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Circulation and salinity of waters in the Davis Strait, South Labrador and Newfoundland Areas in 1974-1975

by

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Abstract

The oceanographic conditions in the Northwest Atlantic are considered in the paper on the basis of analysis of the charts of dynamic topography and discharge and salinity values of the Labrador Current waters on standard hydrological sections in 1974–1975. On the basis of analysis of water masses interaction (horizontal and vertical) with application of the theory of T-S diagrams, the criteria for determination of water boundaries of Arctic origin have been obtained. The regularities of seasonal variations in discharges and salinity of the Labrador Current waters on section 2-A are investigated.

Material and methods

In the second half of 1974 and 1975 hydrological observations on standard sections in the Northwest Atlantic were undertaken during cruise 10 (RV"Gemma"), cruise 13 (RV"Protsion"), cruises 12, 13 and 14 (FRV"Perseus III").

Estimates of statistical characteristics and plotting the curves of seasonal variations of discharges and salinity of the Labrador Current waters on section 2-A along the southern extremity of the Grand Bank by a 50°15'W meridian were carried out due to the data collected by the PINRO vessels for 1959-1975 and ships of the International Ice Patrol for 1936-37,1939-40,1955-70 (U.S.C.G.Bull.,1938, 1941,1942,1956-58,1960-61,1963-64 and U.S.C.G.Oceanogr.Rep., 1965,1971-72).

Geostrophic circulation

In 1974 the hydrological survey of the Davis Strait was undertaken in November-early December,i.e. almost two months later,than in 1975. Geostrophic circulation of waters in November-December 1975 is presented in Fig.1. Comparison of this chart with the analogous ones for September-October 1973 (Kudlo and Borovkov,1975) and for October-November 1971 (Kudlo,1973) showed the similarity of water circulation characters in the area investigated during the period just before winter and in early winter. In 1974,as well as in September-October 1973 the greatest eddy in currents field was observed in the area over the central part of the Greenland-Canadian Swell along the strait axis.

In 1974,the area of the South Labrador was covered with hydrological observations in June-July (Kudlo and Borovkov, 1975). The previous survey of this area was carried on in May 1974 on board the FRV "Perseus III" (Fig.2). The vortex observed in May in the Hamilton Bank area stopped its existence by early July and reminded about itself only with flow curves,showing that in the surveys period the intensification of the Labrador Current had been observed in offshore waters of the bank,in location of depths slope.

Geostrophic circulation in the Newfoundland area in June-August 1974 is also shown in Fig.2. A dense grid of stations,given in Fig.2 by dots allowed to obtain a detailed dynamic chart,comparable by its detailing with that for June-August 1973 (Kudlo and Borovkov,1975).

Dynamic chart plotted due to the data collected by RV "Gemma" for Divisions 3L,3M and 3N for the period from November 1974 to early January 1975 is presented in Fig.3. Compared to summer (Fig.2) a peculiarity of geostrophic circulation over the central part of the Great Newfoundland and Flemish Cap Banks in winter is the availability of eddies with great horizontal squares, the formation of the new ones and intensification or collapse of eddies existed before. This is the evidence of a great variability of circulation elements in the investigated area while maintaining the general scheme of circulation.

Variations of the Labrador Current waters discharge

Water discharges of the Labrador Current on standard sections calculated by dynamic method are given in Table 1. The values of norms and anomalies of discharges per date of observations were determined by the average curves of the annual discharge course, compiled by us earlier (Kudlo, 1973; Kudlo and Borovkov, 1975). The average curve of seasonal variations of the Labrador Current waters discharge on section 2-A along the 50°15'W meridian is shown in Fig.4. The methods of its plotting are described below.

Division 2J. From mid-1974 to late 1974 on section 8-A a decrease of negative anomalies of the Labrador Current waters discharge was registered. An increase of discharges took place from October 1974 to August 1975. In August 1975 the water discharge, was by $4 \cdot 10^6 m^3$/sec. higher, than that at the same time in 1974.

On section 6-A, situated in Division 3L, an increase of current intensity was also observed up to late 1974, that causes the appearance of positive discharge anomaly in December. Compared to the norm (Table 1) a sharp reduction of water transport was marked from December 1974 to June 1975.

On the south-eastern slope of the Great Newfoundland Bank in Division 3N, characterised with sections 3-A and 4-A a further weakening of the current was observed up to late 1974.

On section 2-A, also situated in Division 3N the Labrador Current water discharge in 1974-1975 was close to the norm. However, from January to September the weakening of water transport of the Labrador Current was marked and by late September the Labrador Current waters outflow into this area absolutely stopped.

Salinity variations in the Labrador Current waters on standard sections

An average salinity for the 0-200 m layer on standard sections (Table 2) was calculated for numerical characteristics of water regime of the Labrador Current. Its mean value per date of observations taken from the curve of the annual salinity course for a given section (Burmakin and Kudlo, 1971; Kudlo and Burmakin, 1972; Kudlo, 1973) was accepted for the norm.

The methods of plotting the mean long-term curve of annual salinity course of the Labrador Current on section 2-A (Fig.5) is described below.

Methods of determination of characteristics of the Labrador Current waters on section 2-A

Section 2-A situated in the area of the southern extremity of the Great Newfoundland Bank crosses the sharply expressed frontal zone along the 50°15'W meridian.

Analysis of the horizontal interaction of waters on section 2 -A was carried out on the basis of long-term mean T-S diagrams of water masses in the Grand Bank area (Kollmeyer et.al, 1965). While using the theory of T-S diagrams (Mamaev, 1970), T-S diagram of the boundary between the mixed and Labrador Current waters, corresponding to their 50% mixture, was obtained. The location of the southern boundary of Arctic origin waters was determined by means of the present criterion due to all the observations on the section available.

The northern boundary of the main stream is at the latitude of 43°00'N. The application of the invariable location of the boundary of the current in this case is defined by the localization of the stream over the continental slope and insignificant differentiation of features of the shelf and Labrador Current waters.

According to the results of calculations the average width of the Arctic waters belt on section 2-A constitutes 20 miles,but maximum one - 93 miles. In some cases the waters of Arctic origin were absent on the section. This means that any fixed zone of the section is not significant while studying the water characteristics and intensity of the Labrador Current main stream.

Water discharges in the variable boundaries were defined by the dynamic method; the adduction of the dynamic heights for the stations with different depths was conducted by the method of Somov,M.M.(Zubov and Mamaev,1956). Velocities of the current were calculated from the bottom at depths up to 1 000 m and from a 1 000 m depth for deep water stations, as far as the predominant majority of observations was limited with the present depth.

While analysing the vertical interaction of water masses the process of "cores" mixture (Defant,1961) in the Labrador Current waters (T = -1.8 ÷ -0.8°C,S = 32.9 ÷ 33.1°/₀₀) and North Atlantic deep waters (T = 3.0 ÷ 4.0°C,S = 34.9 ÷ 35.0°/₀₀). was considered. T,S index corresponding to 50% mixture of "cores' of water masses (T = 0.6 ÷ 1.6°C,S = 33.9 ÷ 34.1 °/₀₀) was accepted for criterion of depth of extension of the Arctic origin waters. As the calculations showed,the mean depth of their distribution constituted 147 m. While plotting this T,S index on the average T,S curve of the Labrador Current waters (Kollmeyer et.al.,1965),the boundary of the Arctic origin waters almost coincides with a 150 m depth, that confirmes our results. The 0-200 m layer containing in most cases (94% of a number of observations for the period 1955-75) the whole water strata of the Arctic origin and the 0-1 000 m layer, characterising the total discharge were chosen for calculations of characteristics of the main stream of the Labrador Current.

Seasonal variability of discharges and salinity of the Labrador Current waters on section 2-A

To reveal the situation concerning the seasonal variations of the Labrador Current characteristics, the data for 1955-75 were used.

Interannual variability of discharges and salinity of the Labrador Current waters for a zone covered with them on section 2-A is presented in Figs.4 and 5. Due to considerable variability of discharges, the monthly values of discharge medians were accepted as an average measure for plotting the curves of seasonal course. The curves of seasonal salinity course, mean by layers were plotted on monthly weighted average values, as far as salinity distribution was more evenly and median and arithmetical mean for it are coincided.

The tendency to the changes of the mean discharge curve (Fig.4) in the period of April-June corresponds to analogous regularity of variation of the Labrador Current intensity on section W, revealed earlier (Soule et.al., 1961). Lack of coincidence of mean values of discharges in the 0-1 000 m layer due to our data and to those for 1961, is conditioned by both the difference in methods of discharge estimates, and the difference in volume of material used.

For studying the frequency structure of interannual variations of characteristics of the Labrador Current the method of harmonic analysis of mean curves of annual course was applied. Intensity variations of the current in the 0-1 000 m layer have a complex spectrum of frequencies, in which the variations with the period of 4 and 2.4 months, given 83% of total dispersion are dominant. An analogous phenomenon was marked while analysing the interannual variability of the Norwegian and Florida Currents (Kislyakov,1970). The causes of the origin if these fluctuations are not clearly expressed,however,there are the grounds to suppose that they are related to the processes of cosmic character. The variations with periods of 2.9 and 3.7 months observed in solar activity,serve,to some degree,as a confirmation of this (Maximov and Smirnov,1971).

Annual and semi-annual variations,summarizing effect of which in the 50-200 m and 0-200 m layers constitutes 87% of the total dispersion,play the main role in the salinity variations. The annual variation is conditioned by the influence of the climatic factors,observed in variability of the fresh water balance components.

According to the data from "Atlas of world water balance" (1964) in winter period in the area of current extension minimum continental flow and maximum evaporation were marked.

A joint effect of these reasons equally with the formation process of ice cover in the Labrador Sea cause a salinity increase of the Labrador Current waters. On the contrary,in summer period the role of the freshening processes increases. On section 2-A maximum and minimum of annual salinity variations caused by the effect of the climatic factors are observed in March and September,respectively.

The avaliability of the second maximum in September,corresponding to the semi-annual variation of water salinity relates to the degradation of the frontal zone in the layer above the thermocline. Owing to this,salinity in the 0-50 m layer increases because of flow of the mixed waters of the Gulf Stream system. In this period a salinity increase in the 50-200 m layer is less expressed (Fig.5) and related with depth reduction of extension of the Arctic origin waters.

To assess the influence of advective factors upon the formation of the salinity regime of the Labrador Current waters the method of linear correlation was applied. In the long-term mean sense the relationship between the discharges of the Labrador Current and mean salinity of its waters is absent. This means that salinity variations are defined by the effect of another reasons,as it is shown above,mostly,of climatic character. The effect of advective factors is sufficiently clearly observed only in August-October,when the relationship between current discharges and mean salinity in the 0-200 m layer is characterised with correlation coefficient amounted to - 0.55. Comparison of this value with the maximum one $|r| = 0.52$ at the value level $P = 0.90$ ($n = 11$) indicates the reality of correlation. Contribution of different processes into the seasonal variations of salinity of the Labrador Current waters change on the space of the year.

Conclusions

1.In 1974 in the areas investigated the intensity of the Labrador Current was decreased. Only in August on section 8-A across the Hamilton Bank and in early May on section 6-A over the Flemish Cap Channel insignificant,but in early December on section 6-A considerable ($+2.4 \cdot 10^6 m^3$/sec.) positive anomalies of the discharges were observed. In August 1975 on section 8-A the discharge increase of the Labrador Current waters was also fixed,it was much higher than the long-term mean value ($+4.5 \cdot 10^6 m^3$/sec.).

2.During the whole 1974 on all the standard sections the negative salinity anomalies prevailed,at times they approached the norm. An analogous phenomenon was marked and in summer 1975 in Divisions 2J and 3L. In Divisions 3N on section 2-A the increase of mean salinity in the 0-200 m layer in September 1975 was conditioned by the flow of the Gulf Stream system waters in the upper 50 m layer into the Labrador Current waters.

3.The width of the zone of the Arctic origin waters on section 2-A on the average constituted 20 miles,varying from zero to 93 miles.

4.On the basis of calcúlations of discharges and salinity of the Labrador Current waters on section 2-A in variable boundaries the curves of seasonal variations of water discharge and salinity,average for the period 1955-1975 were plotted.

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Table 1. Water discharges of the Labrador Current,their norms and anomalies on standard sections in 1974-1975

Section, area, layer	Vessel, cruise No.	Date of observations	Discharge, $10^6 m^3$/sec. observed	norm	anomaly
8-A (ABC)	"Gemma",No.9	04-06 July 1974	0.17	4.3	-4.1
0-2 000 m	"Perseus III", No.12	19-20 August 1974	5.08	4.6	+0.5
Division 2J	"Protsion", No.13	30-31 October 1974	5.01	5.0	0.0
	"Perseus III", No.14	17-18 August 1975	9.05	4.5	+4.5
6-A (H_1GH_2)	"Gemma",No.9	02-03 May 1974	3.61	3.1	+0.5
	"Gemma",No.9	26-27 May 1974	1.62	3.2	-1.6
	"Perseus III", No.12	24-25 July 1974	3.29	3.4	-0.1
0-bottom	"Gemma",No.10	06 December 1974	5.05	2.6	+2.4
Division 3L	"Perseus III", No.14	25-26 June 1975	0.28	3.3	-3.0
4-A (I-12 st.)	"Gemma", No.9	26-28 April 1974	2.35	4.5	-2.1
0-1 000 m	"Gemma",No.9	21-22 May 1974	2.32	4.0	-1,7
Division 3N	"Gemma",No.10	13 December 1974	1.93	5.3	-3.4
3-A (4-11 st.)	"Gemma", No.9	24-25 April 1974	3.85	4.9	-1.0
0-2 000 m	"Gemma",No.9	17-18 May 1974	3.07	4.1	-1.0
Division 3N	"Gemma",No.10	30 December 1974	4.15	6.8	-2.7
2-A	"Gemma",No.9	23 June 1974	0.00	0.7	-0.7
0-1 000 m	"Gemma",No.10	01 January 1975	2.99	3.0	0.0
	"Perseus III", No.14	18-19 September 1975	0.89	0.4	+0.5
Division 3N	"Perseus III", No.14	19 September 1975	-0.02	0.4	-0.4

Table 2. Mean salinity of the Labrador Current waters in the 0-200 m layer, its norms and anomalies on some standard sections in 1974-75

Section, area, Division	Vessel, cruise No.	Date of observations	Salinity (°/oo) observed	norm	anomaly
8-A (B)	"Gemma", No.9	04-06 July 1974	33.61	33.53	+0.08
	"Perseus III", No.12	19-20 August 1974	33.36	33.40	-0.04
	"Protsion", No.13	30-31 October 1974	33.12	33.56	-0.44
Division 2J					
	"Perseus III", No.13	19 December 1974	33.70	33.70	0.00
	"Perseus III", No.14	17-18 August 1975	33.21	33.40	-0.19
6-A(G)	"Gemma", No.9	02-03 May 1974	33.63	33.80	-0.17
	"Gemma", No.9	26-27 May 1974	33.75	33.76	-0.01
	"Perseus III", No.12	24-25 July 1974	33.83	33.94	-0.11
Division 3L					
	"Gemma", No.10	06 December 1974	33.90	34.21	-0.31
	"Perseus III", No.14	25-26 June 1975	33.85	33.96	-0.11
4-A (6-12 st.)					
	"Gemma", No.9	26-28 April 1974	33.72	34.08	-0.36
	"Gemma", No.9	21-22 May 1974	33.69	34.02	-0.33
Division 3N					
	"Gemma", No.10	13 December 1974	33.79	33.83	-0.04
3-A (6-11 st.)					
	"Gemma", No.9	24-25 April 1974	33.36	33.84	-0.48
	"Gemma", No.9	17-18 May 1974	33.46	33.70	-0.24
Division 3N					
	"Gemma", No.10	30 December 1974	33.63	34.10	-0.47
2-A	"Gemma", No.9	23 June 1974	33.09	33.40	-0.31
	"Gemma", No.10	01 January 1975	33.52	33.48	+0.04
	"Perseus III", No.14	18-19 September 1975	33.62	33.52	+0.10
Division 3N					
	"Perseus III", No.14	19 September 1975	33.71	33.52	+0.19

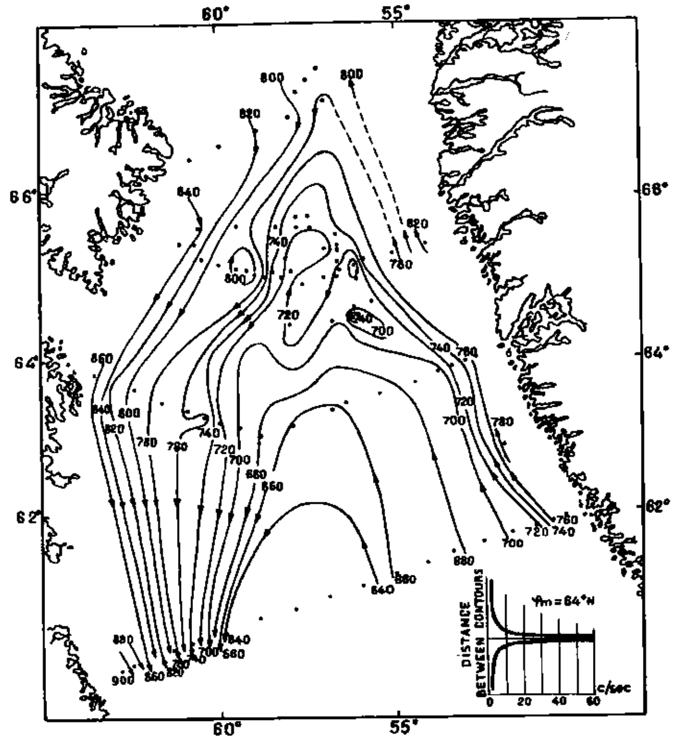


Fig. 1. Geostrophic circulation in the Davis Strait area in the 0-200 dbar 6 November-12 December 1974 (FRV *Perseus III*, cruise 13).

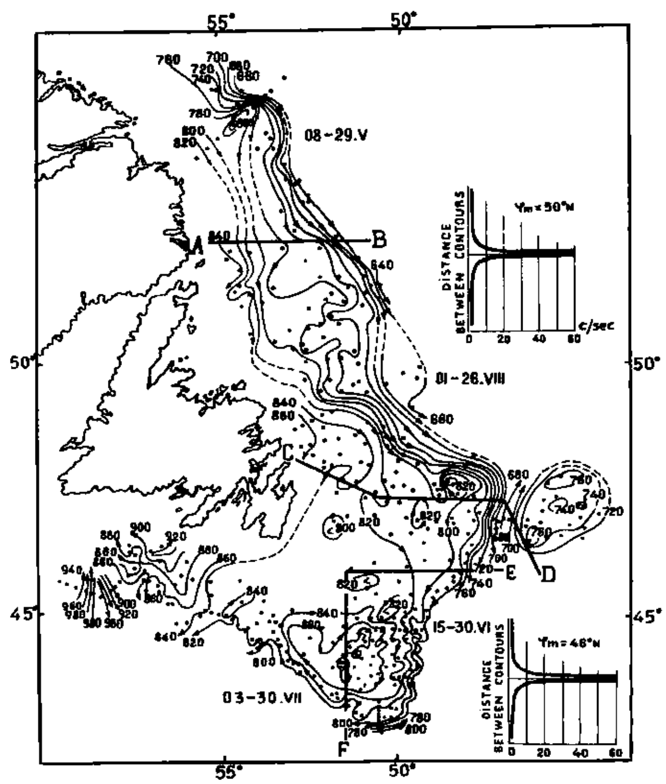


Fig. 2. Geostrophic circulation in the South Labrador and Newfoundland areas in the 0-200 dbar in May-August 1974 (FRV *Perseus III*, cruise 12).

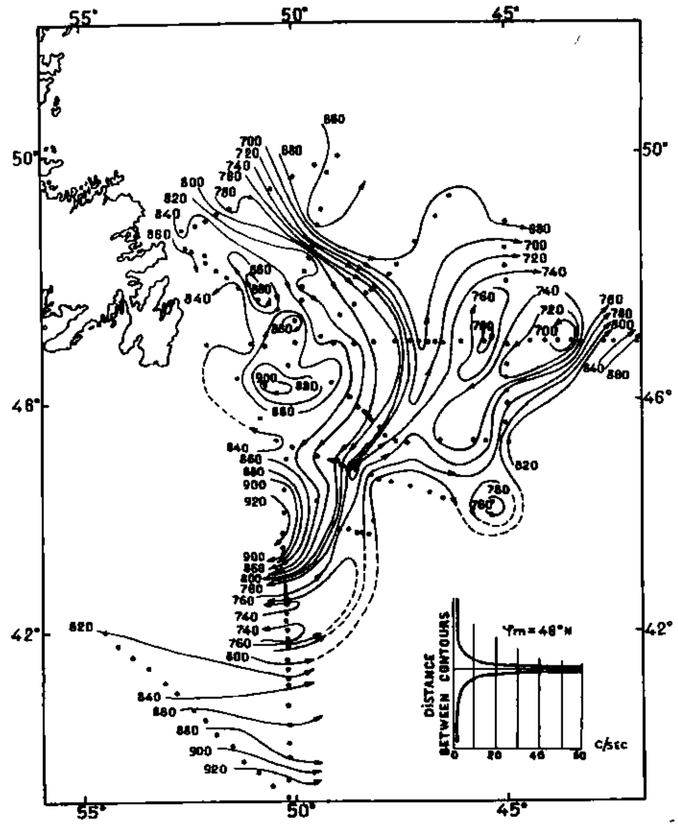
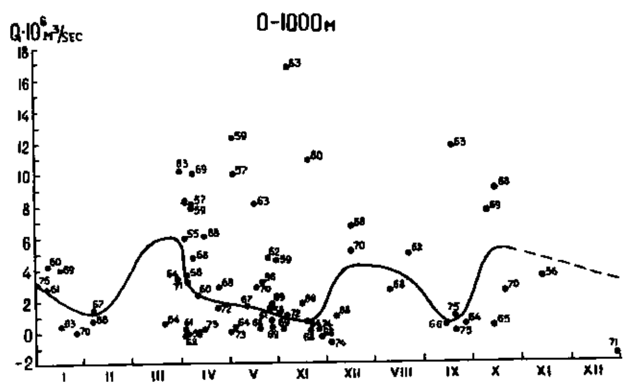


Fig. 3. Geostrophic circulation in the Newfoundland area in the 0-200 dbar 28 November 1974-07 January 1975 (RV *Gemma*, cruise 10).



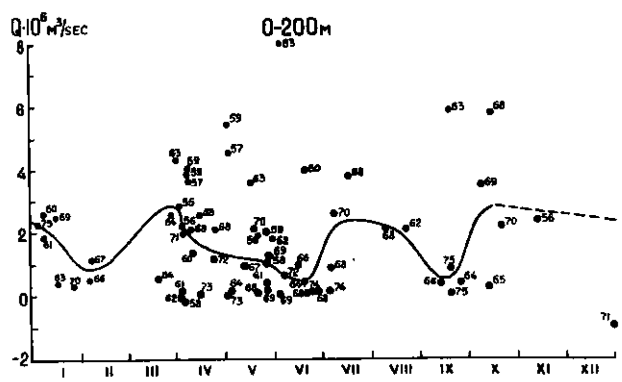


Fig. 4. Interannual variability of discharges of the Labrador Current waters on section 2-A (1955-1975).

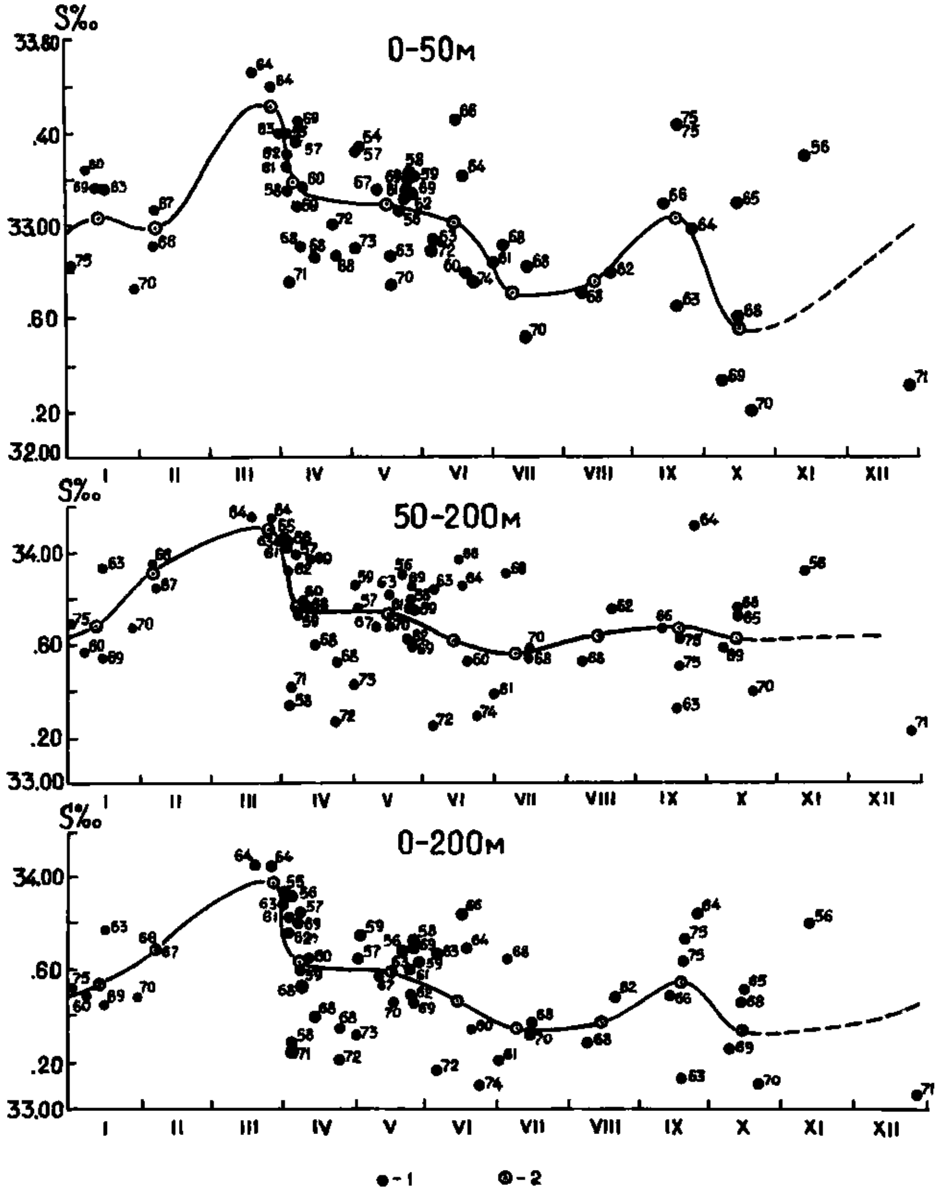


Fig. 5. Interannual variability of mean salinity by layers in the Labrador Current waters on section 2-A (1955-1975); I - actual, 2- monthly mean value.