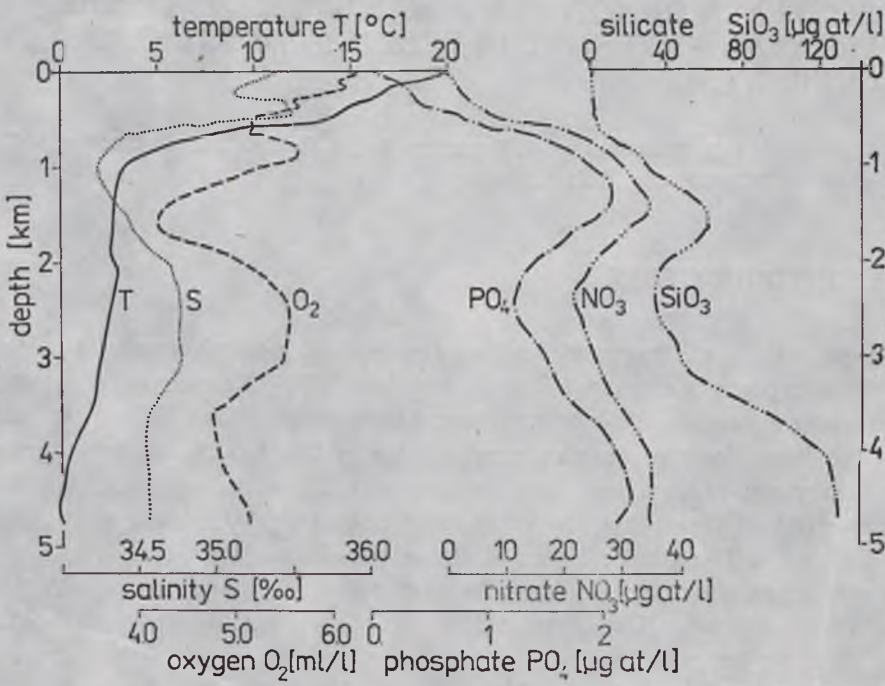

Fig. 1. Vertical distribution of hydrophysical and hydrochemical elements at station No. 50 (Cato Expedition, [6]).
Rys. 1. Pionowe rozmieszczenie elementów hydrofizycznych i hydrochemicznych na stacji nr 50 (ekspedycja Cato, [6]).

2. EXPERIMENTAL

The data presented below were collected in May 1978 in the Argentine Basin (southwestern Atlantic Ocean) at the oceanographic stations located as shown in Fig. 2. The following were determined at each of 46 stations:

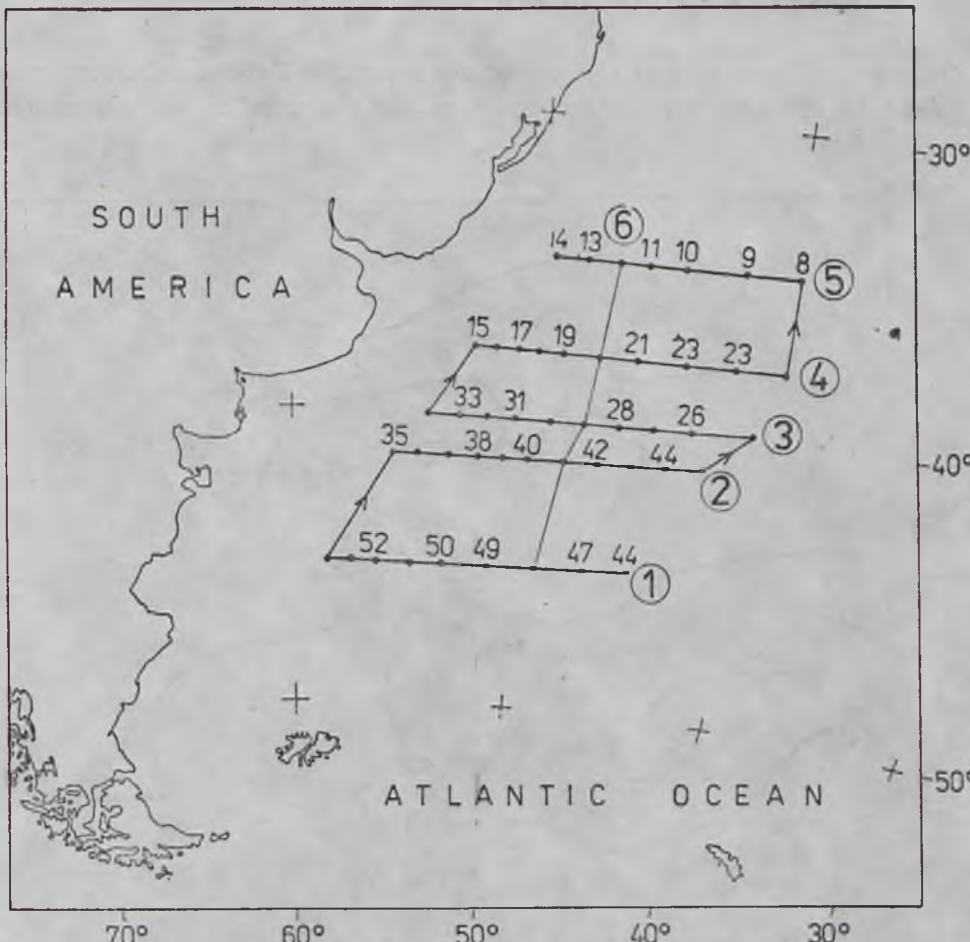

Fig. 2. Location of oceanographic stations.
Rys. 2. Rozmieszczenie stacji oceanograficznych.

— dissolved oxygen content in water by the Winkler method,
— phosphates by the Murphy-Riley method,
— nitrates by the Morris-Riley method, modified by Grasshoff,
— nitrites by the Bendschneider-Robinson method,
— silicates by the Mullin-Riley „blue" method.

Calculations were carried out on an ELLIOT 905 computer. Samples were collected using a BERGEN NAUTIK type Nansen flask at standard levels down to 2000 m, excluding the surface layer down to 200 m. In the latter case, the measuring levels were determined following the analysis of BT records.

3. RESULTS AND DISCUSSION

O x y g e n. The cool and less saline waters of the Falkland Current contained more oxygen than the warmer and more saline waters of the

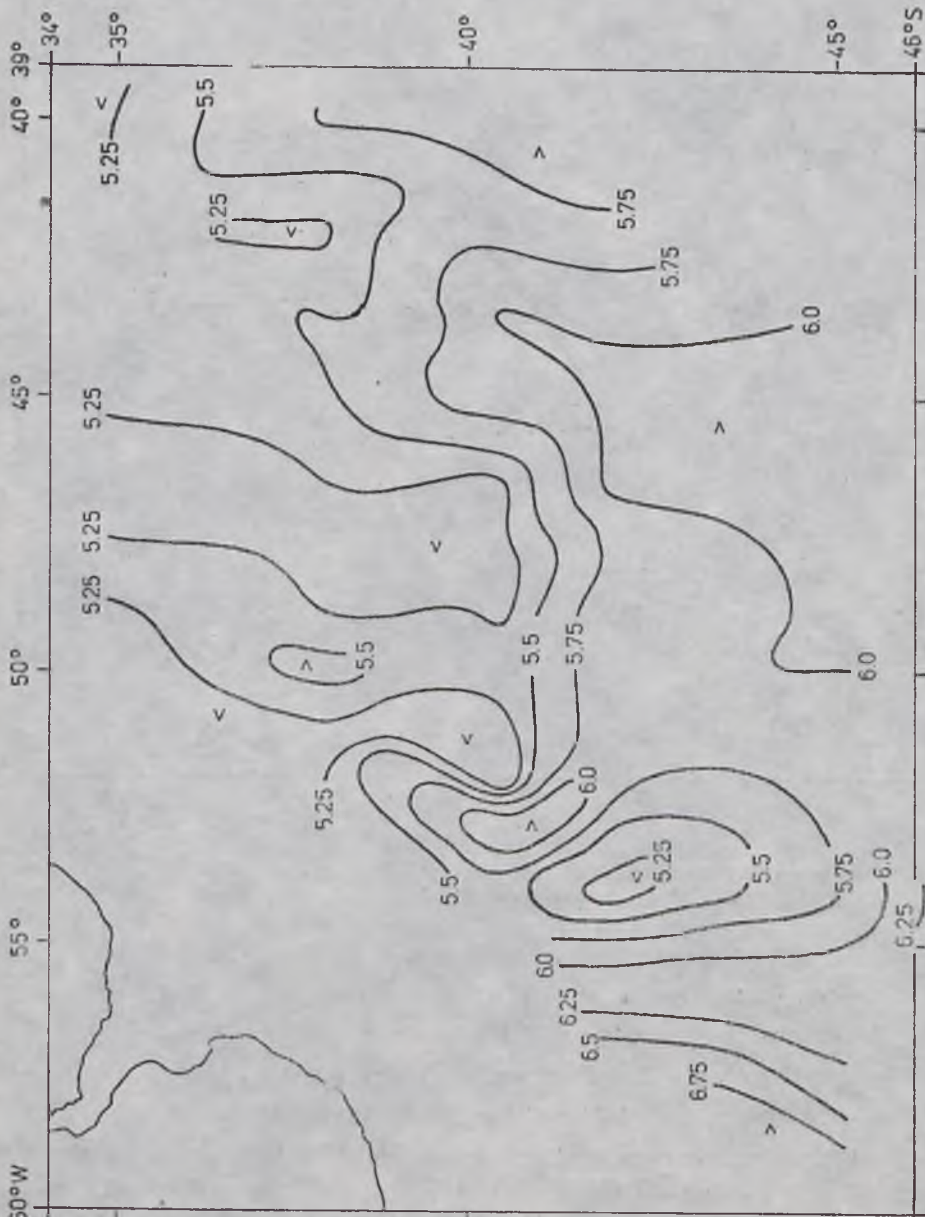

Fig. 3. Oxygen content in the surface layer. May 1978.
Rys. 3. Zawartość tlenu w warstwie powierzchniowej. Maj 1978.

Brazil Current (Fig. 3). The levelling effect of meteorological conditions, atmospheric oxygen, insolation etc., rendered the differences in oxygen saturation between northern and southern surface waters insignificant and the frontal zone indistinct. The oxygen content was similar through

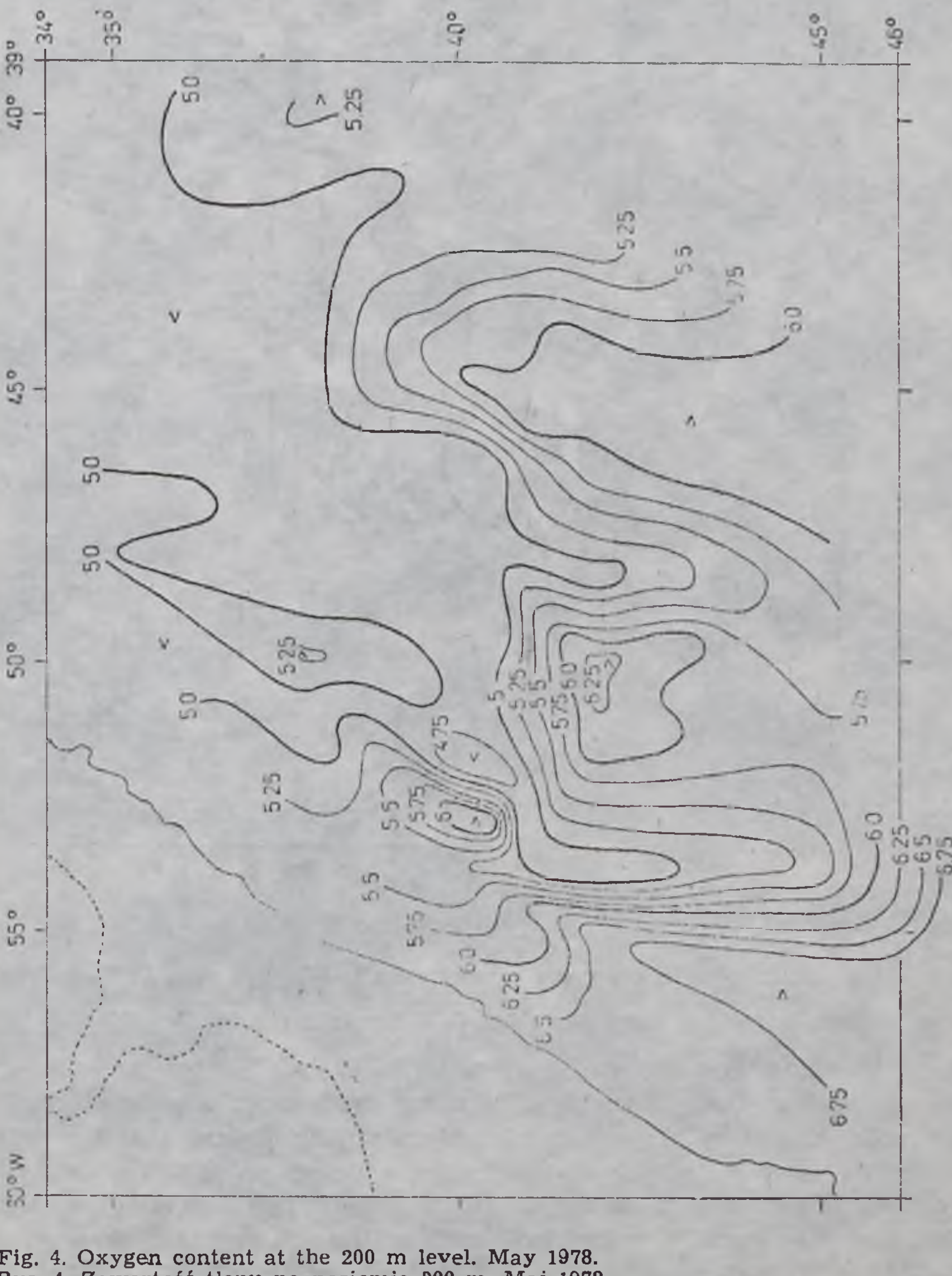

Fig. 4. Oxygen content at the 200 m level. May 1978.
Rys. 4. Zawartość tlenu na poziomie 200 m. Maj 1978.

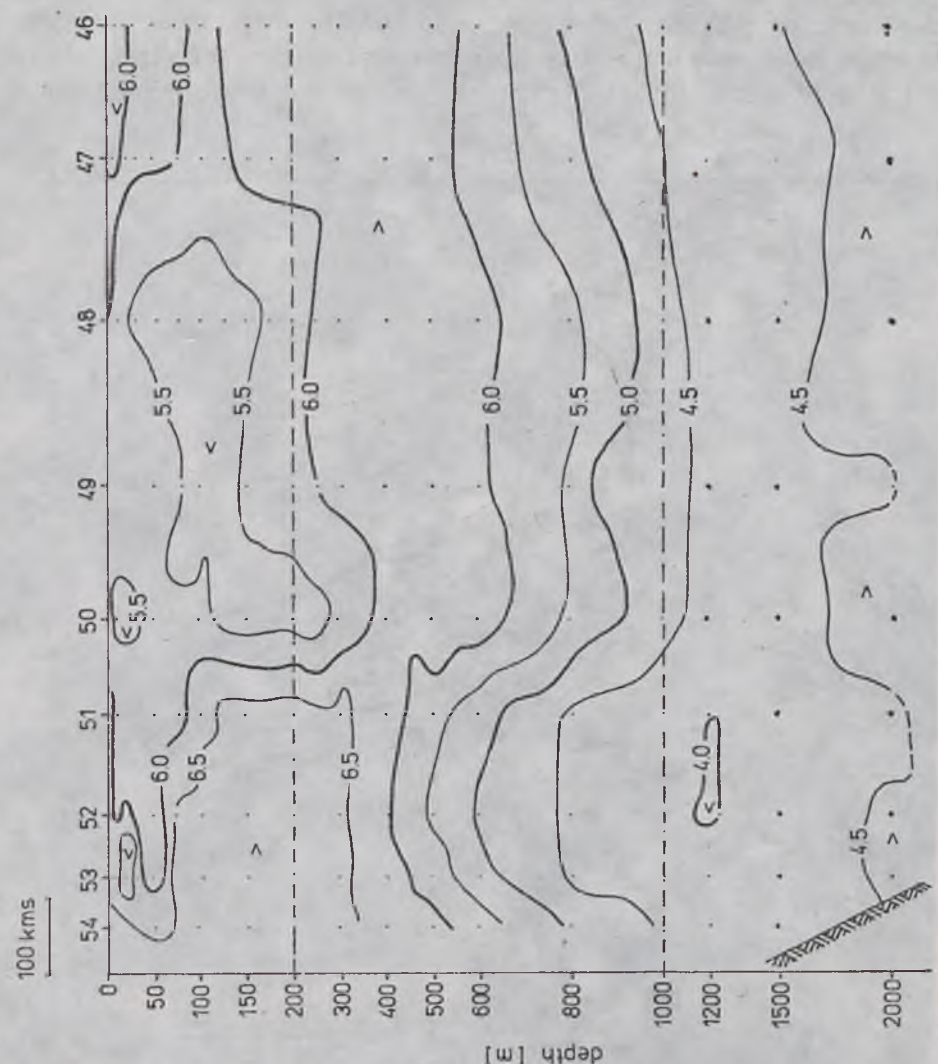

Fig. 5. Vertical distribution of oxygen concentration [ml O_2/l], profile 1 (45° S). May 1978.
Rys. 5. Pionowy rozkład stężeń tlenu [ml O_2/l], profil 1 (45° S). Maj 1978.

out the whole area and varied from 97 to 103%. The oxygen content in the surface layer down to 200 m did not change significantly. At a depth of 200 m the range of waters of the Falkland and Brazil Currents as well as that of the frontal zone were distinctly marked (Fig. 4). The pattern of isooxygens, with well-developed gradients at the junction of waters from the north and south, defines the frontal zone at this depth precisely. North of the frontal zone the oxygen content at

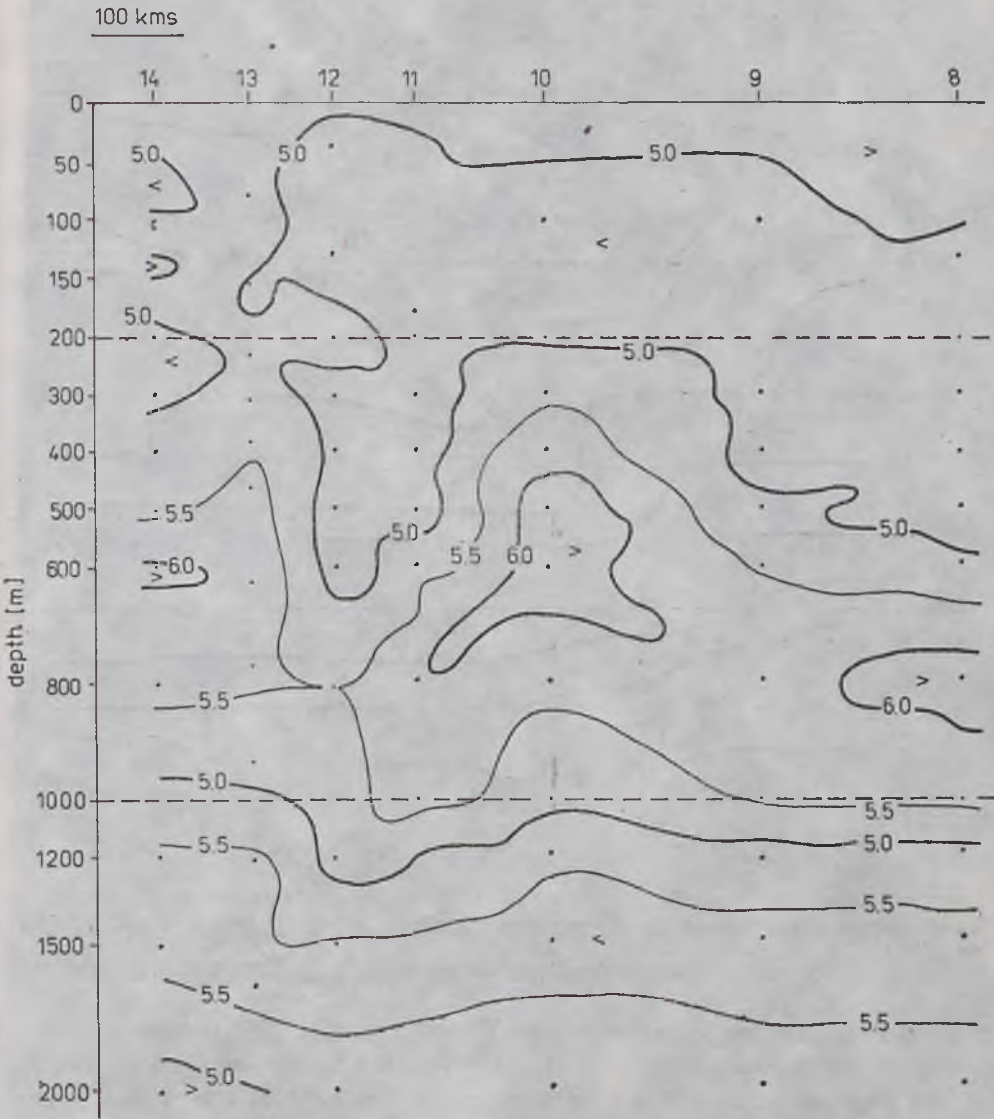

Fig. 6. Vertical distribution oxygen concentration [ml O_2/l], profile 5 (35° S). May 1978.
Rys. 6. Pionowy rozkład stężeń tlenu [ml O_2/l], profil 5 (35° S). Maj 1978.

the 200 m level was uniform and amounted to ca. 5.0 ml O_2/l, whereas the southern part contained more oxygen — ca. 6.75 ml O_2/l, at a saturation ranging from 82 to 90%. The subsurface oxygen minimum occurred at the pycnocline boundary, below the mixing layer. This was probably caused by increased consumption of oxygen in the processes of decomposition of organic matter (Figs. 5, 6, 7). The oxygen maximum associa-

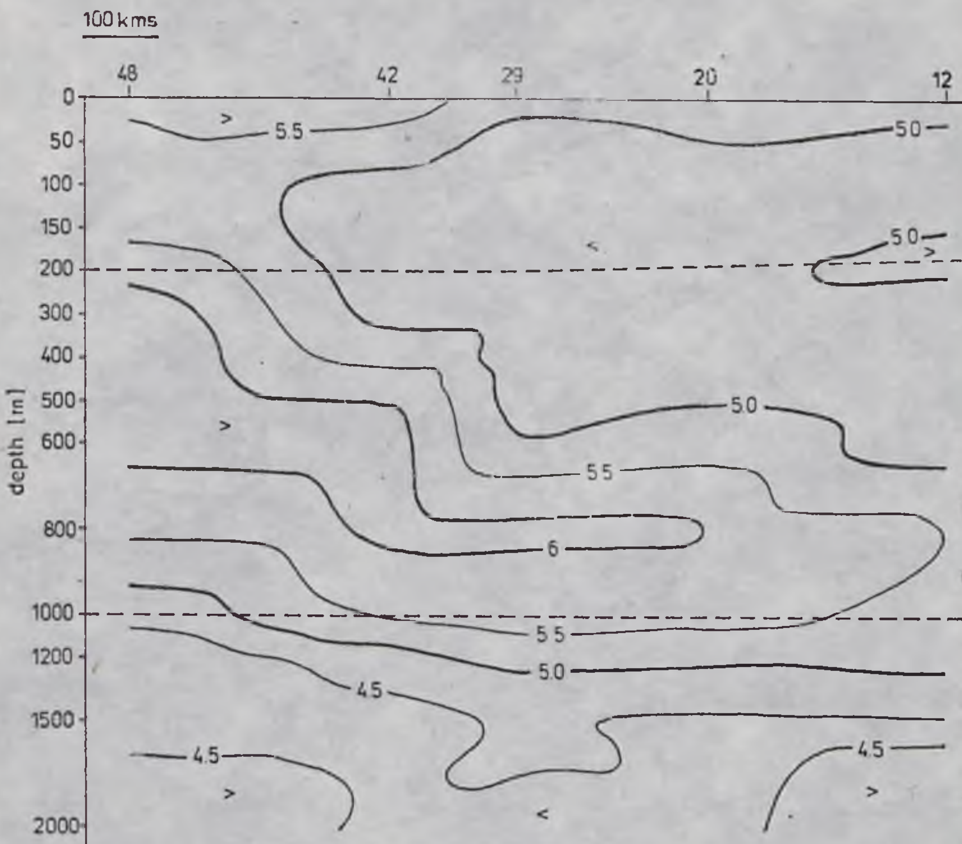

Fig. 7. Vertical distribution of oxygen concentration [ml O_2/l] profile 6 (ca. 48° W). May 1978.
Rys. 7. Pionowy rozkład stężeń tlenu [ml O_2/l], profil 6 (ok. 48° W). Maj 1978.

ted with the Antarctic Intermediate Water mass (AAIW) occurred to the north of the frontal zone, at a depth from 400 to 800 m. In the waters of the Falkland Current, i.e. in the south-west part of the region investigated, the maximum occurred at a depth of ca. 200 m. Shallowing of the Antarctic Intermediate Water should be attributed to the upwelling of water in a cyclonic gyre [5]. The second (after the surface) oxygen minimum occurred at a depth of ca. 1200 to 1500 m and was associated with the mass of the Circumpolar Water (CPW) flowing from the Pacific part of the Southern Ocean through the Drake Passage. Below this the oxygen content increased by about 0.5 ml O_2/l [5]. The increase of oxygen content observed at 2000 m was probably connected with mass of the Upper North Atlantic Deep Water (UNADW).

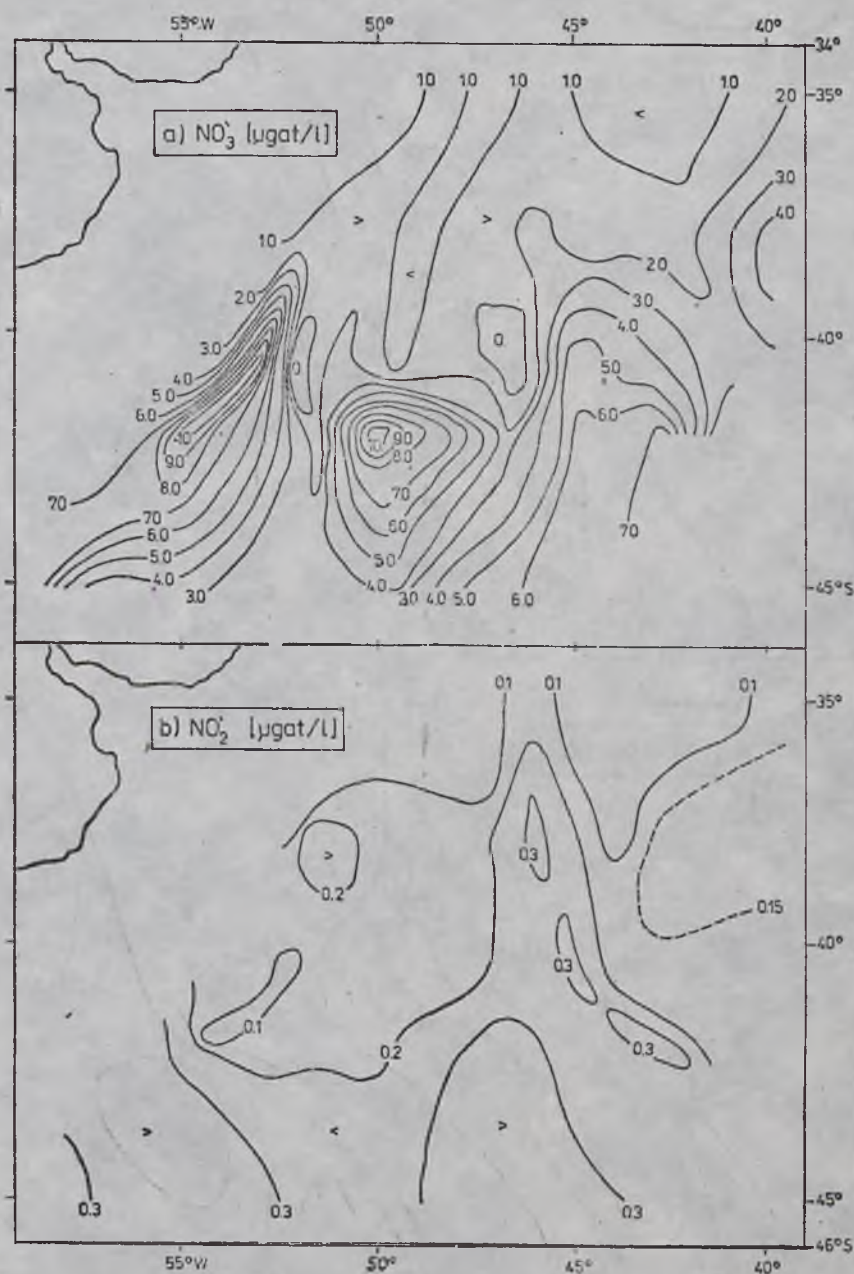

Fig. 8. Contents of nitrites and nitrates in the surface layer. May 1978.
Rys. 8. Zawartość azotynów i azotanów w warstwie powierzchniowej. Maj 1978.

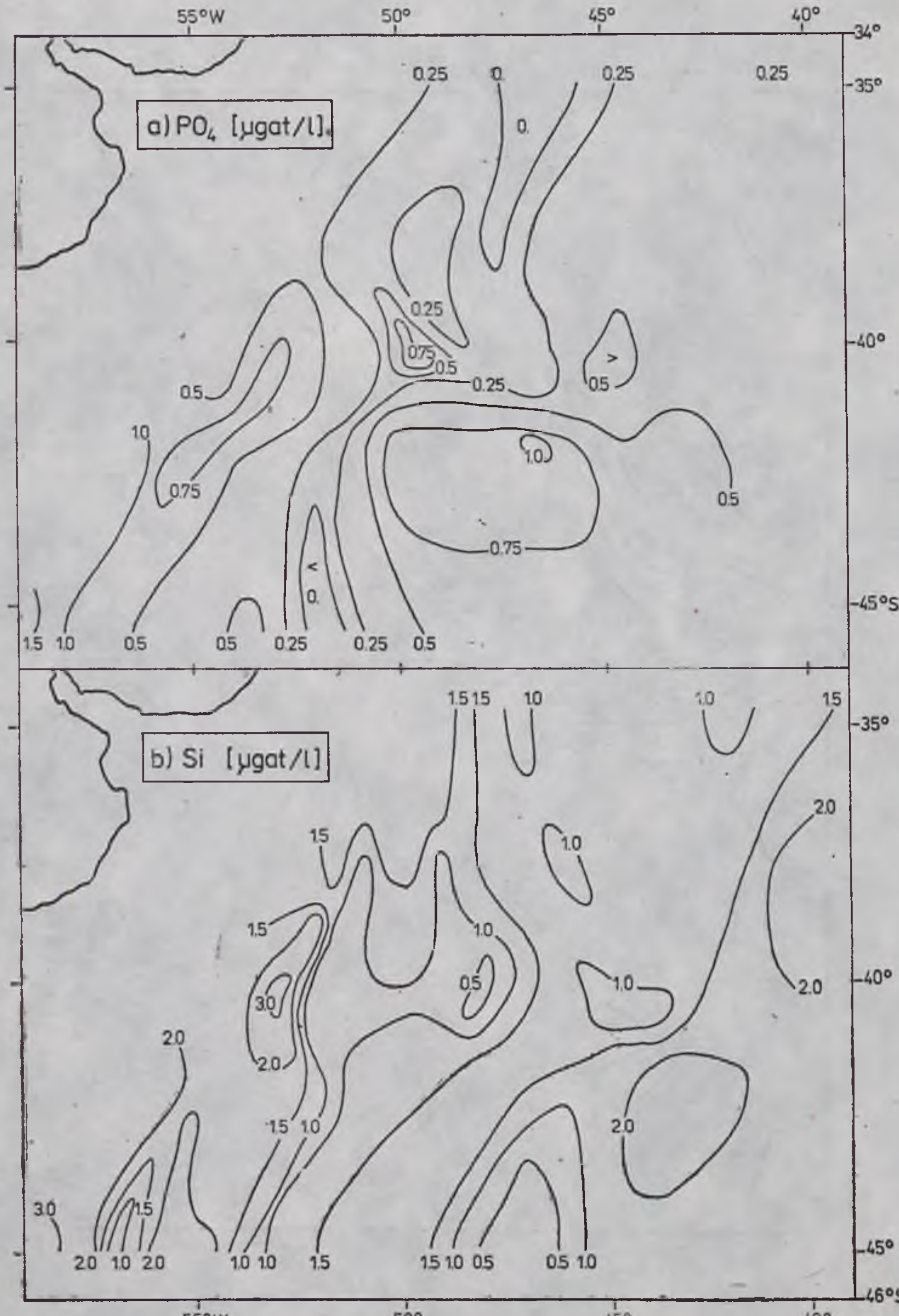

Fig. 9. Contents of phosphates and silicates in the surface layer. May 1978.
Rys. 9. Zawartość fosforanów i krzemianów w warstwie powierzchniowej. Maj 1978.

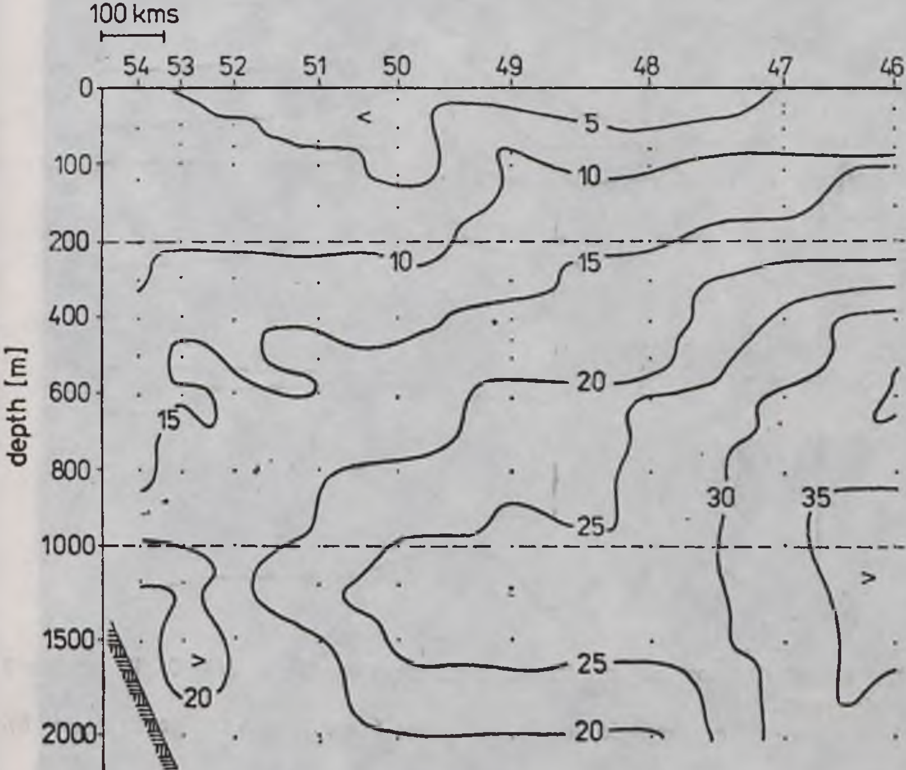

Fig. 10. Vertical distribution of nitrates concentrations [μgat/l], profile 1 (45° S). May 1978.

Rys. 10. Pionowe rozmieszczenie stężeń azotanów [μgat/l], profil 1 (45° S). Maj 1978.

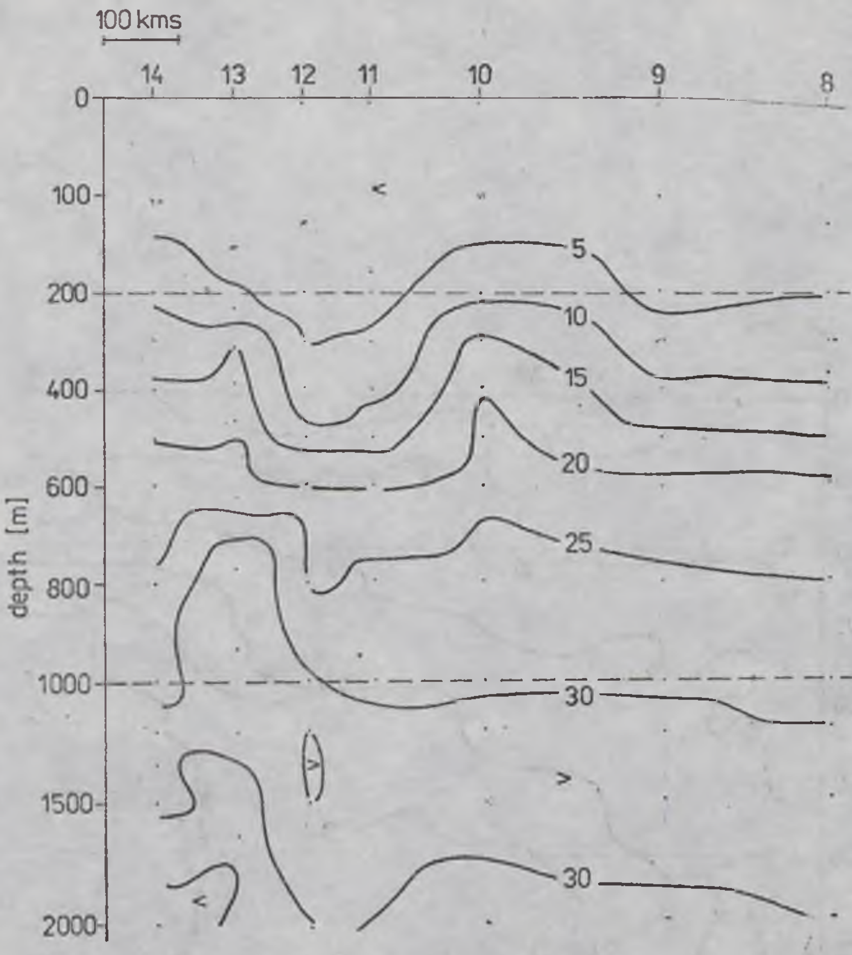

Fig. 11. Vertical distribution of nitrates concentrations [μgat N NO_3/l], profile 5 (35° S). May 1978.

Rys. 11. Pionowe rozmieszczenie stężeń azotanów [μgat N NO_3/l], profil 5 (35° S). Maj 1978.

N i t r o g e n. The contents of nitrogen-containing salts in the surface layer varied over a very wide range, from almost complete depletion to nearly 11 μgat N/ l in the case of nitrates (Fig. 8a) and from zero to almost 0.4 μgat N/l in the case of nitrites (Fig. 8b). In vertical distribution, the contents of nitrates increased with depth to 30 μgat N/l in the northern part of the area investigated and to 35 μgat N/l in the south-east (Figs. 10, 11). The contents of nitrites in the active layer of the ocean was of the order of tenths of μgat/l down to the pycnocline, and decreased to zero below the density jump in the majority of cases.

Phosphorus. The surface layer contained phosphorus compounds in concentrations ranging from below the detection limit to 1.0 µgat P/l, the occurrence of the highest concentrations coinciding roughly with those of nitrates (Fig. 9a). The contents of phosphates increased steadily with depth, reaching concentrations of the order of 2.5 to 2.75 µgat P/l in the 1500—2000 m layer (Figs. 12, 13, 14).

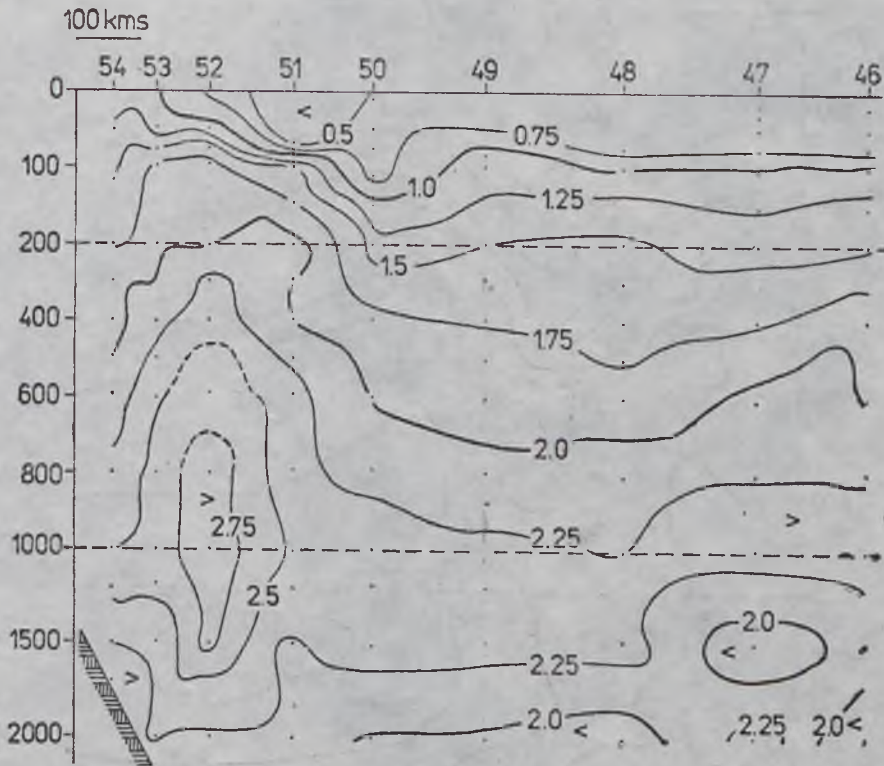

Fig. 12. Vertical distribution of phosphates concentrations [µgat/l], profile 1 (45° S). May 1978.

Rys. 12. Pionowe rozmieszczenie stężeń fosforanów [µgat/l], profil 1 (45° S). Maj 1978.

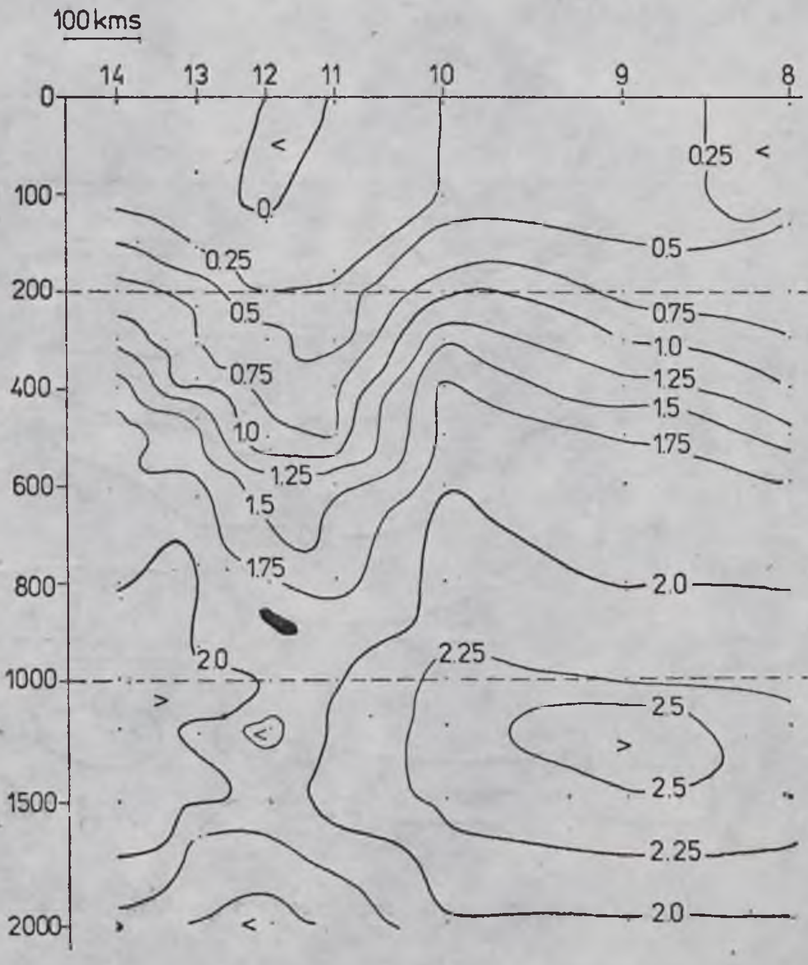

Fig. 13. Vertical distribution of phosphates concentrations [μgat P/l], profile 5 (35° S). May 1978.

Rys. 13. Pionowe rozmieszczenie stężeń fosforanów [μgat P/l], profil 5 (35° S). **Maj 1978.**

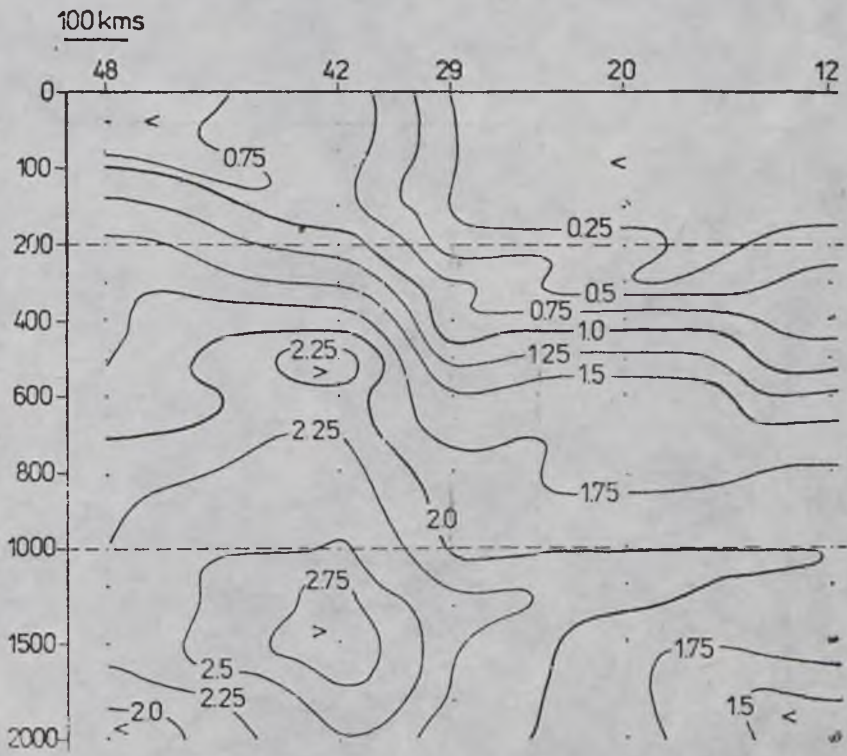

Fig. 14. Vertical distribution of phosphates concentrations [μgat/l], profile 6 (ca. 48° W). May 1978.

Rys. 14. Pionowe rozmieszczenie stężeń fosforanów [μgat/l], profil 6 (ok. 48° W). Maj 1978.

S i l i c o n. The concentration distribution of silicates in the surface layer differed somewhat from that of phosphates and nitrates. The values of higher concentrations intermixed with lower ones from an irregular pattern ranging from 0.49 to 3.89 μgat Si/l (Fig. 9B). In vertical distribution, silicates exhibited a high degree of stratification, increasing steadily with depth and reaching the concentrations of the order of 50 μgat Si/l in the north and 70 μgat Si/l in the south-west (Figs. 15, 16, 17).

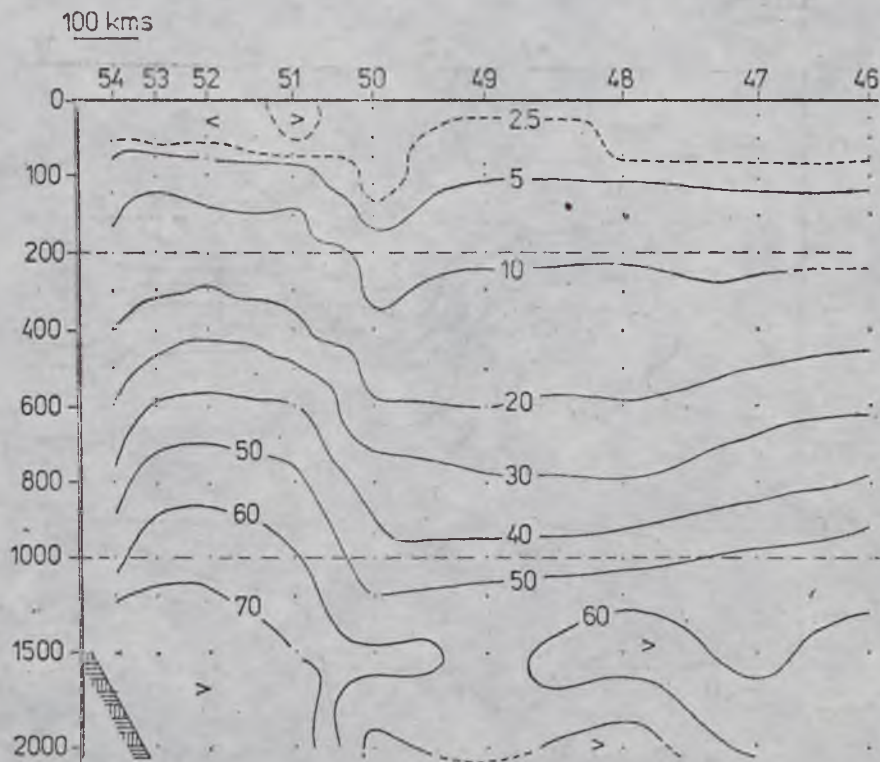

Fig. 15. Vertical distribution of silicates concentrations [μgat/l], profile 1 (45° S). **May 1978.**

Rys. 15. Pionowe rozmieszczenie stężeń krzemianów, [μgat/l], profil 1 (45° S). Maj 1978.

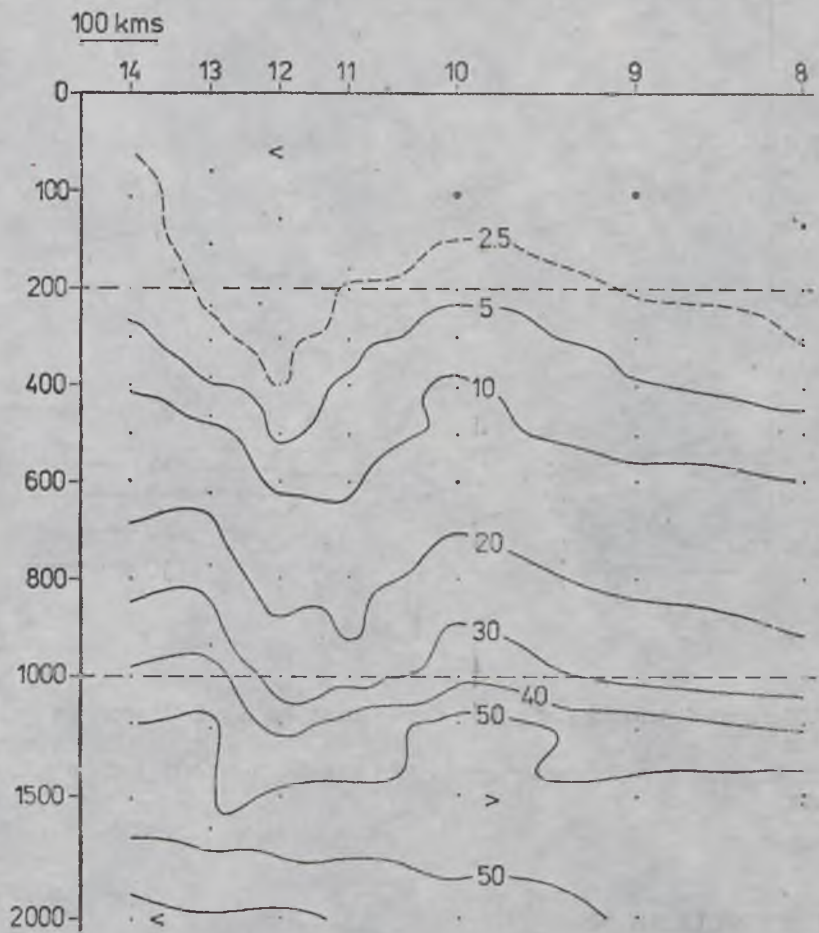

Fig. 16. Vertical distribution of silicates concentrations [μgat Si/l], profile 5 (35° S). May 1978.

Rys. 16. Pionowe rozmieszczenie stężeń krzemianów [μgat Si/l], profil 5 (35° S). Maj 1978.

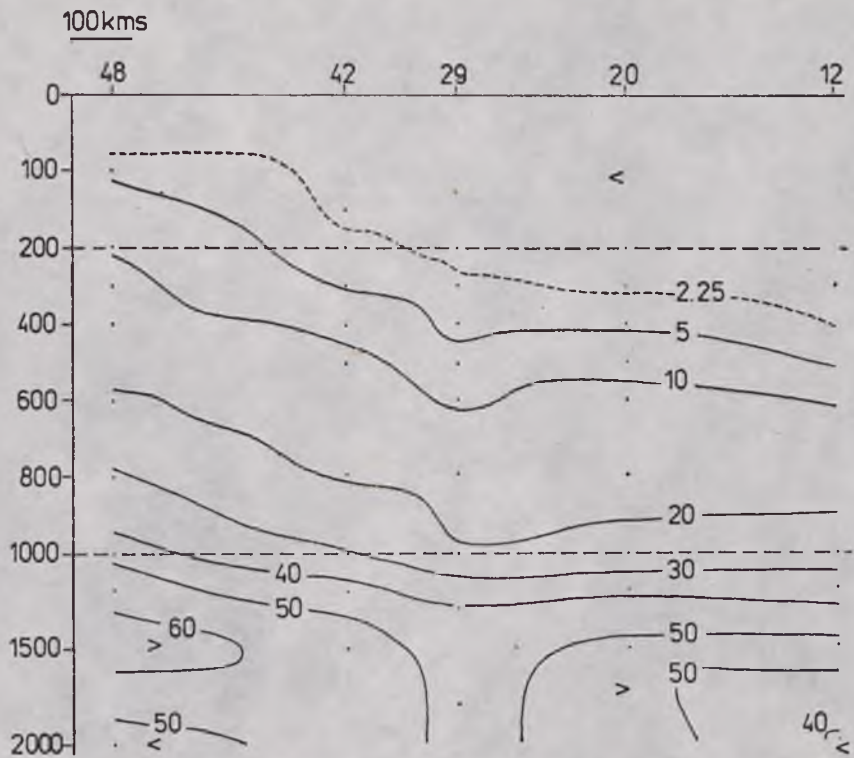

Fig. 17. Vertical distribution of silicates concentrations [μgat/l], profile 6 (ca. 48⁰ W). May 1978.

Rys. 17. Pinnowe rozmieszczenie stężeń krzemianów [μgat/l], profil 6 (ok. 48⁰ W). Maj 1978.

4. CONCLUSIONS

The surface layer bounded from below by a sharp pycnocline was distinctly deficient in biogenic salts, and was also there that a quasi-gradient of concentration of all biogenic salts was formed. This was related to impeded vertical mixing through the pycnocline and hence to reduced transport of salts from the deeper layers of the ocean. At the points where the pycnocline was diffused, the concentrations of nutrients increased steadily with depth down to the measurement limit (2000 m) with the exception of nitrites, the presence of which was occasionally observed below the pycnocline.

The regions of maximum concentrations of phosphates and nitrates coincided with those of the occurrence of cyclonic gyres bringing fertile deep waters to the surface in the frontal zone [5].

Weighted average contents of biogenic salts (μgat/l):

Element	Brazil Current	Falkland Current	Frontal zone	Layer (m):
Si	1.0 —1.5	2.4 —3.6	1.2 — 1.7	0—50
	1.0 —1.8	3.9 —4.9	1.1 — 3.5	0—100
P	0.27—0.33	1.08—1.45	0.57— 0.58	0—50
	0.27—0.42	1.29—1.45	0.58— 0.75	0—100
N-NO_3	1.1 —1.6	5.5 —8.8	2.9 — 7.8	0—50
	2.6 —2.8	6.6 —9.3	2.9 —10.8	0—100

The analysis of the experimental data confirms the conclusion that the waters carried by the Falkland Current are considerably richer in nutrients than those of the Brazil Current, whereas the frontal zone constitutes the region of intermediate concentrations.

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ZAWARTOŚĆ TLENU I SUBSTANCJI BIOGENICZNYCH W STREFIE FRONTALNEJ PRĄDÓW BRAZYLIJSKIEGO I FALKLANDZKIEGO

Streszczenie

Opracowanie zawiera krótki opis dystrybucji soli biogenicznych w zachodniej części Basenu Argentyńskiego do głębokości 2000 m z podkreśleniem obszaru mieszania wód Prądu Brazylijskiego i Falklandzkiego.

Obserwowana ostra piknoklina utrudniała mieszanie pionowe wód, stąd warstwa powierzchniowa była wyraźnie uboższa w sole biogeniczne. Miejsca wystąpienia ostrej piknokliny charakteryzowały się wyraźnymi gradientami stężeń, natomiast tam, gdzie piknoklina była rozmyta, stężenia biogenów wzrastały systematycznie aż do granicy pomiaru, tj. 2000 m, z wyjątkiem azotynów, których obecność pod piknokliną stwierdzona była sporadycznie. Obszary najwyższych stężeń fosforanów i azotanów pokrywają się z miejscami wystąpienia cyklonalnych wirów wynoszących żyzne wody głębinowe w strefie frontalnej prądów.

REFERENCES

1. Buscalia J. L., *On the circulation of the intermediate water in the South-western Atlantic Ocean*, J. Mar. Res., 29, 1971, p. 245—255.
2. Harvey H. W., *The chemistry and fertility of sea waters*, London, 1955.
3. Ingri N., Acta Chem. Scand. 13, 1959, p. 758.
4. Kester D. R., R. M. Pytkowicz, Limnol. Oceanogr. 12, 1967, p. 243.
5. Majewicz A., *Note on dynamic waters in the frontal zone of Brazil and Falkland Currents*, ICES, C. M. 1979/C:13.
6. Reid J. L., W. D. Nowlin, W. C. Pazert, *On the characteristic and circulation of the Southwestern Atlantic Ocean*, Journal of Physical Oceanography, Vol. 7, 1977.
7. Riley J. P., R. Chester, *Introduction to Marine Chemistry*. London and New York, 1971.
8. Sverdrup H. U., M. W., Johnson, R. H. Fleming, *The Oceans, their physics, chemistry and general biology*, 1942.