

ATLANTIC OCEANOGRAPHIC GROUP

St. Andrews, N. B.

#386

THE VERTICAL TEMPERATURE STRUCTURE  
OF THE LABRADOR CURRENT

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Introduction

Written accounts of explorations of the Labrador sea date back to 1266, recording details of a Norse expedition which reached the region of Smith sound. The first recorded crossing of the Labrador sea was by Frohisher in 1576, and in the latter half of the nineteenth, and the early part of the twentieth centuries, considerable detailed oceanographic observations were made in this area.

It was not until the "Chance" expedition of 1926 that an attempt was made to study the detailed physical and chemical structure of the Labrador current (Iselin 1927). In the period 1928-35, the "Marion" and "General Greene" expeditions, sponsored by the U.S. Coast Guard made intensive and detailed study of the waters of the Labrador current (Smith, Soule and Mosby 1937).

In 1948 a northern cruise of H.M.C. ships, provided the opportunity of making certain limited observations in the Labrador current while on board H.M.C.S. "Haida" under Lieut.-Commander Pickard. While in the Labrador current, ten hydrographic stations were occupied by the "Haida", seven while proceeding northward and three on the return journey. At each hydrographic station water

100, 150, 200 and 250 metres. Throughout the cruise, bathythermographic observations were taken at intervals of approximately fifty miles, to depths of 150 metres. A map of the Labrador coast given in figure 1 shows the hydrographic stations and the positions of bathythermograph observations during September, 1948.

### The Labrador Current

The Labrador current has been described (Iselin 1927) as a cold water stream which flows southward over the continental shelf inside of the comparatively motionless homogeneous mass of North Atlantic water. As compared with the main body of water in the Labrador sea, the current is characterized by its low salinity and temperature. As a result of the investigations of the "Marion" and "General Greene" expeditions (Smith, Soule and Mosby 1937), the Labrador current is found to have its origin in the vicinity of Cumberland sound where the West Greenland and Baffin Land currents join.

The Labrador current may be divided into two streams, an inshore and an offshore one. The inshore stream contains the greater volume of the cold water and is confined to the continental shelf. This stream enters Hudson strait on the Baffin Land side, and flows as far as Big island before it recurves southward to mix with the waters flowing out of Hudson bay, and flow out past Cape Chidley (Smith, Soule and Mosby 1937). The offshore stream, which contains waters that are characteristic of the warmer West Greenland current, tends shorewards near the mouth of Hudson strait, but does not enter, and continues to flow southward over the continental slope (Smith, Soule and Mosby, 1937). Continuing down the coast,

the Labrador current follows an easy sinuous course which exhibits two major bends, the one between Cape Harrigan and Cape Harrison, Labrador, and the other between Cape Bauld and Funk island, Newfoundland (Smith, Soule and Mosby 1937).

The characteristic low temperatures of the Labrador current persist as the water flows southward, the great stability of the water layers preventing the penetration of solar heat by convection. On reaching the vicinity of Belle Isle strait, water from the inshore stream is carried, at times, through Belle Isle strait into the gulf of St. Lawrence water moving outward along the southern side of Belle Isle strait enters into the southward flow of the Labrador current. Continuing southward of Belle Isle strait, the Labrador current meets the northern face of the Grand Banks in the latitude of St. John's, and is split, the slope branch continuing down the edge of the Grand Banks, while an inshore branch follows the gully past Cape Race (Smith, Soule and Mosby 1937).

A velocity diagram of the Labrador current (Smith, Soule and Mosby 1937) is shown in figure 2, and the axis of maximum flow is indicated by the velocities shown in miles per day.

In section, from southeast to northwest, the distribution of temperature and salinity in the Labrador current in September is shown in figures 3 and 4, the locations of the hydrographic stations occupied being indicated in figure 1.

Near the axis of the current, the main water mass constituting the Labrador current between depths of 25 and 250 metres has temperatures from  $2.0^{\circ}\text{C}$ . to  $-0.4^{\circ}\text{C}$ . and salinities ranging from

32.50 to 33.50 ‰. To some extent, the surface layer to depths of 25 metres is influenced by surface warming and land drainage, with temperatures greater than 4.0°C. and salinities less than 32.00 ‰.

A large body of cold water of temperatures less than 0.0°C. and salinities between 33.00 to 33.50 ‰ is located in the southern portion of the section. This is arctic water which, on the basis of salinity, is either continuous with an offshore water moving southward along the edge of the shelf, or the last vestiges of the southerly movement of arctic water masses which predominate in the early months of the year (p. 122, Smith, Soule and Mosby 1937).

In the extreme northern portion of the section (station 7H), in the vicinity of the entrance to Hudson strait, a comparative decrease in stratification, both as to temperature and salinity, is indicative of an area of mixing. Here also, at depths of 75 to 250 metres, is located a water mass of temperatures less than 1.0°C. and of a salinity of approximately 33.50 ‰. On the basis of temperature and salinity characteristics this mass of water originates from the Baffin Land current.

#### Temperature-Salinity Diagrams

On the basis of observations made in 1931 by the "Marion" and "General Greene" expedition, temperature-salinity correlation curves were obtained for all observations below a depth of 50 metres in the Labrador current (p. 112, Smith, Soule and Mosby 1937). These correlation curves show that the main water mass of the Labrador current is a mixture of two characteristic waters as follows:

- (1) Baffin Land water exhibiting average temperatures of  $-0.5^{\circ}\text{C}$ . and average salinities of  $33.50$  ‰;
- (2) West Greenland water exhibiting temperatures as high as  $3.8^{\circ}\text{C}$ . and salinities as high as  $34.60$  ‰.

A temperature-salinity diagram was constructed from the 1948 data collected by the "Haida", and shown in figure 5. As the "Haida" data were collected only along the axis of the Labrador current, and to depths not exceeding 300 metres, the diagram gives pre-eminence only to two characteristic water masses as follows:

- (1) A-water exhibiting temperatures greater than  $3.0^{\circ}\text{C}$ . and salinities between  $32.00$  and  $32.50$  ‰;
- (2) B-water exhibiting temperatures between  $-0.5^{\circ}\text{C}$ . and  $1.0^{\circ}\text{C}$ . and salinities between  $32.70$  and  $34.00$  ‰.

The A-water is therefore representative of the coastal contributions to the Labrador current, and confined, in the main, to the upper fifty metres within the coastal belt. The B-water is obviously water of the Baffin Land current, while no sampling of the waters of the West Greenland current is in evidence.

The bathythermograph (Spilhaus 1938), giving a continuous record of water temperatures from surface to depth, provides an excellent means of examining, in detail, the vertical temperature structure of a water mass. While in the Labrador current, bathythermographic observations were taken from the "Haida" at intervals of fifty miles from Belle Isle strait northward and again on the return journey. Twenty-two observations were made, twelve in early September and ten in late September. Positions of the points of

observations are shown in figure 1. Typical records are shown for early September in figure 6.

The development of temperature stratification, as indicated between station 12b, off Hudson strait, and station B2, north of Belle Isle is the main feature of the observations. The changing temperature characteristic of the main water mass, below 50 metres, from 0.0°C. or less at stations B2, B6 and B8 to 1.0°C. or greater at stations B4 and B12 might indicate that the sampling was not altogether along the axis of the current. There are also traces of intrusions of small tongues of water seemingly foreign to the main water mass. These are indicated at stations B6 at depths of 10 to 30 metres and B4, at depths of 50 to 75 metres. The variation in thickness of an approximately isothermal layer from 5 metres at station B10 to 20, 17 and 25 metres at stations B8, B4 and B2 respectively, is another feature of interest.

The bathythermographic observations, taken in the Labrador current were plotted to illustrate the vertical temperature structure in section. The data for early September based on twelve bathythermograms are plotted in figure 7, and the data for late September, based on ten bathythermograms are plotted in figure 8. While the general features of the temperature structure as presented in figures 6 and 7 are similar to those in figure 2, the bathythermograms allow for a more precise determination of the temperature fine structure within the current.

The early September section (figure 6) shows several important features. There is a general stratification in the upper

50 metres that deepens towards the southern end of the section. This is clearly indicated by the depth of the isotherm of  $2.0^{\circ}\text{C}$ , which appears at a depth of 25 metres in the north and 45 metres in the south. The waters below the 50 metre level are, on the average, below  $1.0^{\circ}\text{C}$ . with a minimum of  $-0.67^{\circ}\text{C}$ . Near Hudson strait, the discontinuity of the isotherms at station B12 indicates that this is an area of strong mixing. Although the intensity of mixing is not as great as at station B12, the area of mixing appears to extend from south of station B11 almost to station B13, a distance of approximately 110 miles.

In various portions of the section, traces of water temperatures, seemingly foreign to the main water mass, are to be found. In some cases these are probably tongues of cold water extending outward from the coast. The main water mass is of a temperature between  $0.0^{\circ}\text{C}$ . and  $2.0^{\circ}\text{C}$ . and the after effects of the summer season are shown in the surface layer which at no point is thicker than 45 metres and with the highest temperature in the vicinity of  $5.0^{\circ}\text{C}$ .

The late September section (figure 8) exhibits the same general features as that for early September, with autumnal cooling and resultant vertical mixing shown in the surface layer by lowered temperatures and decreased stratification. One prominent tongue of comparatively warmer water has protruded into the section in the neighbourhood of station B56

#### Discussion

On the basis of the temperature-salinity characteristics of the water sampled at the "Haida" stations while proceeding in the

Labrador current, in September 1948, it is obvious that the track of the "Haida" was in a water mass contributed, to a large extent, by the Baffin Land current, and, that any water mass sampled was either of the Baffin Land current, or a mixture of these waters with waters of coastal origin, and/or modification. Hence the water masses originating from the West Greenland current or in the intermixing of water of the West Greenland current and Baffin Land currents were on the ocean side of the "Haida" track. It has been estimated that the average volume of water contributed to the Labrador current by the West Greenland current and the Baffin Land current is in the proportion of 3 to 2 (Smith, Soule and Mosby 1937).

The vertical temperature structure of the waters of the Labrador current in the main water mass is shown to be quite stable and fairly uniform in temperature characteristics, undergoing only normal seasonal changes in the surface layer within the month of September.

The dynamics of the Labrador current is to a large extent associated with a mixing process where waters of the West Greenland current and Baffin Land currents merge. While this merging probably takes place over a considerable area in Davis strait and Baffin bay and particularly along the continental shelf, adjacent to Baffin island, there is indicated by our observations a large area of mixing in the region of Hudson strait, where probably waters from Hudson bay and Foxe channel merge with waters of the Baffin Land current to create what might be termed Labrador coastal water. In any event, this additional mixing process gives acceleration to the southward movement of northern waters.

Summary

1. The temperature and salinity distributions in a section along the axis of the Labrador current is described for September 1948, as having the main body of water at depths of 25 to 250 metres with temperatures between  $2.0$  and  $-0.4^{\circ}\text{C}$ , and salinities ranging from  $32.50$  to  $33.50$  ‰, while on the surface temperatures greater than  $4.0^{\circ}\text{C}$ . and salinities less than  $32.00$  ‰ are found.

2. The vertical temperature structure of the water mass, along the axis of the Labrador current has been examined in some detail which reveals:

- (a) The development of temperature stratification with variations in the thickness of an approximately isothermal layer from 5 metres at station B10 to 20, 17 and 25 metres at stations B8, B4 and B2.
- (b) Near Hudson strait the discontinuity of the isotherms indicates an area of strong mixing which extends 110 miles southward from station B13.
- (c) Tongues of cold water from inshore are protruding into the section.
- (d) The temperature of the main water mass is between  $0.0$  and  $2.0^{\circ}\text{C}$ .
- (e) Autumnal cooling with resultant vertical mixing is in evidence during September.

3. The vertical temperature structure of the water of the Labrador current in the main water mass is shown to be quite stable and fairly uniform in temperature characteristics, undergoing only

normal seasonal changes in the surface layer within the month of September.

Acknowledgements

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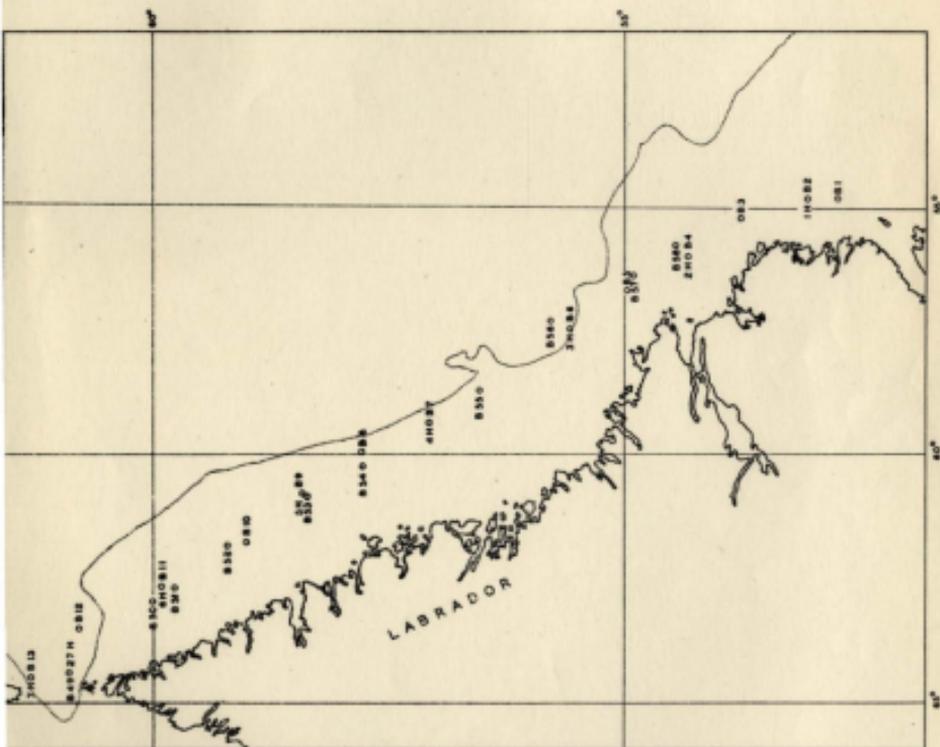


Fig. 1. Labrador coastal waters showing the positions of "Halda" observations in September, 1948.

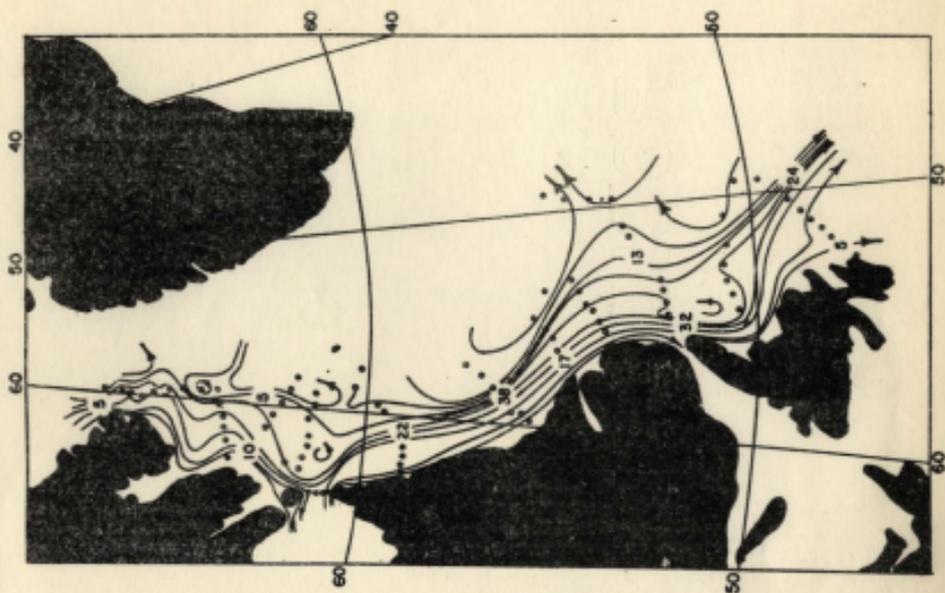


Fig. 2. Labrador Current, July 22 - September 17, 1928  
The velocities shown in miles per day indicate  
the axis of maximum flow.

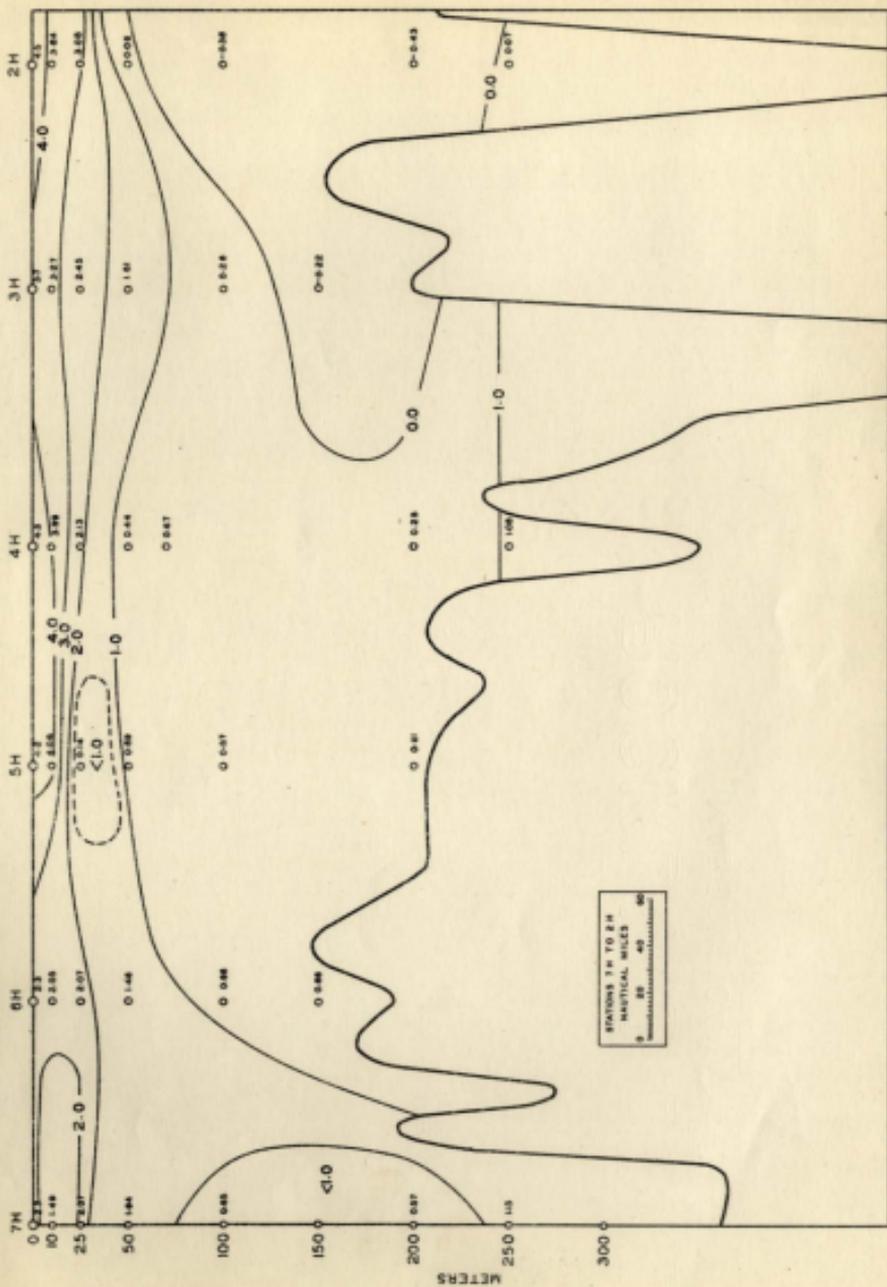


Fig. 3. Temperatures in section September 4-6, 1948, running northwest up the Labrador coast.

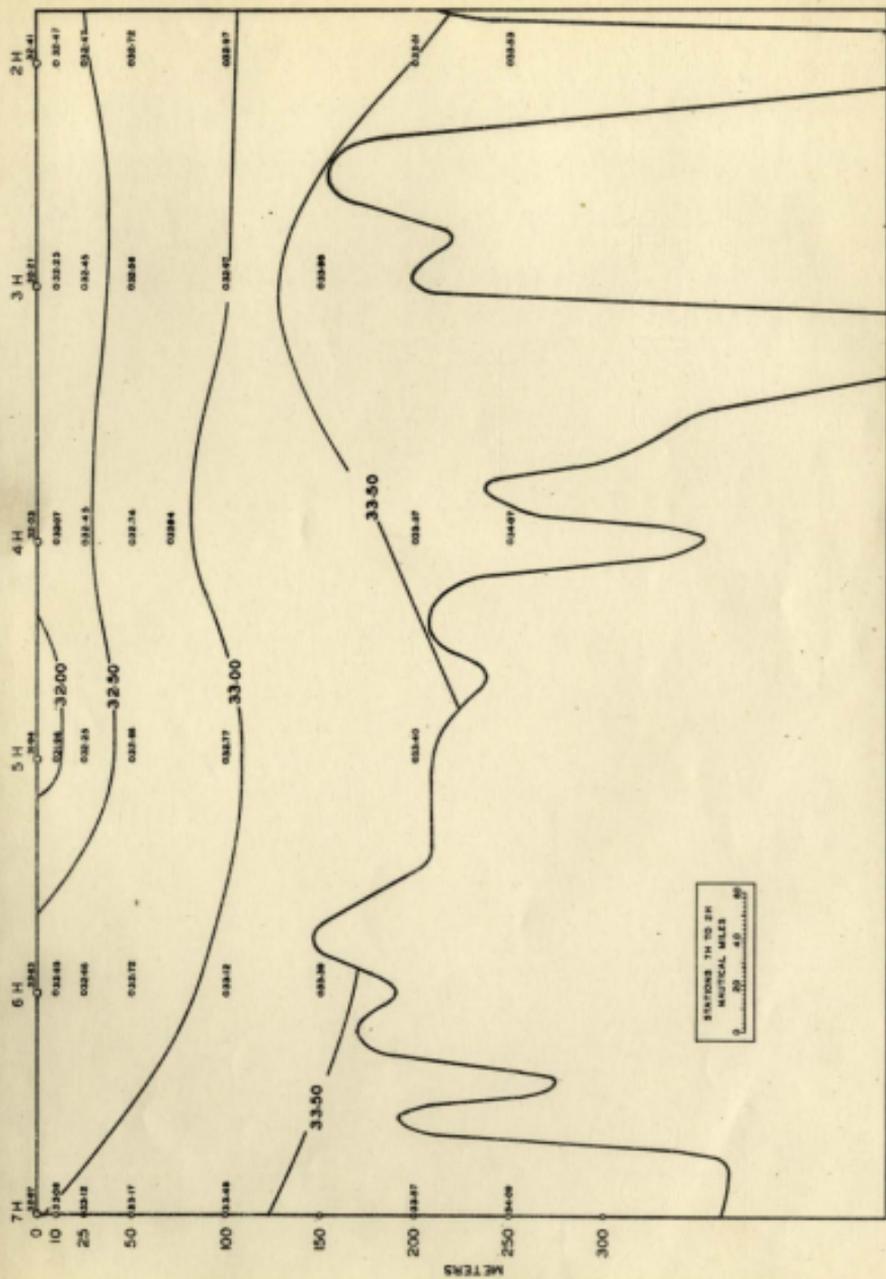


Fig. 4. Salinities in section September 4-6, 1948, running northwest along the Labrador coast.

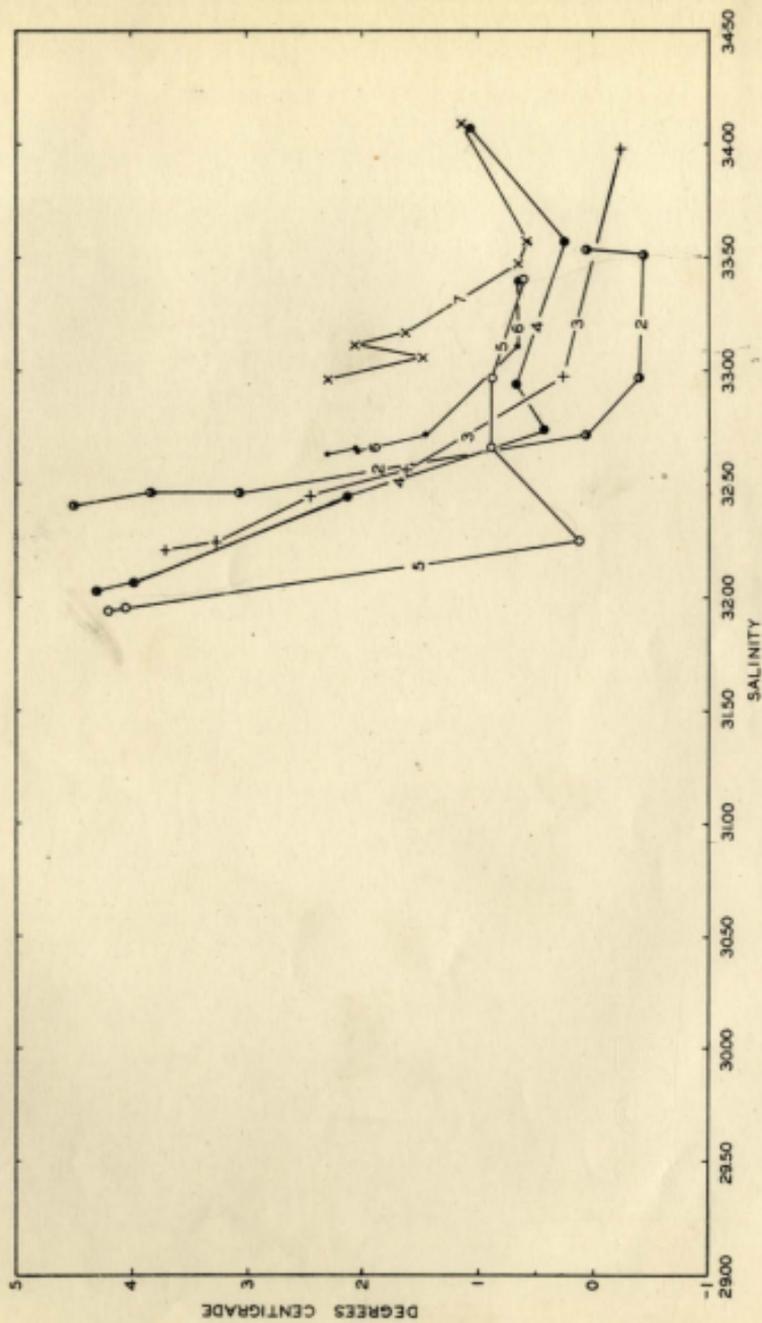


Fig. 5. Temperature-salinity correlation curves for Labrador coastal waters in September, 1948.

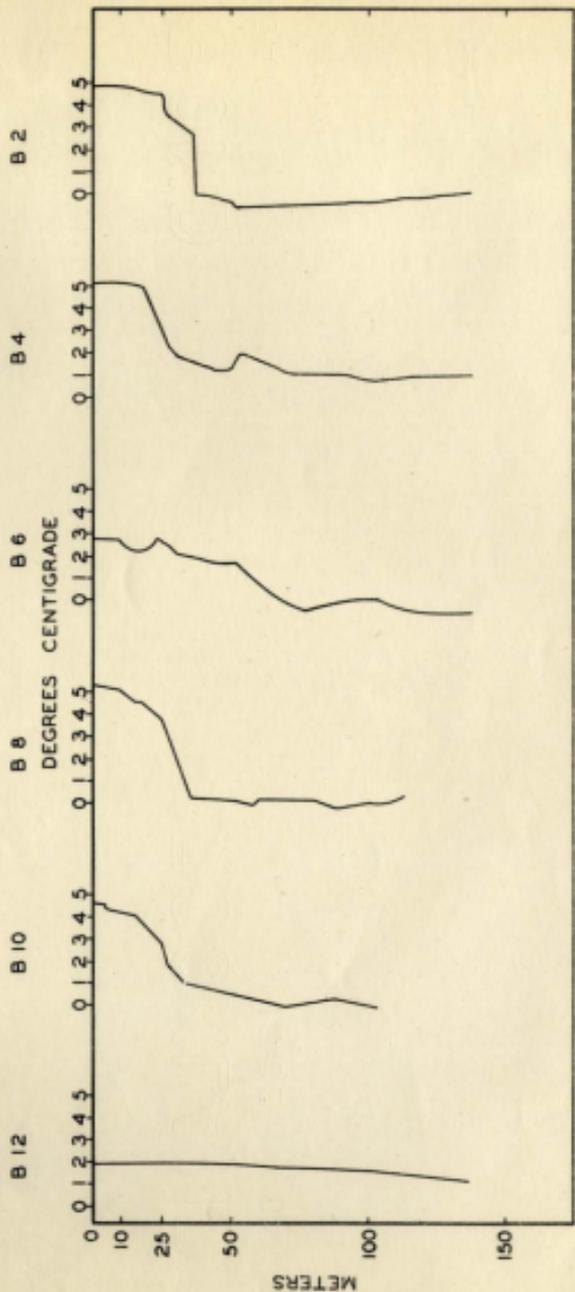


Fig. 6. Typex bathythermograph traces taken in the Labrador Current.

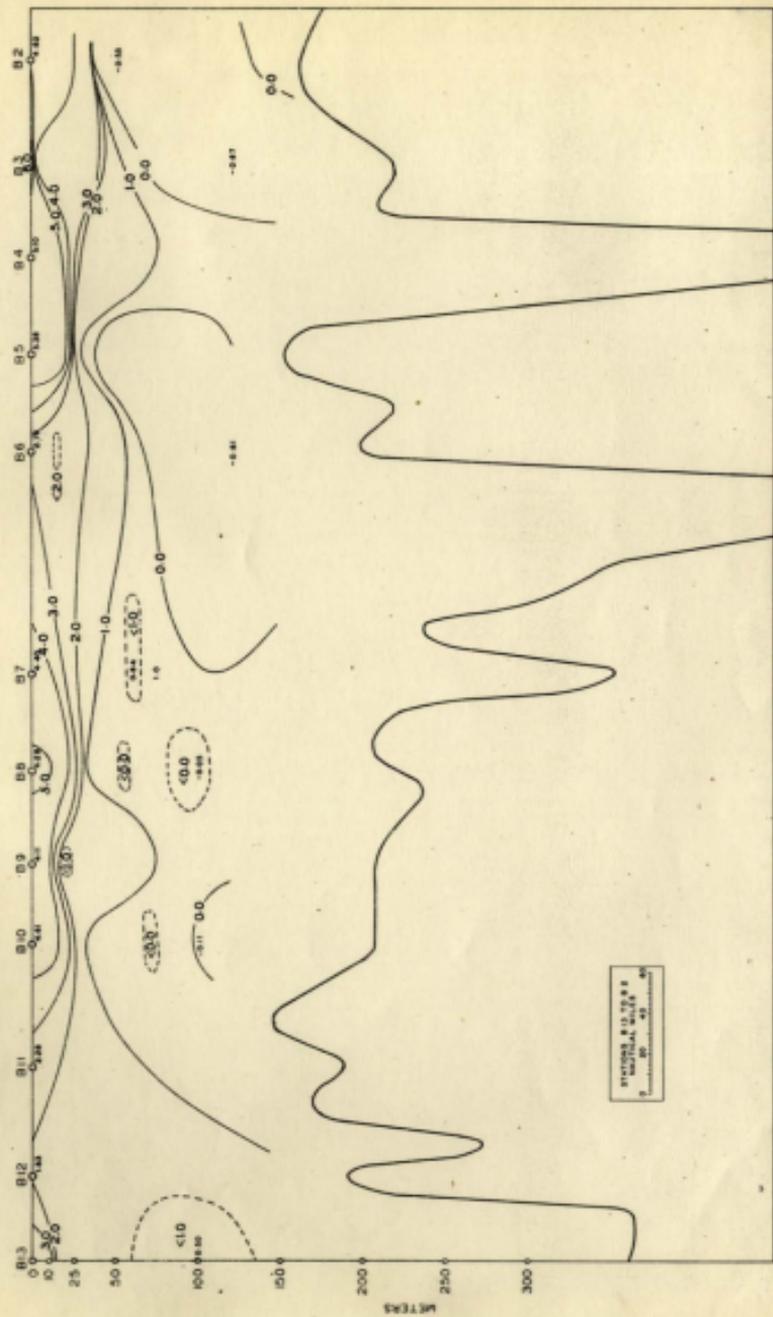


Fig. 7. The temperature structure of the Labrador current in September 4-6, 1948.

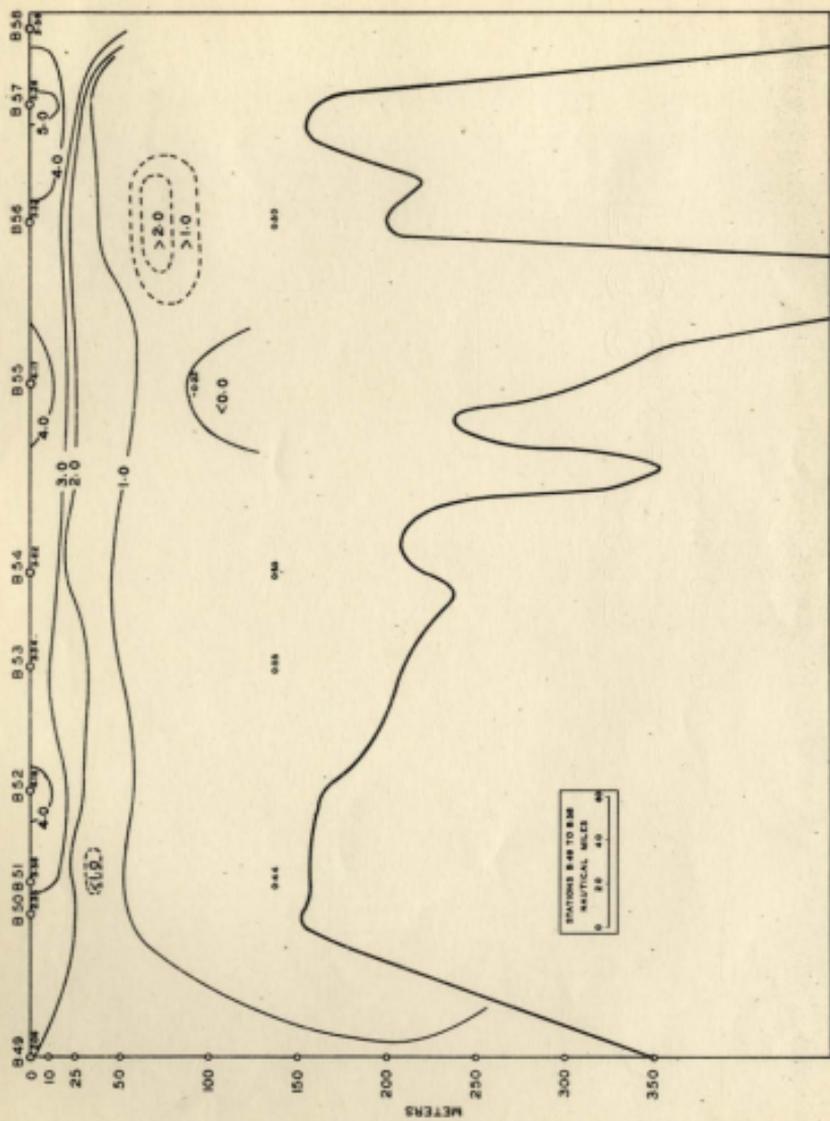


Fig. 8. The temperature structure of the Labrador current in September 23-25, 1948.

