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A volumetric statistical T-S analysis of the Nova Scotia Shelf and Georges Bank water masses

by

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ABSTRACT

Using the method of volumetric statistical T-S analysis, the Nova Scotia Shelf and Georges Bank waters were analyzed for winter and summer periods in greater detail than similar analysis by other authors.

Two T-S diagrams are obtained for the two main seasons with the following values: water volumes by T-S classes, sizes of 0.5° and 0.1°/₀₀ ; water volumes by the three main water masses; total water volume in the area; heat and salt reserve; mean values of temperature and salinity. The analysis showed that the upper intermediate layer (inshore and Labrador waters) makes up from 76% in summer to 86% in winter of the total volume. The bottom waters decrease in volume during winter, and their heat and salt density drops down. This phenomenon may be associated with the local seasonal transformation, but the suggestion of the effect of the changes in the Gulf Stream outlay cannot be ignored.

INTRODUCTION

For the purpose of fisheries prognosis on the Nova Scotia Shelf and the Georges Bank it is necessary to know the disposition and characteristics of the main water masses which were studied earlier (Bryantsev, 1963), and also to have information on the quantitative relations between them.

To obtain the values of the main water masses volumes, to see their quantitative correlation, and, consequently, to estimate the significance of each of them in the formation of the local thermohaline structure - all this is made possible by a volumetric statistical T-S analysis. This method was used for the analysis of the water masses in the World Ocean, in the Atlantic (Montgomery, 1958), Indian (Pollak, 1958), and Pacific (Cochrane, 1958) Oceans, in the Arabian and Red Seas (Dubrovin, 1965) and in the seas of Indonesia (Nefediev, 1961).

However, the authors of the above-mentioned publications used for the analysis only a small number of stations (Nefediev - 158 stations for the seas of Indonesia; Dubrovin - 33 stations for the Arabian and 10 for Red Seas; Cochrane - 150 stations for the Pacific Ocean) and excluded the upper 200-m water layer which is subject to the sharp seasonal changes in temperature.

Also, the above authors made their analyses for one season only (Dubrovin, 1965), or completely disregarded the season.

The uniqueness of the present paper lies in the fact that we have analyzed that previously excluded upper 200-m layer in an area with an extremely complex bottom configuration for the two main seasons, winter and summer, using a great number of stations and the smallest unit area.

MATERIALS AND METHODS

It is known that the Nova Scotia Shelf and Georges Bank are characterized by a rather complex bottom configuration, with the depths varying both by area and by fishing squares (Fig. 1). Therefore, in estimating the volumes, a square of the fishing grid was taken for a unit area having sides of 20' of latitude and 30' of longitude. Since the area of the square increases from south to north from 1420 to 1577 km^2, an average value of 1500 km^2 was taken. In case of a sharp heterogeneity of bottom configuration, i.e., with the depth variations within the square of 50 to 100 and more meters, the square was divided into parts of 1/3 to 2/3 (1/3, 1/2, 2/3) of the square area. For a vertical unit of the volume measurement the depth of 1 m was used.

For the analysis all hydrological stations made by AtlantNIRO were used through the period 1961-1966 for the two main seasons: winter (January, February, March) and summer (July, August, September). Total number of stations was 1153, with 374 of them occupied in winter and 779 in summer.

Temperature and salinity data were averaged in each square or its part for all six years and, thus, were reduced to one T-S curve. In some cases where data were lacking (winter), the same T-S curve was applied to the adjoining square or parts of the square which are homogeneous in bottom configuration and hydrological conditions.

T-S curve fields were divided into classes of 0.5° in temperature and 0.1°/₀₀ in salinity. In each class, layer thickness was determined in meters as a part of the T-S curve cut off the class boundaries. Product of that value multiplied by the area of the square or that of its part to which T-S curve was applied is the water volume for the corresponding temperature and salinity.

The final results of the volumetric statistical T-S analysis are given in two T-S diagrams for summer and winter periods. They show water volumes in km^3.

RESULTS

According to general analysis of the water masses (Bryantsev, 1963) the whole water column on the Nova Scotia Shelf and Georges Bank regions may be divided into three main water masses:

(1) surface waters of low salinity or inshore waters;
(2) intermediate cold waters or Labrador waters;
(3) warm bottom waters and those of high salinity.

Boundaries are determined by the 32.5°/₀₀ isohaline separating the inshore and Labrador waters, and the 33.5°/₀₀ separating the Labrador and bottom waters. The diagrams show the lines corresponding to these salinity values (Fig.2 and 3).

As a result of the statistical T-S analysis we obtained the following estimates: water volumes by T-S calsses, water volumes by three main water masses, and the total volume of the water masses (Fig. 2 and 3). Also obtained are data on the relative quantity of waters of certain temperature and salinity in percentage with a histogram as an illustration. Apart from that, there were also computed the values of the total heat reserve in kg-cal x 10^{12} (with regard to the specific heat of the waters in the area which is 0.94 cal/g), reserve of heat and that of salt in tons, mean temperature and mean salinity. The dotted line on the diagrams shows the volume equal to 75% of the total, the dashed line - that of 50%, and the regular one shows the classes with a maximum volume by three divided grounds.

Three characteristic layers are well traced on the T-S diagrams by disposition of the volumes, the character of volumes distribution by T-S classes confirming the correctness of the preliminary approtionment of the water masses. Zones of 75 and 50% of volume have configuration of T-S curves characteristic for the given area in summer and winter periods.

Classes of maximum volume constitute a nucleus of the corresponding water mass limited by the above-mentioned salinity values. T-S diagram for the winter period suggests that the surface and intermediate waters constitute a general cold surface layer as a result of the autumn-winter convection, although judging by a typical winter T-S curve we should formally separate the two water masses. These are really somewhat different not only in salinity, but also in the disposition of classes of maximum volumes - 989.8 and 1022.8 km^3 (Fig. 3). In the boundary area between the intermediate layer and the warm bottom waters, Fig. 3 also shows a trace of another class with the largest volume, as compared with other classes surrounding it (235.2 km^3). This fact indicates the presence of two modifications of the bottom water masses and gives evidence that it would be more correct to use the 33.3°/₀₀ isohaline as a lower boundary of the Labrador water masses.

Estimates of the total water volumes for summer and winter differ by 675.5 km^3 (Table 1).

TABLE **1.** Volumes of water masses in the Nova Scotia Shelf and Georges Bank regions.

Water masses	Volume, km^3		Summer - winter volume variations
	summer	winter	
(1)	13585	15517	+ 1932
(2)	14087	15020	+ 933
(3)	8741	5200	- 3541
Total	36413	35738	- 676

This difference is a result of errors in the processing of T-S curves. As we can see, the difference is insignificant (about 2% of the total volume). With regard to this fact, we may distribute this "discrepancy" between all the waters proportionally without any great damage to the preciseness. Table 2 presents the ultimate results: values of the three main water masses, their correlation and changes from summer to winter.

TABLE 2. Volumes of water masses in the Nova Scotia Shelf and Georges Bank regions after distribution of the "discrepancy".

Water masses	Summer		Winter		Summer - winter volume variations
	volume, km^3	%	volume, km^3	%	
(1)	13459	37.3	15664	43.5	+ 2205
(2)	13956	38.7	12162	42.0	+ 1206
(3)	8680	24.0	5249	14.5	- 3411
Total	36075	100.0	36075	100.0	0000

DISCUSSION

Based on the results given in Table 2 we may draw the following conclusions:

1. The most significant changes are observed in the volume of the warm bottom waters of oceanic origin which penetrate into the area in question through the deep-water troughs and canyons. Their volume decreases from summer to winter from 8660 km^3 to 5249 km^3, that is, from 24% to 14% of the total volume.

2. The Labrador and inshore waters in both seasons are approximately equal in volume and constitute the main part of the total water volume in the region - 76% in summer and 86% in winter.

3. Changes in the correlation of the water volumes from summer to winter may be a result of the seasonal transformation which causes in winter a decrease of the warm bottom waters and an increase of volume of the cold upper layer which is intensively mixed and consists of the surface and

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Labrador waters. However, we cannot ignore a suggestion of more intensive inflow of the bottom waters in summer period that may displace other within the region under survey.

4. The increase in the inflow of the bottom waters from the ocean in summer period may be associated with the seasonal changes in the Gulf Stream outlay. Evidently, this fact also accounts for increase of average salinity of the bottom waters in summer. This phenomenon is demonstrated in Table 3 which gives mean salinity values for each water mass obtained in the analysis.

TABLE 3. Mean salinity values of the water masses in the Nova Scotia Shelf and Georges Bank region.

Water masses	Mean salinity, °/₀₀ summer	Mean salinity, °/₀₀ winter	Summer-winter variations of the mean salinity, °/₀₀
(1)	32.01	32.05	+ 0.04
(2)	32.92	32.88	- 0.04
(3)	34.12	33.85	- 0.27
Total	32.87	32.66	- 0.21

It is rather notable that the total mean salinity in the layer of the surface and Labrador waters does not change from summer to winter. After the autumn-winter convection and the wind mixing, the salinity of the surface layer somewhat increases, while the waters of the intermediate layer decrease their salinity to an equal degree. Similarly, the bottom waters in winter not only decrease in volume, but also obtain a lower mean salinity. The latter may indicate a decrease in inflow of the bottom waters from the ocean in winter period.

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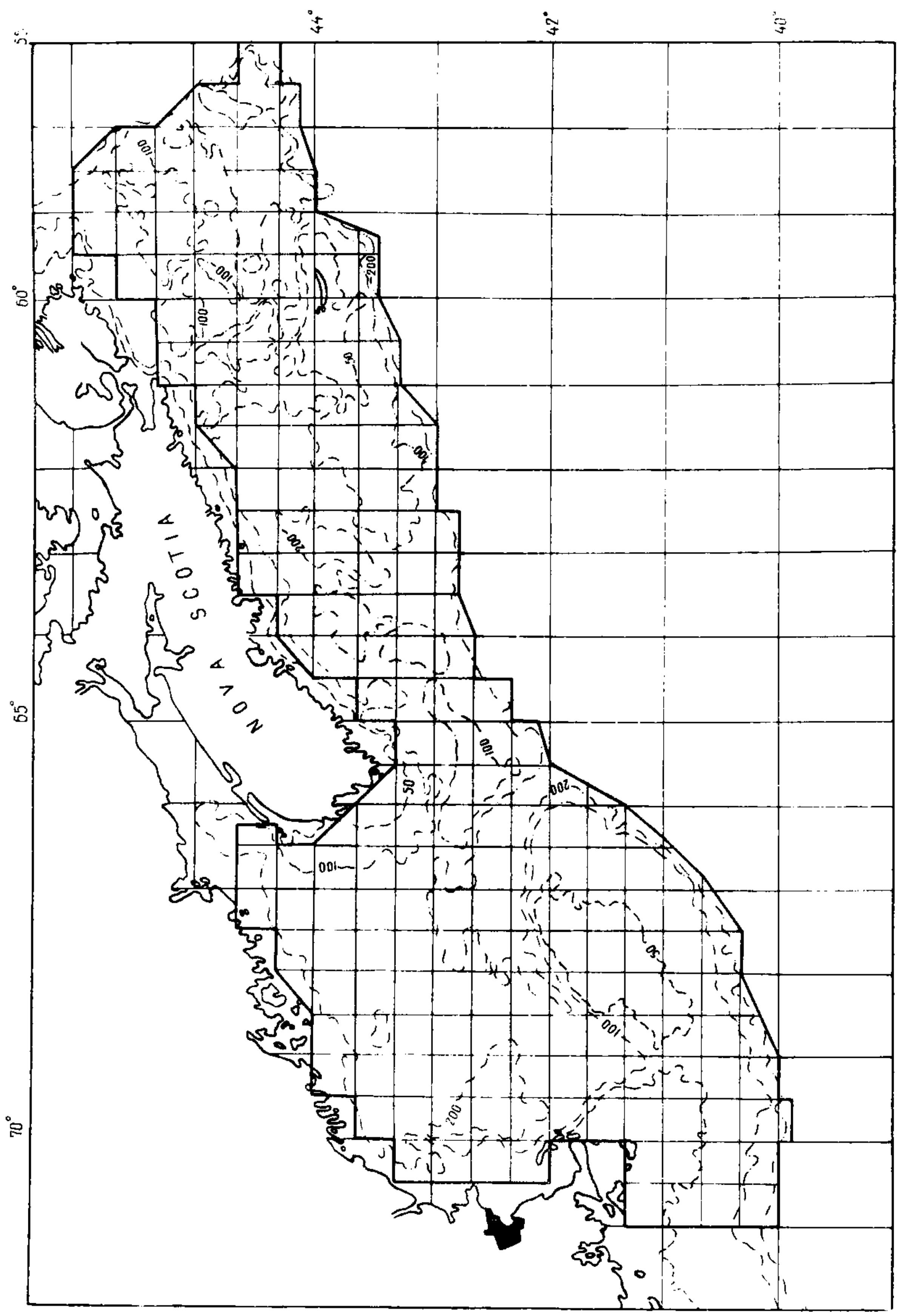

Fig. 1. The boundaries of the research area.

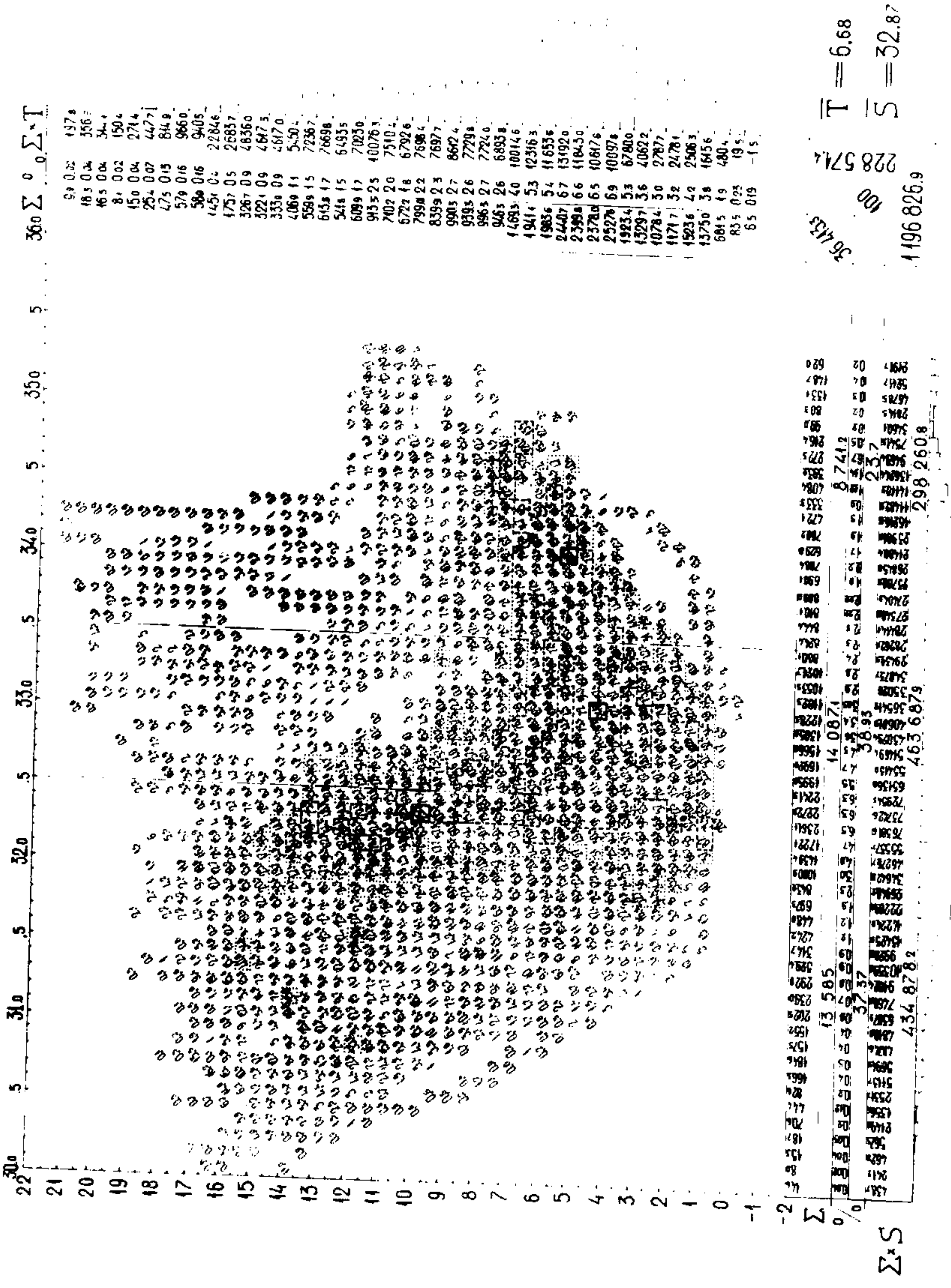

Fig. 2. Volumetric statistical T-S diagram for the Nova Scotia Shelf and Georges Bank regions (summer).

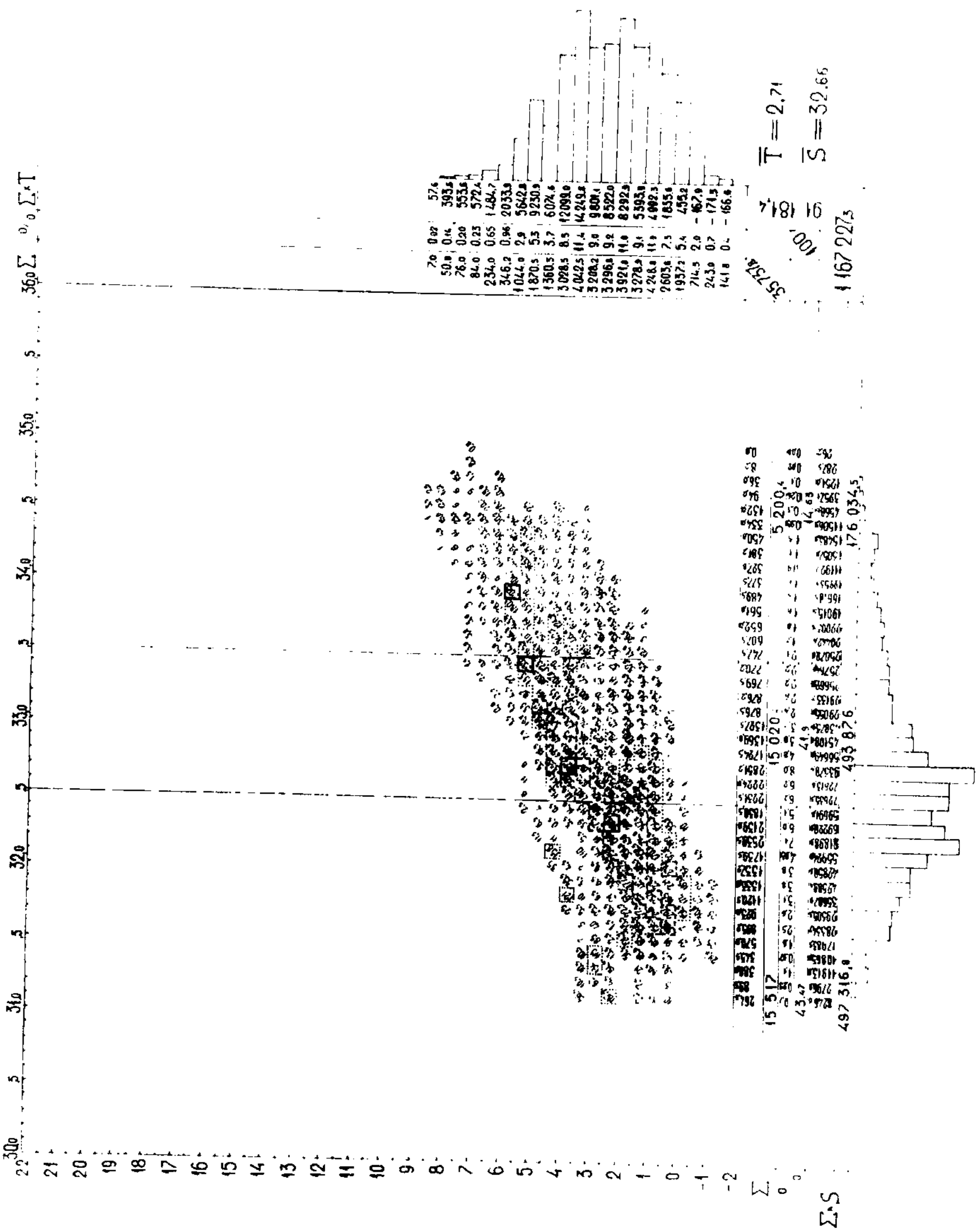

Fig. 3. Volumetric statistical T-S diagram from the Nova Scotia Shelf and Georges Bank regions (winter).