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Circulation of Waters in the South Labrador and Newfoundland Areas in 1970-1971

by

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A B S T R A C T

Spatial changes in the geostrophic circulation of waters in the South Labrador and Grand Bank areas in 1970-1971 were considered on the basis of dynamic charts compiled according to data obtained during five cruises of research vessels of PINRO to those areas. A considerable stability of the circulation system, against the background of which changes in separate details of the systemm occur (an enlargement of the area of action of the Labrador Current, change in its velocity, origin of vortexes etc.) was revealed. These changes, apparently, determine the origin of anomalies of temperature and other elements.

Change in the intensity of the Labrador Current was followed on the basis of data on its water transport across the sections 8-A, 6-A and 3-A calculated by the dynamic method and through determination of water transport anomalies. Great fluctuations in the water transport and their anomalies are revealed.

The intensity of the current along its axis varies with time equivocally.

In 1970-1971 research vessels of PINRO "Protsion" and "Rossiya" conducted several hydrological surveys in Subareas 2J,3 and 4V. Treatment of the data obtained by the dynamic method (Zubov and Mamaev,1956) made it possible to consider the peculiarities of circulation of waters in the areas mentioned for the last two years.

Variability of circulation of waters was studied by two ways :

a) by compiling and comparing the dynamic charts;

b) by analyzing the sequences of values of water transport on some hydrological sections intersecting the main branches of the currents in the area.

The first way allows for analyzing the changes in circulation with space and time. The second one gives numerical characteristics of the intensity of the currents and allows for evaluating the intensity value relative to normal.
was taken as the reference surface since the area investigated is rich in banks with depths shallower than 200 m.

A comparison between the dynamic charts themselves and charts by other authors (Smith et al.,1937;Buzdalin and Elizarov, 1962) shows that in 1970-1971 the main pattern of circulation of waters in the area investgated did not differ,in principle, from the pattern known. So,the Labrador Current and its branch, moving around the Flemish Cap Bank in a clockwise direction, anticyclonic movements of waters in the central part of the Grand Bank and Flemish Cap Bank and other peculiar features of circulation are clearly seen on all the charts.

The most comprehensive chart of circulation was constructed on the basis of data of observations on 355 hydrological stations worked out during the 13 cruise of R/V "Rossiya" (Fig.2). On the standard stations observations were made at standard depths,at trawl stations they were carried out at depths of 0, 20,50,100,200,300 m and near the bottom. An increase in the velocity of the Labrador Current in the core of the stream and its strong eddying is clearly seen on the chart. Relief of the bottom is one of the reasons of eddying,because the meanders of the stream mostly originate in the area of submarine canyons located at right angles to the axis of the current.

On the south-western slope of the Grand Bank the velocity of the Labrador Current decreases;it is deflected to the right and flows onto the shallow of the Grand Bank. At about 45°N, 53°W the main stream almost connects with the coastal branch of the Labrador Current. The latter flows further in a westerly direction along the southern coast of Newfoundland.

Figures 1-3 point to a great stability of the system of circulation of waters in the area investigated and to the constancy of action of main factors forming this system.

However,the comparison of the charts shows that concurrent with the common character of the pattern of circulation,there are differences in some details of the system from one survey to another one. The differences mentioned,i.e. peculiarities of circulation of waters,apparently,are responsible for the origin of anomalies of temperature and other hydrological elements in separate parts of the area.

These are the most distinctive features of circulation of waters in 1970-1971,that were revealed on the basis of dynamic charts :

1. In the Hamilton Inlet Bank area the Labrador Current, apparently,became weaker from winter to spring and strengthened again by autumn. The main stream in the 0-200 m layer moved east of the bank above the continental slope (Fig.1).

2. In autumn the velocity of the current was maximal on the Zundal Bank (Fig.1).

3. In winter and spring of 1970 an enlargement of the area of action of the Labrador Current was observed to the south of the parallel of Belle Isle. In autumn this phenomenon was not observed (Fig.1).

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4. In winter of 1970 on the north-eastern slope of the Grand Bank of Newfoundland waters moved in a clockwise direction (Fig.1A). The subsequent surveys reveal there both complete absence of vortexes (Fig.1B and C,Fig.3A) and a slow movement of waters in an anti-clockwise direction (Fig.2B).Consequently, this area of the Grand Bank is characterized by weak currents of unstable directions. The main volume of the Labrador Current waters moves along the continental slope into the Flemish Channel passing around the Grand Bank of Newfoundland.

5. On the southern half of the Grand Bank a vast vortex is usually located with its waters moving in a clockwise direction. Small secondary vortexes,that are mostly developed in the frontal zone,are observed in the outlying areas of the vortex.

6. Eddying of the stream of the Labrador Current from time to time causes intensive influxes of cold waters onto the shallow on the north-eastern and south-western slopes of the Grand Bank (Fig.2B).

7. Above the Green and St.Pierre Banks the currents are weak and unstable in directions. Apparently,circular motion of waters is most often observed there (Fig.2B).

On the Flemish Cap Bank waters mainly move in a clockwise direction,but on the south-eastern part of the Bank secondary eddies with a movement of waters in an anti-clockwise direction are observed (Fig.2A,3A).

Observations on the section along the isobath of 275 m on the south-western slope of the Grand Bank (Subareas 3C and 3P) made during the 6 cruise of R/V "Protsion" are indicative of the existence of great influxes of the Gulf Stream waters onto the shallow of the Bank and into the deep water layers,from a depth of 100-200 m to the bottom,of the Laurentian Channel (Fig.4). A comparison between the diagrams of vertical distribution of temperature,salinity and isotach shows that on the south-western slope of the Bank :

a) transformed waters of the Gulf Stream underlie the Labrador Current waters in the areas of canyons and trenches,

b) there exists an intensive exchange of water masses in the direction that is transversal to the axis of the Labrador Current. The latter circumstance promotes transformation of cold waters of the Labrador Current.

Variation of the circulation intensity

The value of transport across a selected section is an integral indicator of the circulation intensity.The main sections making up the existing pattern of standard sections cross the Labrador Current approximately at right angles.The transports were computed for sections 8-A,6-A and 3-A,i.e.for various parts of the Labrador Current.The average curves of the yearly course of transports based on many years' data (U.S.Coast Guard Bulletin,1956-1964) were used as the basis to estimate the anomaly of transports.These curves were partially corrected by us using the results of our observations and calculations.

Section 8-A coincides with the section South Wolf Islands-c.Fairwell.The transport across the section was calculated from 53°43'N to 55°12'N i.e. within the limits of all 3 branches of the Labrador Current (ABC) (see Fig.1 in a paper by Kudlo and Burmakin,1972) right to the bottom (0-2000m). We can assume that the values of transports thereby calculated are similar to American data.From the data collected by R/V "PerseusIII" during the 6th cruise the transport of the Labrador Current on the Hamilton Inlet Bank in July 1971 (table 1) was lower than the norm by $3.7 \cdot 10^6 m^3$/sec which is a minimum value from a series of observations for July.

The distance between section 6-A along 47°N and the International Ice Patrol section along 46°50'N being small makes it possible to assume that the values of transports of the Labrador Current across these sections do not differ essentially.

The transports from the PINRO materials across section 6-A were calculated from 49°07' to 46°30W ($H_I G H_2$) (table 1) and combined with American data pertaining to section F. The average (normal)curve is satisfactorily substantiated with the data only for the April-July period.For the rest of the months a preliminary curve of the seasonal course of transports based on single observations was constructed. In relation to this curve the intensity of the Labrador Current on section 6-A from May to October 1970 varied from the norm to considerably exceeding it in August and then dropped by 0.5 $10^6 m^3$/sec below the norm in October (table 1). In March 1971 the transport was higher than the norm but by the end of April decreased nearly to the norm exceeding it by only 0.3 $10^6 m^3$/sec and at the end of May dropped below the norm by 1.5 $10^6 m^3$/sec.

Section 3-A was identified with section U of the International Ice Patrol.

The transport of the Labrador Current across section 3-A from the PINRO observations in 1971 was calculated from 45°00'N,49°10'W to 44°50'N,48°30'W.The curve of the seasonal course of transport from April to June 1971 appeared to be reverse to the long term curve of the yearly course of transports of the Labrador Current across this section (table 1).Within a period of 3 months the anomaly of transports varied from -3.0 to +3.2 000 000m^3/sec.A series of observations being short diminishes the reliability of the "normal" curve used to compute the anomaly of transports.

Though the data on the transport of water masses by the Labrador Current pertaining to its various parts are scarce they indicate that its intensity varies greatly.The intensity of the Current in various parts varies with time having different signs: at one and the same period one section can exhibit a high positive anomaly while another shows a high negative anomaly. What causes this phenomenon is not yet clear but there can be no doubt this process is a decisive one in the forming of water temperature anomalies in various parts of the Current.

Conclusions

1.The general circulation in the South Labrador-Newfoundland area is highly stable.

2.The intensity of the Labrador Current in its various parts varies having different signs.One of the reasons of it is the eddying of the current and cold water influxes on the shallows of the Grand Bank.

3.On the South-West slope of the Grand Bank and in the trenches between the Green Bank and St.Pierre Bank the penetration of warm waters in shallows is observed.This phenomenon as well as the lateral exchange accelerate the transformation of the cold Labrador waters.

4.The intensity of the Labrador Current on the Hamilton Inlet Bank in July 1971 was the lowest for a whole period of observations.In March 1971 the transport across section 6-A was higher,then decreased to the norm and at the end of May dropped below the norm by 1.5 $10^6 m^3$/sec.On section 3-A the anomalies of the transport from April to June 1971 varied from a high negative to ahigh positive value.

Table 1

Transports of the Labrador Current and their anomalies across some standard sections in the Labrador and Newfoundland area in mill.m^3/sec

(1970–1971)

Sections and sectors	Date	Transport		
		Observed	Norm	Anomaly
8-A, ABC	29-30 July 1971	2,I4	5,8	- 3,7
6-A, $H_I GH_2$	19-20 May 1970	3,28	3,2	0,0
	8 Aug.1970	6,38	3,5	+2,9
	5-6 Oct.1970	2,92	3,4	-0,5
	19-20 Mar.1971	4,03	2,9	+I,I
	30 Apr.-1May1971	3,42	3,I	+0,3
	24-25 May 1971	I,67	3,2	-I,5
3-A	19-20 Apr.1971	I,98	5,0	-3,0
	15-16 May 1971	3,72	4,2	-0,5
	26 June1971	6,20	3,0	+3,2

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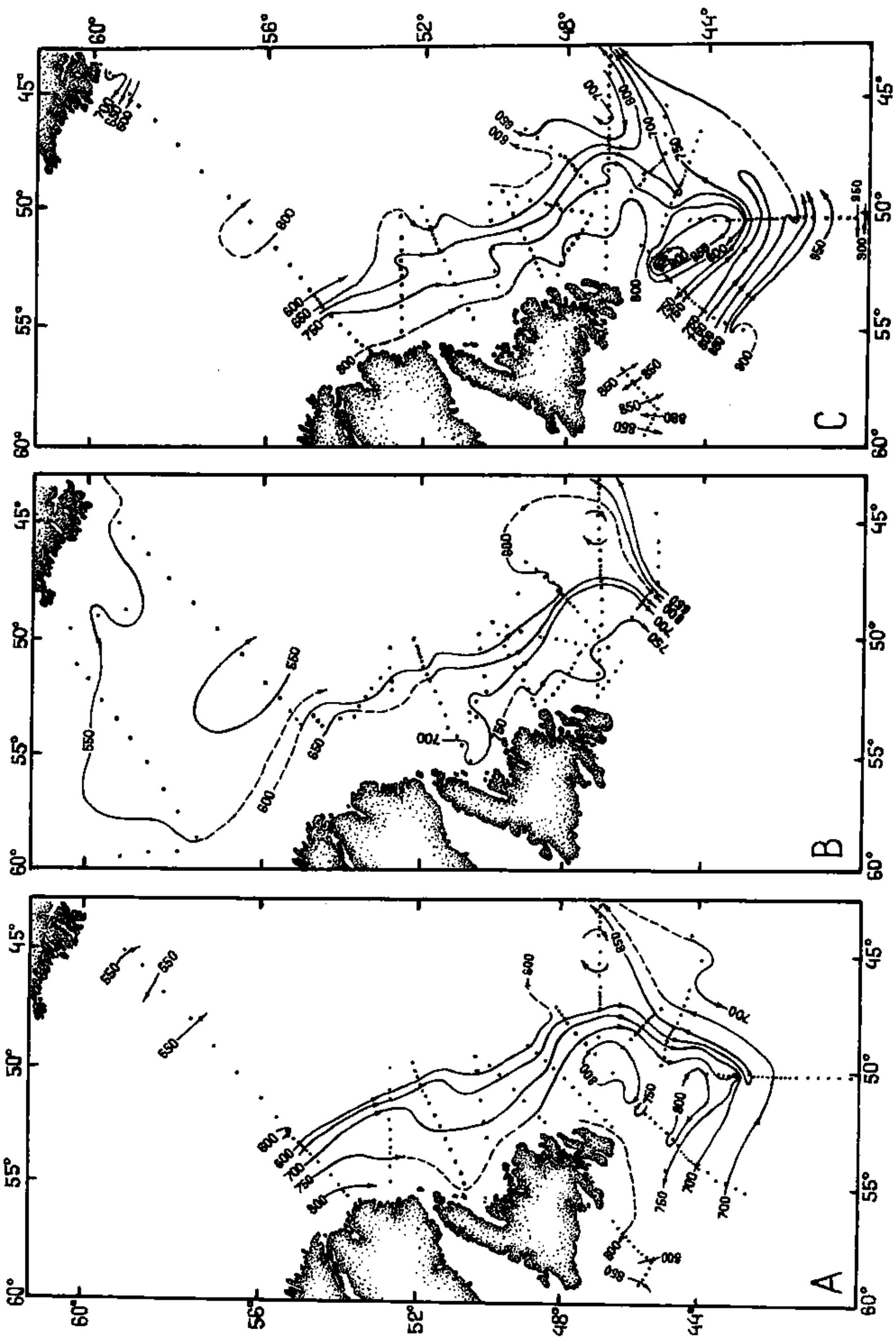

Fig.1

Fig.1. Dynamic charts (0-200 decibars) from data of the 2nd,3rd and 4th cruises of R/V "Protsion" in 1969-1970: December 14 1969-February 14 1970 (A),April 23-June 12 1970 (B), September 1-October 30 1970 (C).

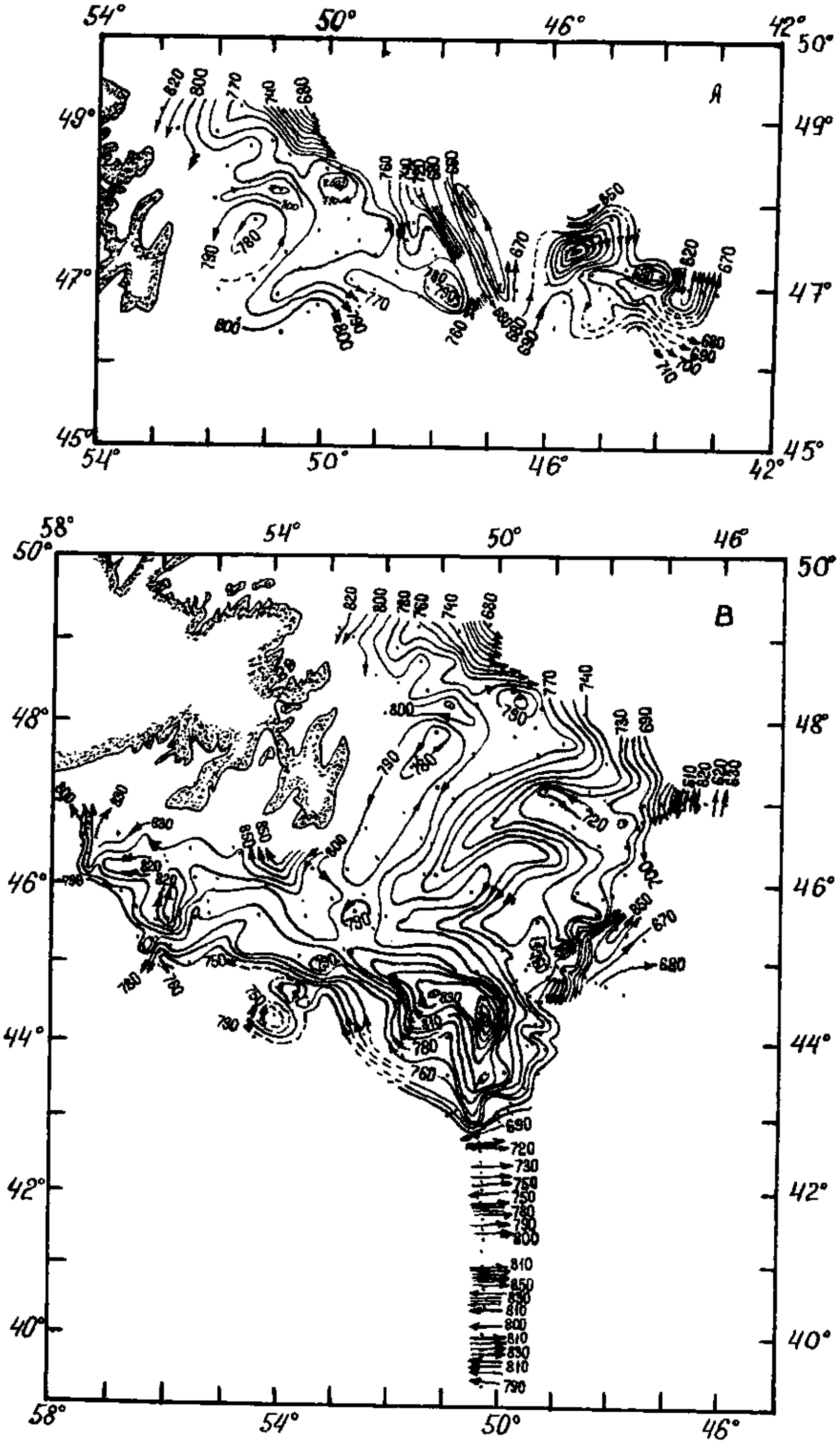

Fig.2

Fig.2. Dynamic charts (0-200 decibars) from data of the 13th cruise of R/V"Rossia" in 1970: July 24-August 13 (A), May 15-July 31 (B).

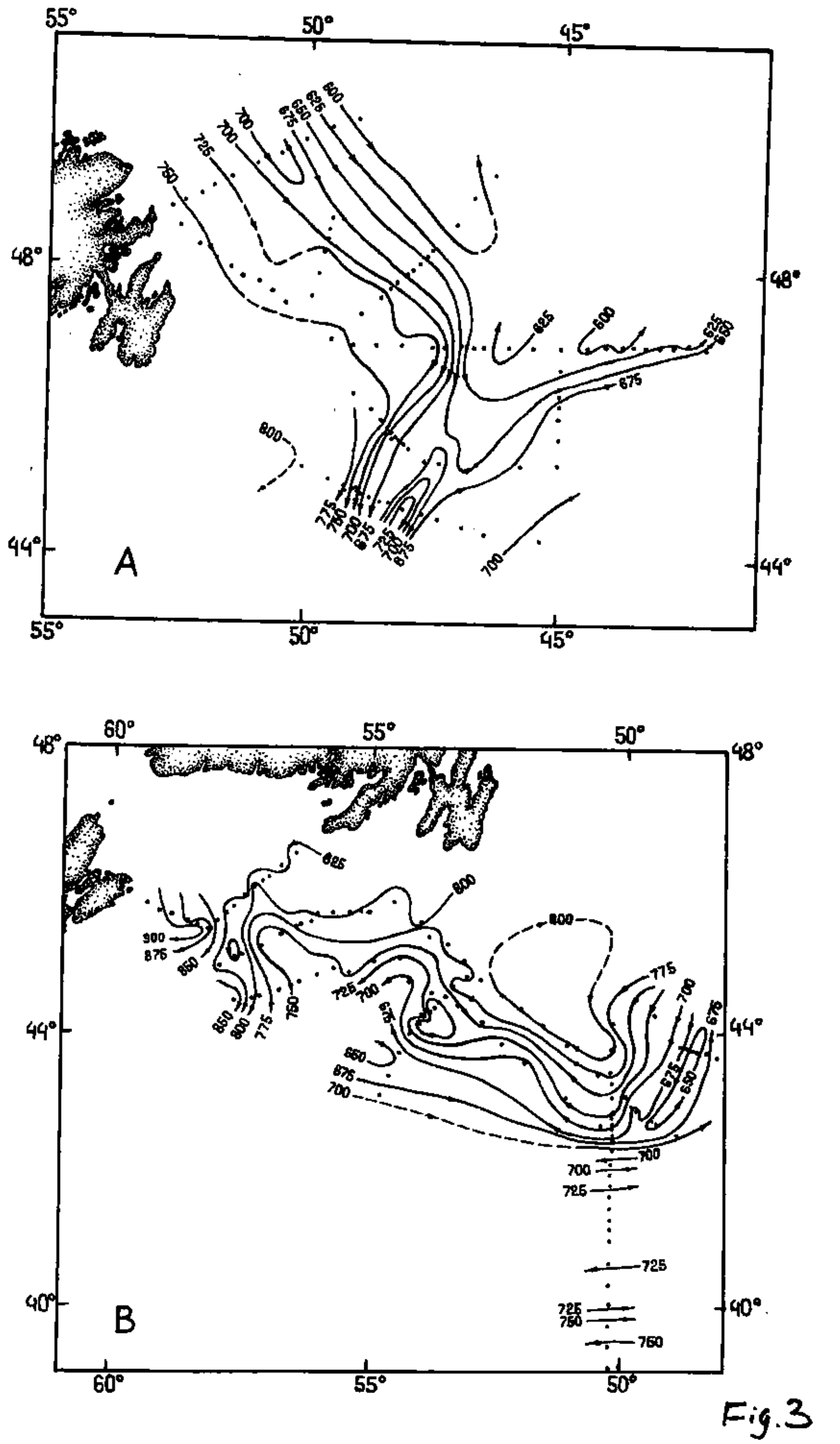

Fig.3. Dynamic charts (0-200 decibars) from data of the 6th cruise of R/V"Protsion" in 1971:April 19-May 8 (A), March 22-April 11 (B).

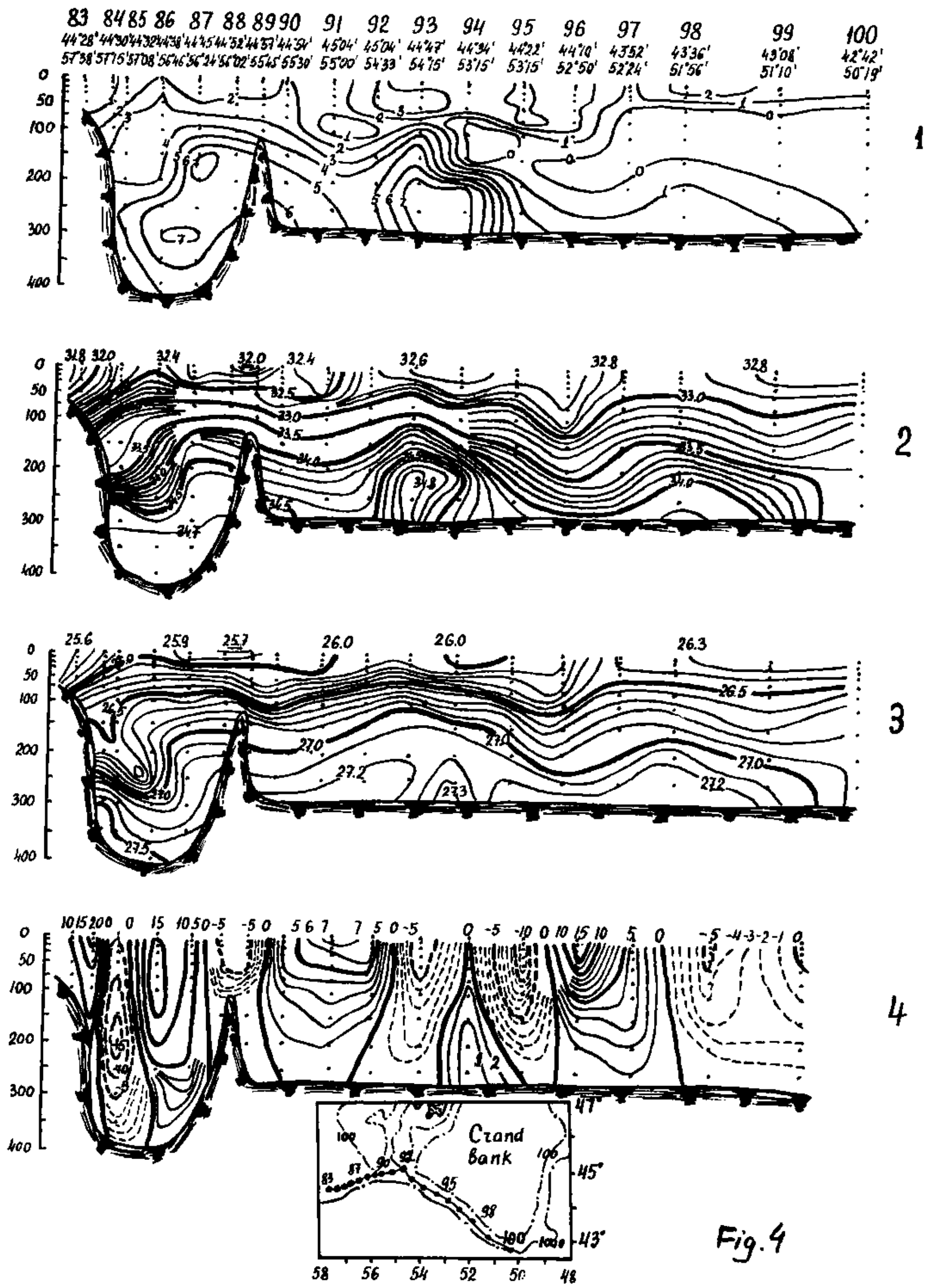

Fig.4. The distribution of temperature (I), salinity (2), conventional density (σ_t) (3) and isotachs (4) on the section along the 275m isobath on the South-West slope of the Grand Bank, March 30-April 2 1971, the 6th cruise of R/V "Protsion".

Solid isotachs represent southward flows.