THE OCEANOGRAPHY OF LANCASTER SOUND

by

A.E. Collin

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Department of Geography,
McGill University,
Montreal.

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A.E. COLLIN

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Abstract

The oceanographic regime of Lancaster Sound displays characteristics of two distinct water masses. The upper layer is physically similar to that encountered in the Arctic Ocean and is typical of conditions recorded in M'Clure Strait and on the Arctic continental shelf. Below the depth of 200 metres, water characteristics are identical to those observed in Baffin Bay. Baffin Bay water intrudes into Lancaster Sound and is defined as far west as Prince Regent Inlet. Analyses, using two T-S techniques, are carried out to show that water of Baffin Bay characteristics occurs at all sampling positions below 250 metres in the eastern end of the Parry Channel and the equivalent thickness of this influx is of the order of 200-400 metres.

Water movement in Lancaster Sound is dominated by an eastward flow through Barrow Strait and a distinct westward current along the south coast of Devon Island. It appears that a not insignificant north-south transfer takes place through Wellington Channel and Prince Regent Inlet. Maximum eastward surface current in Lancaster Sound is about 50 cm./sec. whilst the speed of the surface current along the north shore of the passage is 23 cm./sec.

The total southward flux through the Canadian Arctic Archipelago is calculated to be 40,051 km^3/year; of this, 16,000 km^3/ year pass eastward through Lancaster Sound.

PREFACE

This thesis contains a description of the oceanographic conditions of Lancaster Sound and the adjoining channels and an analysis of the water movement and volume transport through these passages.

The data have been collected over a period of six field seasons during which time a great number of oceanographic observations have been recorded in the eastern Arctic and the Arctic Ocean in the area bordering the Canadian Arctic Islands and in the channels of the archipelago. Most of these observations and measurements are from regions which have never before been subject to oceanographic investigation. The thesis is an original undertaking being the first comprehensive synthesis of oceanographic data collected in the Canadian Arctic and the Arctic Ocean during the years 1956-61.

I am deeply indebted to the Fisheries Research Board of Canada for the period of leave and the financial assistance which made it possible for this work to be completed at this time. In particular, I wish to acknowledge the assistance given me by Dr. J.L. Kask, Chairman of the Fisheries Research Board and by Dr. H.B. Hachey, Secretary of the Canadian Committee on Oceanography, whose approval and encouragement enabled me to pursue this study. Dr. N.J. Campbell, Oceanographer-in-Charge of the Atlantic Oceanographic Group at Halifax, has been a constant source of inspiration and a most patient teacher; and I have also gained much advice and constructive criticism from Dr. L. Lauzier and Mr. W.B. Bailey, both of the Fisheries Research Board. In addition, I have profited greatly from discussions with Dr. M.J. Dunbar of the Department of Zoology, encompassing all fields of marine research, and from the guidance of Professor J.B. Bird of the Department of Geography.

Dr. E.F. Roots, Co-ordinator of the Polar Continental Shelf Project of the Department of Mines and Technical Surveys, has made it possible for me to complete this work in conjunction with my duties with the Project and has encouraged the full use of the excellent research facilities of the Department.

Finally, I wish to emphasize the fact that the collection of oceanographic information, perhaps more so than in any other scientific field work, is an undertaking that requires highly integrated team work, the success of which is dependent upon the co-operation and industry of every man taking part. With this in mind, I offer my sincere thanks to the staff of the Atlantic Oceanographic Group, to the Commanding Officers and crews of C.G.S. "Labrador" and "Sackville" and to my American comrades on T-3. In conclusion I wish to express my gratitude to my colleagues of the Polar Continental Shelf Project who cheerfully accepted trying conditions for the sake of the oceanographic observations.

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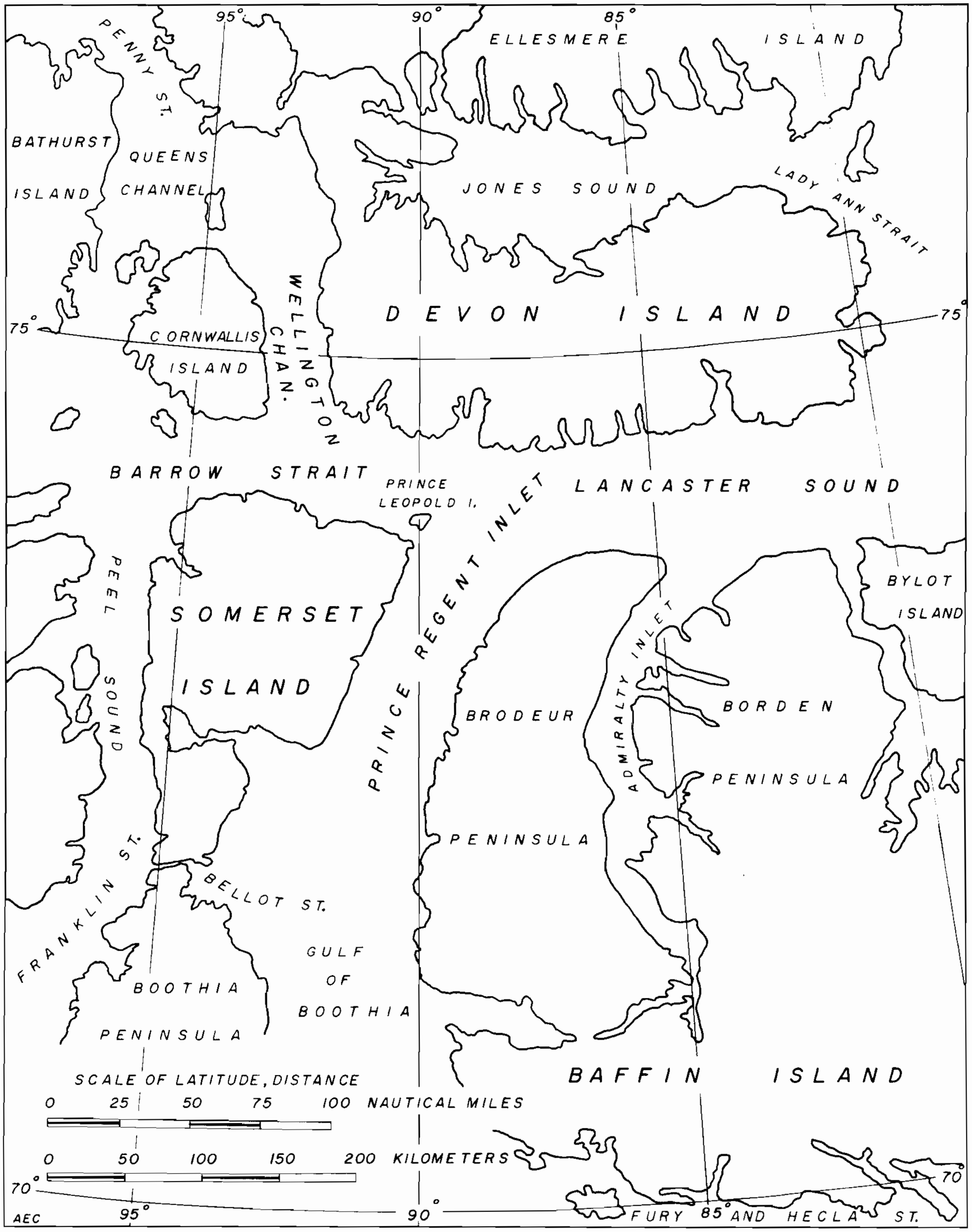

Fig. 1 The Lancaster Sound region.

CHAPTER I

HISTORY OF EXPLORATION

AND

PREVIOUS OCEANOGRAPHIC INVESTIGATIONS

The passage of the nuclear powered submarine U.S.S. Seadragon through the Northwest Passage from Baffin Bay to the Beaufort Sea in the summer of 1960 finally solved the historic problem of a rapid and easy transit from the Atlantic to the Pacific by way of northern Canada.

With the exception of the Antarctic, the Canadian Arctic Archipelago is perhaps the last of the major sectors of the earth's surface to be explored and charted by man. Lack of interest or incentive has not been the reason for the relatively late investigation of such a large sector of the North American Continent, for, since the seventeenth century the merchant nations of the world have sought a shorter, faster sea passage to the north Pacific by way of North America. It was the prolonged search for this water-way, the legendary Northwest Passage, that compelled men to continue the exploration of this area in a succession of expeditions beginning in 1616 with the discoveries of Baffin and ending with the tragedy of the Franklin Expedition in 1846. The obstacle which has in the past effectively blocked, and even at present certainly hinders passage in these channels is the massive and unpredictable sea ice that chokes the passages and straits of the archipelago throughout nine months of the year. It is the ice of the arctic seas of the world that has formed the barrier which has jeopardized and retarded the discovery and survey of these regions. In modern times stronger, more powerful ships have been designed in an expanding effort to overcome this ever present obstacle but the use of ships in areas of heavy and persistent sea ice is, at best, slow and highly dependent upon the uncertain movements of the ice.

The development of long range aircraft as vehicles of northern transportation and supply and the increasing use of light, single engined planes and helicopters for local flying have made the entire Canadian Arctic accessible to summer survey and research parties. In conjunction with the perfection of aircraft as a means of arctic transportation, the adaptation and simplification of the techniques of aerial mapping have at last clearly defined the exact coastlines of the arctic islands and revealed the extent of our northern territories.

The eastern entrance of Lancaster Sound was discovered in 1818 by Sir John Ross on his first voyage to Baffin Bay. On this voyage, Ross, on his return from northern Baffin Bay, ventured into the eastern end of the sound, but mistakenly supposed it to be blocked in the western end by the "Croker's Mountains" (Ross, 1819 vol. 1). Ross' journal leads one to believe that the Croker Mountains run north and south across Lancaster Sound in the vicinity of 85° west longitude and it has been suggested that he mistook Mt. Croker on northeast Somerset Island as being one of a chain of mountains blocking the sound. However, this reasoning seems a little doubtful, as Mt. Croker is 90 miles to the westward of the position of Ross' Croker Mountains and the apparent error in Ross' positions, as determined from his co-ordinates of Cape Cockburn and Cape Sherard, would put his position another 12 miles to the eastward. The result would be a total difference of over one hundred miles between the present Mt. Croker and the Croker Mountains as reported by Ross.

The reasons why Ross did not penetrate further into Lancaster Sound will never be understood. He was severely criticized for his apparent neglect but steadfastly stood to his opinions until proved wrong by Parry the following year.

Despite the disapproving judgment which was passed upon the voyage of 1818, Ross did achieve noteworthy results in the scientific measurements which he conducted. He designed and successfully operated two new oceanographic instruments. One of these, the "hydraphorus" was a self closing bottle which was capable of bringing up a sample of the water from any desired depth. The other, a "deep sea clam", was a device for bringing a sample of the bottom deposits to the surface. Both these instruments served very efficiently and Ross, in his journal, makes a number of comments on his results. It was also on this voyage that the first subsurface temperatures were taken in the American Arctic.

The scepticism which surrounded Ross' report of Lancaster Sound and the conflicting opinions of some of his officers resulted in a second voyage to Lancaster Sound in 1819 under the command of Lieutenant W.E. Parry. This expedition was in essence the opening of the Northwest Passage and from it all future exploration evolved.

Parry succeeded in passing westward through Lancaster Sound and Barrow Strait only to be stopped by ice in M'Clure Strait in the summer of 1820. Soundings and subsurface water temperatures were also taken at this time; however, the notable contribution of the voyage was the geographic exploration of the great series of passages leading to the westward through Lancaster Sound. On a successive attempt in 1821, Parry tried to find a passage through Hudson Strait and Foxe Basin into Prince Regent Inlet. During the summer of 1822, the expedition was successful in sailing into the eastern end of Fury and Hecla Strait only to be stopped once more by the ice. Parry's final attempt to sail through the Northwest Passage was carried out in 1824. On this occasion, the plan was to sail south into Prince Regent Inlet and so find an outlet to the west through Boothia Peninsula, but, as on his two previous attempts, Parry's ships were stopped by the ice and eventually one ship, the "Fury", was abandoned on the west coast of Prince Regent Inlet. The undue risk of proceeding onward in one ship forced Parry to turn for home.

The next attempt to find the eastern entrance to the Northwest Passage was a private enterprise under the command of John Ross in 1829. In the "Victory", the first power-assisted vessel to sail in this region, Ross passed southward into Prince Regent Inlet and the Gulf of Boothia where severe ice conditions forced him to abandon his ship and make his escape by boat. Ross and his crew were picked up by a whaler in the eastern end of Lancaster Sound after spending four winters in the Arctic. Ross once more had made a critical error in missing the discovery of Bellot Strait, but, as in his first voyage to the Arctic Archipelago, he made outstanding contributions to the geography of the western coast of Prince Regent Inlet and the Gulf of Boothia. During this expedition, the magnetic north pole was located and King William Island was discovered.

The outline of the western shore of the Gulf of Boothia as far south as Rae Isthmus was charted by Rae in 1847 and in 1851 Penny mapped the coastlines of Wellington Channel and the strait that now bears his name. Thus, by the middle of the nineteenth century, the major segments of the coastlines of this region had been investigated and roughly sketched in on Admiralty charts. The blank spaces which remained were the east coast of Committee Bay and the Gulf of Boothia as far north as Bernier Bay, the north end of Penny Strait, Peel Sound and Franklin Strait.

The Penny Strait area was explored and mapped by the large expedition under the command of Sir Edward Belcher in 1852-54. This fleet of five ships, the most extensive of the Franklin search parties, was based at Beechey Island and exploration was concentrated in Wellington Channel and Penny Strait. Through the efforts of Belcher, the coastlines of Wellington Channel and Penny Strait were surveyed and mapped but, of course, nothing was found of the lost expedition.

The search for the Franklin Expedition provided a strong incentive to continue the exploration of the archipelago. No longer was it a race to find a passage to the west; it was now a concentrated effort to satisfy the conscience of a powerful government and a struggle to ease the anxiety of influential individuals, the most prominent of whom was Lady Franklin. These compulsions controlled the great period of Arctic exploration from 1848 to 1859. In 1859, M'Clintock succeeded in finding the final evidence of the Franklin disaster on the northwest shore of King William Island and in so doing completed the exploration of the waters to the west of Somerset Island and Boothia Peninsula.

In 1867 Hall completed the outline of Committee Bay by extending the discoveries of Rae along the west coast of Melville Peninsula. Thirty years later, Lavoie of the Dominion Government Expedition under the command of Captain Bernier traced in the west coast of Brodeur Peninsula and the north shore of Fury and Hecla Strait.

The extensive exploration conducted by Captain Bernier in the eastern Arctic between 1906 and 1911 marks the end of the initial period of exploration in the area described in this report.

Previous Oceanographic Investigation

The history of oceanographic investigation in the eastern Arctic does not coincide chronologically with that of geographic exploration. In the early stages of Arctic sailing, the urgency of the discovery of the Northwest Passage took full priority over any other interest and later, during the period of the Franklin search, little time could be spent in scientific observations. Several of the early Arctic captains were interested in recording observations of the natural history of the country and on more than one expedition instruments and methods were developed to sample the bottom and measure the more obvious currents. In addition, all the journals of Arctic sailing contain descriptions of ice and weather conditions in northern waters.

One of the first Arctic expeditions for which there are records of oceanographic observations is that of Sir John Ross in 1818. On this cruise, subsurface temperatures were taken with a Six's thermometer at 80 and 250 fathoms depth in the eastern end of Lancaster Sound (Ross, 1819 and Prestwick, 1875). For this work Ross designed a type of water bottle which closed at a certain depth and a device for bringing up a sample of the bottom sediment. In 1819, Parry took subsurface temperatures and recorded water depths and ice conditions in Lancaster Sound and Barrow Strait (Parry, 1821). The Franklin Expedition of 1845 was equipped with a number of bottles and copper cylinders in which messages were to be sealed and the containers dropped into the sea north of 65° north latitude (Wordie, 1945). Young (1879), on his first attempt at the Northwest Passage in 1875, took a number of soundings and measurements of surface temperatures with a Casella's thermometer. The Second Norwegian Arctic Expedition in the "Fram" was in the Canadian Arctic from 1898 to 1902. During this time, surface temperatures and bottom samples were taken but no further oceanographic measurements were obtained as the expedition was not equipped for this type of work (Mohn, 1907). The following year A.P. Low (1906) in the "Neptune" visited Lancaster Sound and took routine depth measurements and ice observations but no additional oceanographic information was forthcoming from this cruise. The voyages of the Canadian government ship "Arctic" under Captain Bernier contributed significant details of ice conditions and depths to the growing fund of knowledge of these waters. In 1908, J.G. Macmillan (1910), the geologist on board the "Arctic", measured surface temperatures and salinities of the surface water at 57 stations in the eastern Arctic. These observations include a series of temperature and salinity measurements taken at Winter Harbour during the winter of 1908-09 (Bernier, 1910). The Canadian Arctic Expedition succeeded in recording a number of tidal observations in the western Arctic in 1914-16. Measurements were taken at Cape Isachsen, Borden Island, Cape Kellett, and at three locations on the north coast of Alaska but unfortunately the accuracy of these data is impaired by the lack of a suitable control position at which a continuous tidal record could be maintained for comparison purposes (Dawson, 1920).

In 1928, there were two important oceanographic expeditions to Davis Strait and Baffin Bay. Only seven oceanographic stations were completed in Lancaster Sound at this time; nevertheless, these two cruises account for a large part of our present knowledge of these waters. In the same year, the United States Coastguard Expedition in the "Marion" carried out an extensive oceanographic survey in the Labrador Sea and Davis Strait working as far north as Disko Island. This survey was continued by the "General Greene" expeditions of 1931, 1933, 1934 and 1935 and the report of the entire survey was compiled by Smith, Soule and Mosby in 1937. The Danish "Godthaab" Expedition of 1928 complemented the "Marion" survey and conducted investigations as far north as Smith Sound.(Riis-Carstensen, 1931). Further reference will be made to observations taken by the "Godthaab" in the eastern end of Lancaster Sound and Jones Sound.

During the time the Royal Canadian Mounted Police vessel "St. Roch" was on patrol duty in the western Arctic from 1935 to 1937, Sergeant (now Superintendent) H.H. Larson took a number of surface observations of density and temperature in Coronation Gulf, Amundsen Gulf, and the coastal waters as far west as Bering Strait (Tully, 1952). No additional oceanographic observations, except soundings and ice observations, were taken from the "St. Roch" while the ship was in the eastern Arctic.

Recently, Arctic exploration and reconnaissance has expanded through the combined efforts of the United States and Canadian governments to gain more thorough and precise information of the high latitude regions. In 1947, Task Force 68, U.S.S. "Edisto", established the Resolute Bay weather station and re-supplied other stations in the eastern Arctic. The following year Task Force 80, consisting of U.S.S. "Edisto" and U.S.C.G.C. "Eastwind", performed the duty of supplying the eastern weather bases and also claimed the honours of reaching the farthest north for ships under their own power in the vicinity of Cape Sheridan, north Ellesmere Island. Task Force 80 returned to the Atlantic by way of Lancaster Sound, Prince Regent Inlet and Fury and Hecla Strait, thus becoming the first ships to transit an inland waterway from Lancaster Sound to Hudson Strait (Arctic Circular, vol. 1, No. 8, 1948).

During the summer of 1950, "Edisto" conducted an ice reconnaissance and oceanographic survey in Baffin Bay, Kane Basin and Davis Strait, at which time two stations were taken in Lancaster Sound and one in Barrow Strait. In 1952, "Edisto" in company with U.S.S. "Atka", continued the oceanographic investigation in Baffin Bay and the eastern Canadian Arctic and the following year "Atka" expanded the survey in Davis Strait and Baffin Bay. Although this cruise did not enter into the waters of the Canadian Archipelago, one station was occupied in the eastern end of Lancaster Sound.

D.V. Ellis (1956) of the Fisheries Research Board of Canada carried out a series of temperature and salinity determinations in conjunction with biological studies in Admiralty Inlet and Eclipse Sound during 1954-55. When the "Monte Carlo" was in Baring Channel in the summer of 1954 the Dow Expedition ran numerous lines of soundings through the channel and carried out a preliminary reconnaissance of the immediate coastline.

In August 1954, H.M.C.S. "Labrador" made her historic voyage through the Northwest Passage and obtained subsurface water temperatures and related oceanographic data through the entire length of the passage (Bailey, 1955). Ninety-six oceanographic stations were occupied in the Arctic during August and September, including sections across Lancaster Sound, Barrow Strait, and Wellington Channel (Bailey, 1957). In 1956, the survey was continued from H.M.C.S. "Labrador" in Fury and Hecla Strait, Gulf of Boothia, Prince Regent Inlet, and Lancaster Sound. During this cruise 44 oceanographic stations with plankton samples, ice observations, and bottom sediment samples were completed in the waters north of Fury and Hecla Strait. In the next year, the Arctic oceanographic programme was extended northward to include a more detailed survey of the Lancaster Sound, Barrow Strait system with a repetition of the 1956 stations in Prince Regent Inlet and the Gulf of Boothia. The programme included a reconnaissance survey of Bellot Strait and an investigation of Wellington Channel, Peel Sound and Franklin Strait. This project was completed by late September 1957.

In the brief history of oceanographic investigation in the Canadian eastern Arctic, detailed analysis must rely primarily on the great volume of data collected from H.M.C.S. "Labrador" during the period 1954-57. The "Labrador" cruises are exceptional in that notwithstanding the pressing demands of ship requirements having higher priority, the oceanographic programme never suffered major cancellations and on all cruises an exceptionally high proportion of the oceanographic survey was completed with reliable results. The oceanographic observations conducted from "Labrador" were not static but included serial observations of temperature and salinity at all stations and analyses of dissolved oxygen and inorganic phosphate at selected stations. A precise pattern of plankton sampling and bottom coring and dredging was completed on each cruise and in certain channels, such as Bellot Strait and Fury and Hecla Strait, current measurements were taken from the ship's survey boat which was anchored in the stream. In Foxe Basin several attempts were made to trace the drift of ice floes by a technique of ice dyeing and aerial spotting and at other locations simple drift poles were used to gain an accurate estimate of the current. In addition, continuous records of ice conditions and local weather were maintained throughout the entire cruise. "Labrador", being a relatively new ship, was equipped with excellent sounding and navigational instruments which ensured precise depth readings and positions at all stations.

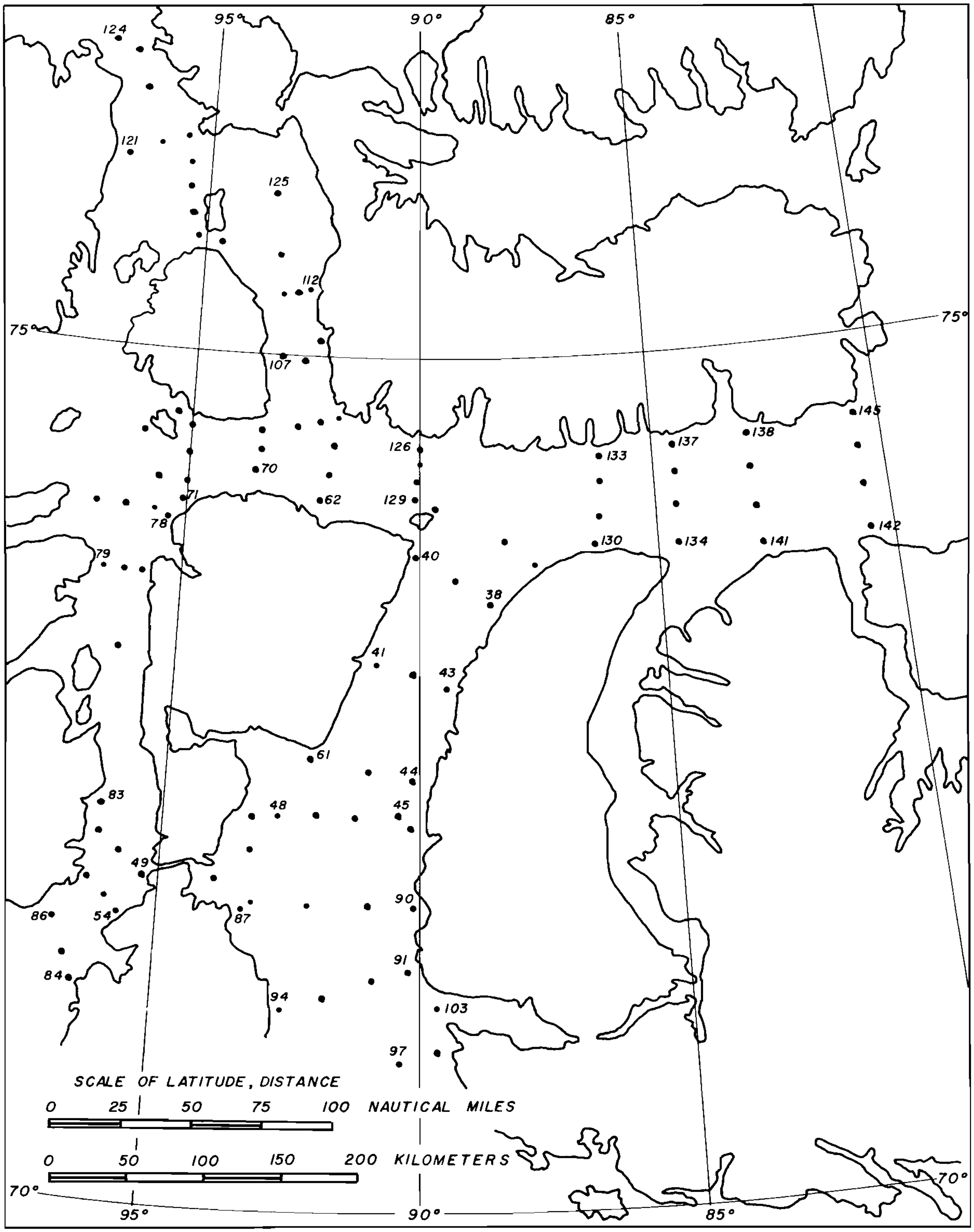

Fig. 2 Distribution of oceanographic stations, 1957.

The Pacific Naval Laboratory of the Defence Research Board conducted underwater acoustic measurements in Barrow Strait during April and May 1959 and in the summer of 1960 further oceanographic observations were taken by the Department of Mines and Technical Surveys in Lancaster Sound (Milne, 1960). The Hydrographic Service recorded subsurface conditions of temperature and salinity at a number of positions in the eastern Arctic in the course of the summer navigation season in 1961 and the Pacific Naval Laboratory continued the acoustic work in Barrow Strait in August 1961.

CHAPTER II

GEOLOGY AND CLIMATE

Knowledge of the boundary conditions at the bottom and at the air-water interface is a valuable tool in the study of inshore waters for, other than through mixing due to density gradients within the system, the physical properties and local movement of the water are strongly affected by the irregularities of the boundary. An understanding of the geological evolution of the region is necessary if a reliable bathymetric chart is to be made from the available soundings, and the general features of the local climate are essential for a thorough appreciation of the problems of sea ice formation and local surface temperature variation.

Significance of Boundary Conditions

Unlike deep ocean water movements the circulation and exchange of the coastal waters is influenced to a much greater degree by the restrictions imposed by the form of the coastline and the topography of the sea bottom. The effect of this boundary is manifest in several ways, the most obvious of which appear as inshore currents influenced by the trend of the shoreline, the barrier between water masses caused by an elevation of the sea bottom, and the deflecting effect on the direction of flow of a water mass moving over an uneven bottom.

The distribution pattern of the sediments is related to the topography of the sea floor and is indicative of water movements along the ocean bed. From underwater photographs, ripple marks and dunes deposited in the lee of obstructions on the sea floor have been identified, which are now accepted as the most reliable proof of significant currents along the bottom. Permanent features, such as sand deposits at great depth and erratic boulders found far offshore, are assumed to be the result of periodic water movements off the continental shelves and of rafting by sea ice. Finally, the bathymetry of the coastal region can reveal evidence of past changes in sea level. Submarine canyons on the continental shelf, fiord-like depressions and submerged terraces are unusual features of the ocean bottom that presently affect the circulation of the coastal waters and can be interpreted as evidence of past changes in the level of the sea.

The variations of the local weather have a corresponding influence on the physical properties of the surface waters. In arctic Canada sea ice forms a cover over the coastal waters for at least six months of the year. In some regions the ice is a permanent feature with little open water appearing in summer; in others, for example Lancaster Sound, open water usually persists throughout the three summer months. Local surface air temperatures and wind control the formation and development of the sea ice and in summer the open surface of the water is warmed and diluted by insolation and the addition of relatively fresh melt-water from the decaying ice.

The ice cover over undisturbed waters acts as a protective layer that restricts wind driven surface mixing and seasonal warming in the surface waters. According to the T-3 values there is little variation in water temperature at a depth of 10 metres below a permanent ice layer about 3 metres thick. Additional observations completed in

1960 and 1961 show that in winter the temperature of water of salinity 32.00‰ lying under a permanent ice cover 2.5 metres thick is nearly constant at -1.7°C.

The surface temperature in ice free waters reacts rapidly to the warming effects of insolation and convection. Grainger (1959) has shown that in a sheltered bay in northern Foxe Basin the warming of the surface water is detected almost immediately after melting ice is reported in the spring and throughout the summer the depth of the thermocline steadily increases to a maximum of 50 metres.

Geology

Within recent years great advances have been made in the geological reconnaissance of the Arctic through the use of helicopters and light aircraft as transport vehicles in the field. The Geological Survey of Canada has led the way in the development of these techniques starting with Operation Keewatin in 1952 and has completed, with unqualified success, large scale survey operations in all types of northern terrain, including the northern islands of the archipelago. The construction of northern airfields has encouraged the use of aircraft for survey and photographic missions; as a result trimetrogen aerial photographs are now available for all northern areas. Within the last ten years the tools of the field geologist have improved significantly and work and development have progressed accordingly.

The question of the geological continuity of the Canadian Arctic Archipelago has been dealt with in recent papers by geologists of the Geological Survey. Modern opinion holds that geologically and physiographically the archipelago is the flooded northward extension of the North American Continent (Fortier and Morley, 1956; Fortier, 1957). Therefore, it is to be expected that geological features of the mainland will extend into the islands.

With few exceptions the surface rocks of the archipelago are younger from southeast to northwest, forming the marginal depositional border around the central stable region of the Canadian Shield (King, 1959). The rocks within the thesis region are primarily lower Palaezoic sedimentaries except for small areas along the east coast of Devon Island and in the Boothia Peninsula-Peel Sound region where Precambrian rocks, which form the shield to the south, appear at the surface.

Except for the eastern end of Lancaster Sound, which lies within the structural province of the Canadian Shield, and the Cornwallis Upland which includes Cornwallis and Bathurst Islands as well as a small area of western Grinnell Peninsula, the survey area is situated in the Arctic Plateaux and Lowland physiographic regions (Fig. 3). Southern Prince Regent Inlet and the Gulf of Boothia lie within the Arctic Lowland region while the remainder of the area under discussion is situated within the two major provinces of the Arctic Plateaux physiographic region. The Jones-Lancaster Basin which forms the eastern province includes most of the area of Lancaster Sound and Barrow Strait, whereas, western Barrow Strait and Viscount Melville Sound lie within the Melville Basin. These two physiographic regions are separated by the northward extension of the Boothia Upland which includes the Boothia Peninsula and the western part of Somerset Island. The Jones-Lancaster Basin within which most of the research area is

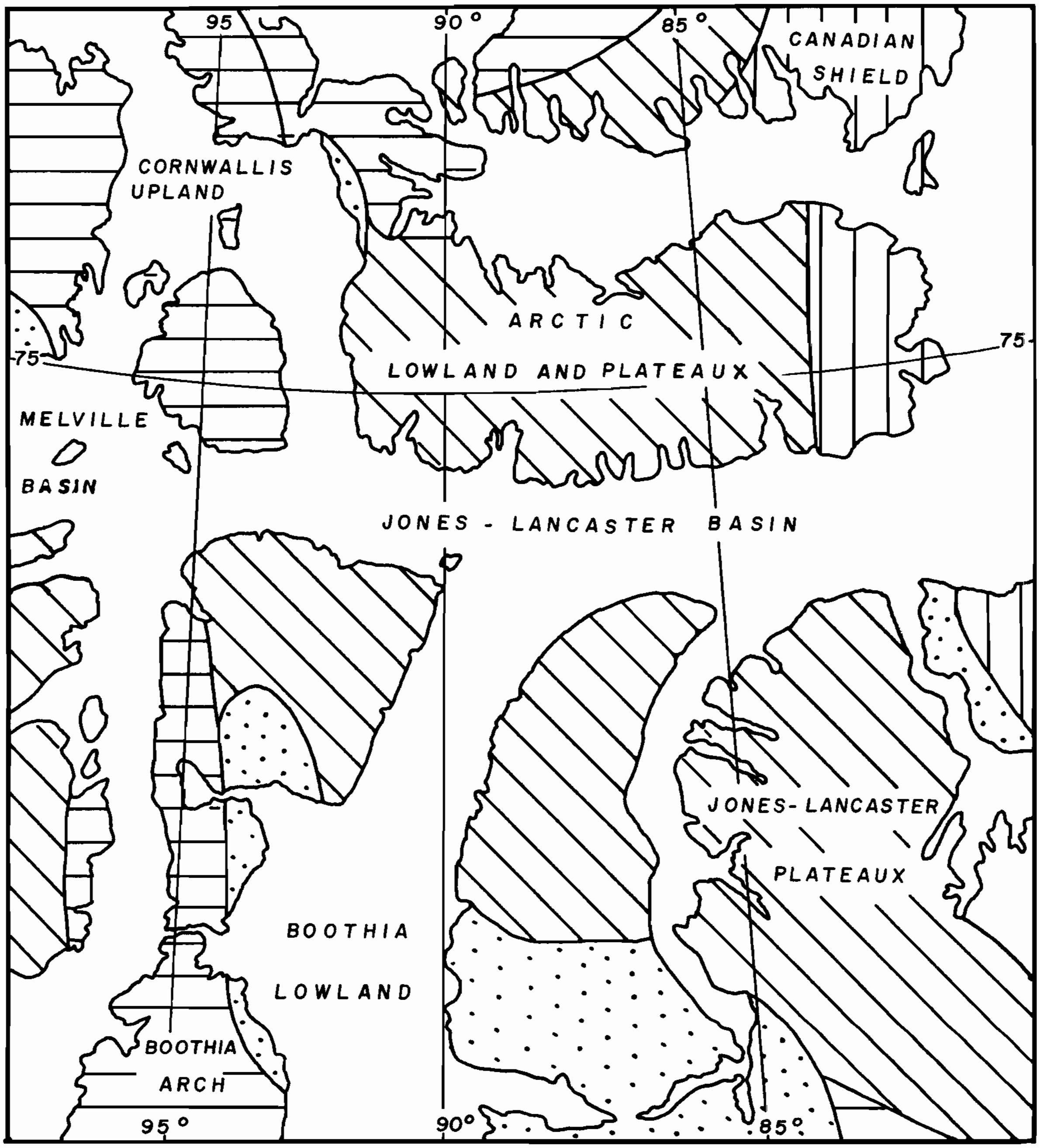

Fig. 3 Physiographic regions of Lancaster Sound, according to Fortier (1957) and Prest (1957).

situated is formed of thin, Lower Palaeozoic rocks consisting mainly of Middle Ordovician to Upper Silurian siltstones, carbonates and sandstones; in the vicinity of Lancaster Sound the strata dip gently to the west (Fortier, 1957; Thorsteinsson, 1960).

The landscape of the archipelago, except possibly for a narrow marginal sector in the northwest, has been subjected to glaciation and, in the lowlands, subsequent submergence and recent emergence. The dominant topography of the area was apparently formed by Tertiary earth movements and the major physiographic outlines were developed by the processes of glaciation during the Pleistocene. Bird (1959) has presented a detailed analysis of recent physiographic investigations in northern Canada and Craig and Fyles (1960) are responsible for definitive studies of the Pleistocene geology of the area.

The entire Lancaster Sound region was subject to glaciation during the Pleistocene. There is little evidence pertaining to the glacial source areas which controlled the development of ice in Lancaster Sound but it has been suggested that at the glacial climax an ice-sheet "high" coincided with Foxe Basin (Bird, 1959). During intervals of weaker glaciation the region was covered by a series of local, coalescing ice-caps, the remnants of which are possibly still in existence on several islands in the study area. During the Wisconsin glaciation continental ice extended northward as far as Lancaster Sound and Barrow Strait in the eastern Arctic. Bird (1959) suggests that it is unlikely that continental ice crossed Lancaster Sound-M'Clure Strait; however, Prest (1957) states that at its greatest development the ice-sheet covering the eastern Queen Elizabeth Islands was probably confluent with that of Greenland to the east and Baffin Island to the south. There is no evidence of ice of the Baffin Island centre extending northward over Lancaster Sound or of northern ice moving as far south as Baffin Island. Thus, at the maximum extent of the Wisconsin glaciation, Lancaster Sound must have been subjected to simultaneous ice action from both north and south and probably, at one stage, acted as a discharge channel emptying into Baffin Bay.

Post glacial and continuing changes in sea level are the most recent factors affecting the physiography of the Arctic Archipelago. Emergent geomorphological features such as strand lines and shell deposits are common throughout the survey region whilst in many locations skeletons of marine mammals have been found as high as 300 feet above the present sea level. A number of marine level determinations based on such evidence as marine shells, strand lines and offshore deposits located above sea level have been recorded in the Canadian Arctic. Blackadar (1956) has reported evidence of submersion at 420 feet in southern Admiralty Inlet and on the southwest coast of Baffin Island the highest marine strandlines are at 400-500 feet in western Foxe Peninsula (Bird, personal communication). A wealth of evidence from Cornwallis Island indicates a definite emergence of 275 feet and a reported maximum submergence of 545 feet in the vicinity of Resolute Bay (Nichols, 1953; Thorsteinsson, 1958).

Recent geophysical reconnaissance in the archipelago has produced aeromagnetic and gravity information which has contributed significantly to the understanding of the geological development of this region. The recent sequence of events through which the present configuration of the islands has evolved is considered to be: early

Tertiary peneplanation and development of a first-cycle drainage pattern extending over the entire area of the archipelago which at that time was totally above sea level. It is suggested that the present distribution of land and water within the archipelago follows closely the original pattern of the Tertiary river valleys (Fortier and Morley, 1956). There followed a period of late Tertiary vertical earth movements resulting in a relief somewhat greater than at present and basement faulting at several localities along the south coast of Devon Island (Gregory et al., 1961). Development of local ice-caps on the eastern islands took place during the Pleistocene and reached its maximum stage at the formation of a continuous ice-sheet merging with the Greenland ice-cap to the east and the Baffin Island source region in the south. Sporadic emergence followed closely the deglaciation of the eastern islands whilst a more uniform and greater rebound took place toward the interior.

Climate

Resolute Bay has been chosen as the representative station for the study area, primarily for two reasons. The station is centrally located in the Canadian Arctic Archipelago and is well within the boundaries of the region under investigation and, although Resolute Bay has a shorter history than the only other station in the area, Arctic Bay, the Resolute Bay data are preferable to those recorded at Arctic Bay for use in a discussion of normal conditions. The sheltered position of the Arctic Bay station and its proximity to the open water areas associated with the eastern end of Lancaster Sound cause the records of this station to be unsuitable for a general discussion of the eastern Arctic climate. In addition, the meteorological station at Arctic Bay has recently been closed, thus bringing the present series of observations to an end and eliminating the possibility of future data for comparative purposes.

The climate of the eastern Canadian Arctic is characterized by long, severe winters and short, relatively cool summers. It is essentially a polar climate modified in summer by the large areas of open water in Baffin Bay, Lancaster Sound, and the numerous passages to the westward. In winter the snow covered sea ice has essentially the same influence on the general climate as the surrounding land surface, except in areas where the sea surface does not completely freeze over. One such area is known to exist in the northern end of Baffin Bay and others have been reported by Schule and Wittmann (1958) in Barrow Strait and Lancaster Sound.

Meteorological records indicate that there is no significant variation in climate within the study region which could possibly act as a local modifying factor affecting the oceanographic regime; nevertheless, recent reports of sea ice conditions in the early spring in the vicinity of Resolute Bay suggest the presence of local winds in Barrow Strait which may cause unseasonal movements in the ice and extreme conditions of temperature and salinity in the surface water. Mean monthly temperatures at Resolute Bay and Arctic Bay differ by less than 9°F and the difference in mean monthly precipitation is never greater than 0.34 inches or approximately 5 per cent.

The high latitude of the area has a marked, controlling influence on the climate, for, even though during the summer there is an extended period when the sun is continuously above the horizon, the low angle of the sun's rays counteracts the effect of the prolonged period of insolation. In winter there is a similar period when the sun is continuously below the horizon. Since no solar radiation is received at the earth's surface during this time and radiation from the surface continues, the length of the dark period is an important factor in determining the depth of minimum water temperatures and the thickness of the sea ice. At Resolute Bay the sun remains above the horizon continuously from the 28 of April to the 25 of August; however, the maximum elevation of the sun is only 51.5°. A second factor which limits the actual heat received at the earth's surface during the uninterrupted period of insolation is the extensive cloud cover over the archipelago. The monthly average duration of recorded sunshine at Resolute during the summer of 1955 was only 29 per cent of that possible and the average cloud cover during this period was 79 per cent.

The presence of extensive bodies of open water also has a strong influence on the summer climate in the Lancaster Sound region. In summer a high proportion of the water areas are ice free and the cool surface water is exposed to the air. Since the surface water temperature is rarely over 32°F the large areas of open water act as a cooling agent during the summer months with the result that summer temperatures are consistently lower than they would be in a continental region of the same latitude. As a corollary, a comparison of Resolute and Mould Bay records illustrates the moderating effect of areas of open water. Mould Bay daily mean temperatures are consistently lower than those at Resolute and total precipitation is less for all months at the western station. As would be expected this effect is most pronounced during the late summer months of August, September and October. At Resolute the average daily temperature of the warmest month, July, is 40°F and the maximum diurnal variation is only 10°F.

In winter the entire sea surface is frozen over with the exception of several areas within the Lancaster Sound system in which the ice remains in a continual state of unstability owing to exceptionally strong currents in restricted waterways or possibly the peculiarities of local orographic winds. Such areas have been identified in Barrow Strait and the north end of Baffin Bay. Although the sea surface is covered with a more or less continuous layer of ice during the winter months the ice thickness rarely exceeds 6.5 feet during the early part of the winter. As a result a certain amount of heat escapes through the ice and thus exerts a slight moderating influence on the surface air temperature (Hare, 1956; Bespalov, 1959). During the latter part of the winter, rafting and hummocking must greatly increase the average thickness of the sea ice and so further restrict the passage of heat upward from the warmer waters below.

The ramifications of the eastern Arctic channels as well defined topographic depressions in a landscape having a total relief of over 4,000 feet are also a strong influence in the local control of the surface winds. Petterssen _et al_. (1956) describe this regional characteristic:

> "No one can examine detailed Arctic wind data from coastal and inland points without being impressed by the fact that local surface wind speed and direction are largely determined

> by exposure of the station (and wind instruments) and by the location of the area with respect to land and water bodies and to the regional orography."

An example of topographic influence of this nature is to be found in the wind data recorded on vessels sailing through Lancaster Sound. On numerous occasions strong transverse local winds are experienced off the entrances of Navy Board and Admiralty Inlets while the prevailing wind direction throughout the length of Lancaster Sound is from the southeast.

The trend of recorded surface air temperature at Resolute Bay shows that throughout the year there is a continuous, cyclical, variation in average temperatures; there being no distinct periods of sudden change (Fig. 4). Only six months of the year have average temperatures above 0°F and of these six, only three have average temperatures above freezing. The most recent monthly records of weather observations which are available show that frost-free days can be expected only in June, July, and August.

The mean annual surface air temperature of the Barrow Strait area is in the order of 3°F and the annual range is 71°F; however, extreme temperatures could possibly increase this figure by half again. Maximum summer temperatures and the greatest number of frost-free days occur in July. In 1955, the maximum temperature recorded during the month was 49°F and there were 22 days without frost as compared to June with a maximum of 48°F but only 4 days on which the temperature did not drop below freezing. On the other hand, August had a second maximum of 49°F but the number of frost-free days decreased to 19. The average temperature during the three summer months is 37°F but, as is the case at all the Arctic weather stations, snow and severe frost have been recorded for every month of the year.

The period of summer temperatures is brief and the decline begins about mid-August and continues until February when the annual minimum temperatures occur. During the winter months of December, January, February, and March, the average temperature is -25°F and the coldest month is February with an average of -32°F.

Although the length of the records at Resolute Bay and Arctic Bay is far short of that required for official analysis, there appears to be an interesting comparison between the average surface air temperatures at the two stations to the extent that mean temperatures at Arctic Bay are consistently higher than those at Resolute. The difference, which appears to fluctuate seasonally, varies between 3° and 7°F. Minimum differences of 3°-4°F occur between June and August; the maximum variation is recorded in the fall and winter months of October to January.

The Canadian Arctic Archipelago is situated within one of the most arid regions of the world. Total annual precipitation at the meteorological stations surrounding Lancaster Sound averages under 6 inches except at Dundas Harbour on the south coast of Devon Island where the total annual precipitation is 9 inches. To the north of Resolute Bay total annual precipitation decreases to a minimum of 2.6 inches at Eureka and 3.3 inches at Isachsen and to the south, total annual precipitation increases to 8.8 inches at Coral Harbour, 12.1 inches at Nottingham Island, and 13.5 inches at Pangnirtung. The precipitation data show that higher values may be expected at the eastern stations. For example, the figures for Pangnirtung, Clyde River, and Pond Inlet average 9.9 inches while those for Resolute, Arctic Bay, and Coral Harbour average 6.7 inches.

Precipitation at Resolute Bay reaches a maximum of 1.0 inches in August and a minimum of under 0.1 inches in January as shown in Fig. 4. Snow, which is recorded throughout the year, forms the sole precipitation during the winter months from November to May and makes up at least 56 per cent of the total annual precipitation. At Resolute, maximum monthly snow fall of over 5 inches is recorded in May and October and the annual minimum occurs in July. Rae (1951) has drawn attention to the fact that the conversion factor of 10 used by the Meteorological Service in computing the equivalent rainfall is not valid for Arctic areas. He suggests that a factor of 5 is more accurate for high latitude stations where the density of the snow approaches 0.2 gr/cm^3. Using 5 as a conversion factor the total precipitation at Resolute would become 8.4 inches and the proportion which falls as snow would be 72 per cent. The percentage of the annual precipitation which falls in the form of rain would thus be 28.

During the summer months of June, July, and August precipitation occurs primarily in the form of rain although snow is also recorded during these months. The total annual rainfall is 2.4 inches with the maximum monthly rainfall of 0.9 inches in July. Therefore, using 10 as the conversion factor, 44 per cent of the total annual precipitation occurs as rain during the short summer months.

An examination of the wind data of the weather stations at Resolute, Arctic Bay, and Pond Inlet immediately reveals the fact that

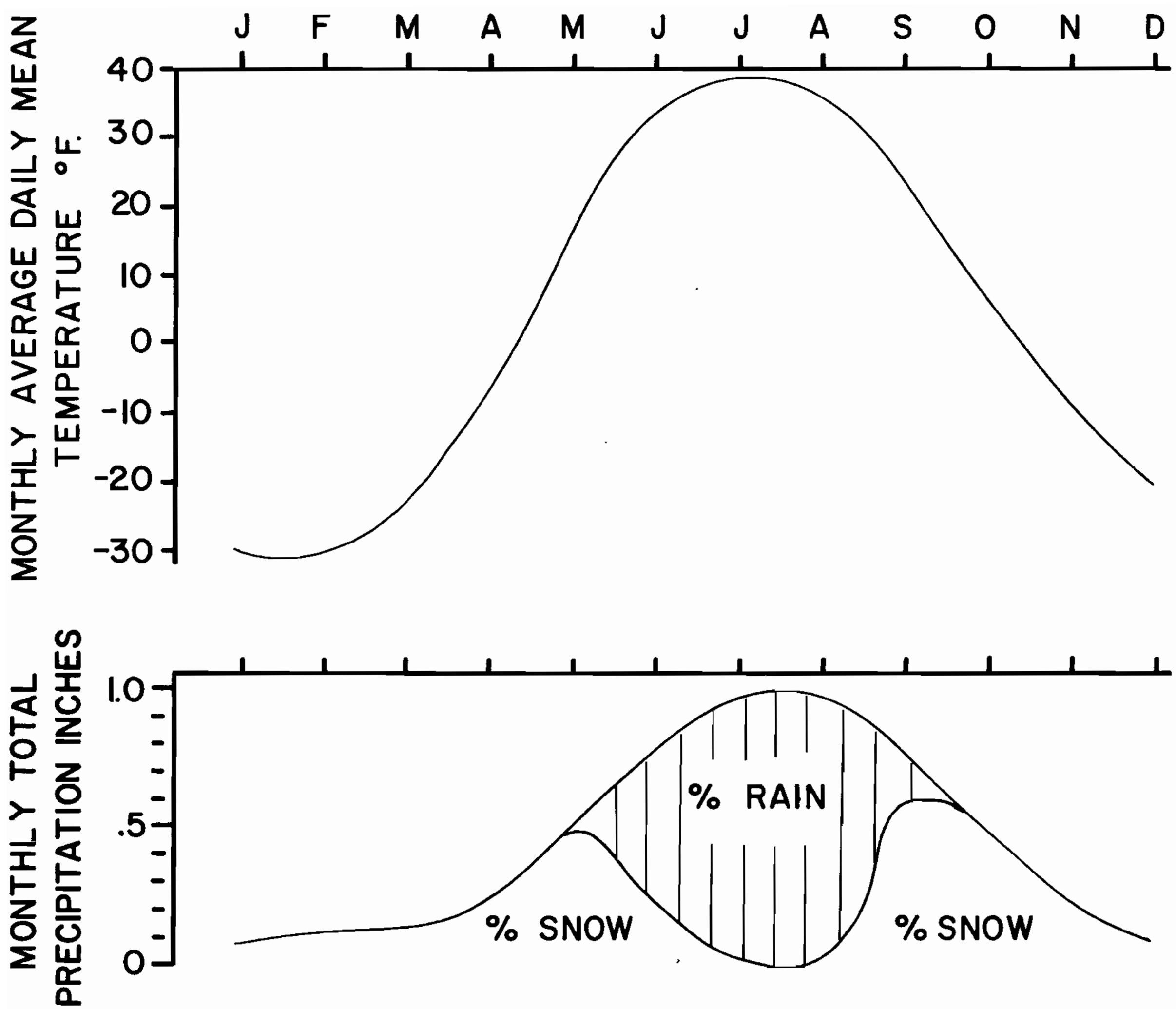

Fig. 4 Precipitation and temperature, Resolute, N.W.T.

calculated mean winds are not reliable indicators of surface wind conditions over such an extensive area. The reasons for this are twofold and are primarily the result of the location of the station with reference to local topography and to the short history of the station records. For example, the station at Resolute Bay was established in 1948 and those at Arctic Bay and Pond Inlet in 1941. In the case of Resolute Bay, local winds must be influenced by the wide, east-west passage of Barrow Strait to the south and the winding channels and irregular land masses to the north. Similarly, wind records at Pond Inlet and Arctic Bay reflect the local control effected by the steep-sided inlets of Admiralty Inlet and Eclipse Sound. In effect, average surface winds as derived from the mean sea-level pressure charts are not reported in the eastern Arctic. In their stead there is a complex pattern of surface winds, controlled by the dominant pressure field but strongly modified and directed by the steep local topography and the trough-like inland passages.

The normal winter, sea-level pressure pattern over the Canadian Arctic consists of two dominant systems; a broad high pressure ridge over the Mackenzie that extends northwestward over the Beaufort Sea and a trough of the Icelandic low that reaches northward through Davis Strait and Baffin Bay. Thus, the undisturbed pattern would result in northwesterly winds over Baffin Island, northeasterly winds over Ellesmere Island and generally north to northwest winds over the central archipelago.

In summer the mean surface pressure pattern indicates an extremely uniform, high pressure area over Baffin Island with a shallow low in the Hudson Strait, Baffin Bay area. As a result, pressure gradients are weak and surface winds are controlled mainly by local topography (Rae, 1951; Hare and Orvig, 1958).

The 1955 wind summaries of Resolute Bay show a situation somewhat different from that of the mean wind diagrams for the eastern Arctic. In 1955, dominant winter surface winds were from the east at an average of 10.6 m.p.h. for 26 per cent of the recorded time, while during the summer northeast winds at an average speed of 12.7 m.p.h. occurred for 32 per cent of the time. The average wind speed throughout the year was 11.5 m.p.h. with the highest monthly average of 15.6 m.p.h. recorded in August. The highest maximum wind speed was 49 m.p.h. in May and the lowest monthly maximum wind speed was 30 m.p.h. measured in June.

At Arctic Bay north winds at under 10 m.p.h. were prevalent during 1955. Winds from the south were dominant only in February and October and throughout the remainder of the year winds from all except a meridional direction were rare, a fact which illustrates the local control of the surface air movement.

CHAPTER III

BATHYMETRY

The coastal features of the eastern Arctic Islands are firmly controlled by the geology and structure of the region and have been only superficially modified by recent marine action. As a result, the geologic structure is often expressed in the morphology of the coast.

The coastlines of the Lancaster Sound region are characterized by steep, regular cliffs in several locations 500 feet or more in height. A fine example of this coastal form is found in the St. Georges Society Cliffs in Adams Sound near Arctic Bay where the vertical cliffs rise to 850 feet above the surface of the water (Blackader, 1956). The north coast of Bylot Island is of similar rugged appearance but the general form of the coastline is somewhat less steep and the tops of the crags appear more rounded.

East of Croker Bay, the north and south coasts of Lancaster Sound are of identical structure and similar appearance. Along these shorelines the cliffs rise to a thousand feet within a short distance of the shore and several ice tongues reach sea-level along the flank of the Cunningham Mountains. This sector of the coast is backed by crags ranging in summit level between 3,000 and 3,500 feet and the 3,520 foot peak of Cape Warrender is within a mile of the coast. At Dundas Harbour, on the north coast, the cliffs rise to 1,700 feet along the western side of the harbour.

West of Croker Bay the Palaeozoic sediments which overlie the gneisses are obvious in their control of the coastline and the change in structure is accompanied by a change in the physical character of the coast. The jagged cliffs of the eastern end of the sound are gradually replaced by a flat plateau which rises in uniform, perpendicular cliffs from the sea to an elevation of about 1,000 feet (Low, 1906; Kurtz et al, 1952).

Between Croker Bay and Beechey Island, at the southwest corner of Devon Island, the coast is extraordinarily regular and massive in appearance. Many steep-sided inlets and ravines cut inward through the towering cliffs and the perfectly symmetrical, horizontal stratification of the sediments gives the cliff face an intricate, layered appearance with colours that vary from black to almost white or pale pink. These spectacular cliffs continue westward to form the south and west coasts of Beechey Island.

The south coast of Lancaster Sound is similar to that on the north side except that the slope of the land backing the shore is not quite so high and impressive. In the region of Cape York the 900-foot cliffs stand several hundred yards south of the cape.

The north coast of Somerset Island forms the largest segment of the south shore of Barrow Strait. At Port Leopold, the northeasterly point of the island, the shoreline is formed by cliffs identical in appearance with those of Leopold Island. Here the plateau is at an elevation of 1,000 feet and the horizontal limestone beds appear in the cliff face as flat layers of different thickness, each of a distinctive shade of dirty yellow. The Somerset Island highland recedes from the sea westward until at Garnier Bay the shore is formed by a very low coastal plain backed at a distance of several miles by high hills. This type of coastline continues until, at Cape Rennell, the abrupt marginal cliffs again appear at the water's edge. Westward of this cape the coast is lower but still retains its severe features to the westward extreme at Limestone

Island.

The northern margin of Barrow Strait is formed by the relatively low, indented south coast of Cornwallis Island. Unlike the coast to the east, this shoreline is formed by low-lying, sandy beaches with numerous rivers and streams emptying into the sea. The highest points on this shore are at Cape Hotham which has an elevation of 700 feet and at Prospect Hill, elevation 400 feet, while to the west of Resolute Bay the coast is relatively low and featureless as far west as Cape Rosse.

Lying between Cornwallis Island and Devon Island, Wellington Channel extends 100 miles to the north. On the east, the coast formed by the western margin of Devon Island from Beechey Island to Prince Alfred Bay is largely formed of continuous crags and bluffs of 500 feet or more in height. Along most of its length the cliff is faced with a very narrow shingle beach, but north of Baring Bay the low foreshore widens to form a broad coastal flat.

The west coast of Wellington Channel which is formed by the eastern margin of Cornwallis Island is very similar to the opposite shore of the channel. High, steep coasts are predominant in the south, whilst to the north extensive beaches are prevalent. The precipitous coast extends from the entrance of the inlet to the vicinity of Petersen Point, while north of the point low beaches form the shoreline with occasional, moderately high headlands, such as Advance Bluff, appearing as conspicuous landmarks.

North of Wellington Channel, Queens Channel and Penny Strait complete a connecting seaway leading into the large unnamed sea north of Bathurst Island.[1] The western border of Grinnell Peninsula and the northeast

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1 Several names have been proposed for the body of water lying between Ellef Ringnes Island and Bathurst Island but as of September 1961 no name had been officially accepted and none was being seriously considered. Canadian Board of Geographical Names, Department of Mines and Technical Surveys, Ottawa, September 1961.

coast of Bathurst Island form the shores of these passages.

The coast of the Grinnell Peninsula is slightly lower in elevation than that to the south but retains the characteristic sombre appearance, with the steep, scree-faced cliffs north of Cape Beecher appearing as the dominant feature of the land. Cape Sir John Franklin at the northern end of Penny Strait is a low promontory behind which conical Mount Percy rises to over 1,000 feet within 2 miles of the shore. The west coast of Queens Channel and Penny Strait is a flat, gravelly beach backed at a distance of several miles by low, rounded hills of about 300 feet elevation. At the northern end of Penny Strait a headland of 500 feet, Organ Heigths, forms the most noticeable feature of the landscape.

To the south of Lancaster Sound, Prince Regent Inlet and the Gulf of Boothia form a wide 400 mile long, waterway which extends from Lancaster Sound to Fury and Hecla Strait. At the southern end of Prince Regent Inlet the narrow gorge of Bellot Strait separates Somerset Island from Boothia Peninsula.

Dominant headlands form the northern coasts of Prince Regent Inlet. On the western side, the edge of the plateau often reaches the coast in cliffs but more typically forms a uniform summit level at about 1,000 feet elevation within 3 or 4 miles of the shore. The slope is cut by many deep, steep-sided gorges which extend for some distance westward into the plateau, while south of Fury Point the landscape becomes much subdued with gentle slopes leading inland from the low foreshore to the central highland. At Bellot Strait the coast-line again becomes bold and rugged with an elevation of over 1,000 feet at the eastern end of the strait.

South of Bellot Strait the east coast of Boothia Peninsula is low and deeply indented through the entire length of the Gulf of Boothia. North of Simpson Peninsula the coast remains low and uniform; however, south of the peninsula the shoreline becomes steeper and severely dissected. According to Rae (1850) the western shore of Committee Bay is framed by a low, flat coastal plain of disintegrated limestone.

The highlands of the east coast of Prince Regent Inlet extend as far south as Cape Kater where the edge of the bluff stands at 400 feet elevation. Between Cape Kater and the western end of Fury and Hecla Strait the coast is low and the topography characterless. Lavoie (in Bernier, 1911), while exploring this shoreline named the monotonous tundra south of Bernier Bay "The Plain of the Departed" in reference to the barren aspect of the landscape. At the western end of Fury and Hecla Strait the coastline once again becomes steep and foreboding with heights of 600-800 feet within a mile or so of the shore.

South of Fury and Hecla Strait the eastern coast of Committee Bay as far south as 60° north is composed of gently sloping, till-covered slopes that increase in height to 300-600 feet in the region of Gary Bay. Between Gary Bay and Wales Island the shoreline becomes steeper and more imposing with many small bays and indentations, while to the south of the island, Sim (personal communication) has reported that an expansive coastal plain extends to the end of Committee Bay.

One hundred miles to the west of Prince Regent Inlet, Peel Sound and Franklin Strait form a parallel waterway leading to the south for a distance of 200 miles. The coasts of Peel Sound are topographically similar to the western shore of Prince Regent Inlet. In the north, irregular cliffs of 200-500 feet are characteristic, while to the southward the shoreline becomes more moderate until at Bellot Strait the land steepens to form a fluted highland, surrounding which lies a narrow sloping foreshore.

The drainage pattern of the archipelago is poorly formed due to the recent emergence of the islands and the sporadic, seasonal run-off. The short period of heavy flow during the early summer allows little time for valley formation and the stream channels are characteristically steep and straight-sided.

The coastlines are typical of those of a submerged and heavily glaciated region. There is generally a narrow foreshore which is often backed by sheer cliffs. Along major sections of the coast, notably on the northern side of Lancaster Sound, the beach is entirely lacking and the dissected cliffs plunge vertically into the sea. In other sections, for example the east coast of the Gulf of Boothia south of Bernier Bay, the dominant slope of the interior highland is a considerable distance inshore; consequently, the coastline presents an extremely low, featureless appearance.

In the areas underlain by sedimentary rocks, the coastal cliffs are especially bold and often castellated and fluted along the prevalent joint planes and fault zones. In these regions the bays are generally long and penetrate far inland at right angles to the trend of the coast with tertiary valleys at right angles to the main indentations adding to the geometrical pattern of the region (Nichols, 1936).

Bathymetry

An investigation of the bottom configuration and cross profiles of the channels of the Lancaster Sound system has only recently become feasible through the publication of the Canadian Hydrographic charts of the area. These charts, which cover the entire Lancaster Sound system, are the provisional edition corrected to February, 1958.

The soundings in Prince Regent Inlet and Wellington Channel are primarily of recent Canadian origin. In Lancaster Sound the depth information has been contributed by the relatively large number of ships which have travelled this passage since the days of Franklin. The fact that the sound is the westward leading waterway to Resolute Bay has made it a familiar thoroughfare for ships plying the eastern Arctic and as such it is better charted than any other passage north of Hudson Strait.

In 1948, the U.S.C.G.C. "Eastwind" and the U.S.S. "Edisto" carried out the initial soundings in Prince Regent Inlet and the Gulf of Boothia as far south as Fury and Hecla Strait. H.M.C.S. "Labrador" expanded the survey in 1956 and 1957 working as far south as 60°40' in the southern end of the Gulf of Boothia and, in 1957, completed an intensive hydrographic survey in the Bellot Strait region that produced the first detailed bathymetric information about the strait.

The first hydrographic reconnaissance of Peel Sound and Franklin Strait was carried out in 1957 by H.M.C.S. "Labrador" with assistance from the U.S.C.G.C. "Storis", "Bramble" and "Spar" in Franklin Strait and the western approaches to Bellot Strait. The same year "Labrador" completed a preliminary survey of Wellington Channel, Queens Channel, and Penny Strait to 76°40' north. During the summer of 1960 further oceanographic observations were conducted from C.G.S. "Labrador" in Lancaster Sound, and in 1961 C.G.S. "John A. Macdonald" and "Baffin" completed additional surveys in Barrow Strait and Penny Strait. The preliminary soundings, which are usually confined to the middle of the channel, as is evident from the chart of Peel Sound, produce rather inadequate data for bathymetric analysis; however, there is normally sufficient depth information for the construction of longitudinal profiles of the passages.

The bathymetry of the Lancaster Sound system includes several interesting features which are indicative of the continuity of the channel pattern through the entire archipelago (Fig. 5). Within the watercourse the deepest water occurs in Pond Inlet in the vicinity of Mount Herodier where soundings of over 600 fathoms have been recorded. In Lancaster Sound the maximum depth of over 500 fathoms is found in the eastern end of the seaway along the southern side of the passage, and the hundred fathom contour is continous as far westward as Cornwallis Island. Depths of over 200 fathoms extend into Admiralty Inlet, Navy Board Inlet, and Prince Regent Inlet, but limiting depths of only 85 fathoms are reported in the southern end of Wellington Channel. Troughs with depths of over 400 fathoms form significant bathymetric features in Navy Board Inlet and Pond Inlet.

Bellot Strait is similar to Fury and Hecla Strait in several respects although there is considerable difference in size. In both channels the deepest water occurs in the western end in the form of a narrow trench over 150 fathoms deep. In Bellot Strait this depression reaches a maximum recorded depth of 180 fathoms and in Fury and Hecla Strait the maximum is 185 fathoms. Scattered islands and a shoaling bottom characterize the eastern end of both passages.

The bottom topography of Peel Sound and Franklin Strait illustrates a feature common in a young glaciated coast, unusual in normal mature coastlines, but now found to be typical of the channels leading into Barrow Strait and Lancaster Sound. This passage contains over a hundred fathoms of water throughout all but the southern end of Franklin Strait where scattered soundings indicate a gradual decrease in depth. The deepest section of the strait does not occur in the northern end as might be expected from an exclusively fluvial derivation of the drainage pattern but, as is the case with many other inlets and passages in this region, the maximum depth appears as a steep-sided, elongated depression near the head of the strait, that is, off the western end of Bellot Strait. Here the depth of the channel is over 250 fathoms and a basin of over 200 fathoms depth extends for over 20 miles to the north and south. The bottom configuration of Wellington Channel, which enters Barrow Strait from the north, is similar to that of Peel Sound and Admiralty Inlet although average depths are on a smaller scale. In this passage the typical headward deepening, which is also mentioned by Taylor (1956) as a feature of the inlets of the south coast of Devon Island and which is most apparent in Eclipse Sound and Peel Sound, is again present and relatively well defined. At the southern end of Wellington Channel the average depth is of the order of 75 fathoms and no soundings of over 83 fathoms appear on the chart. Northward, there is

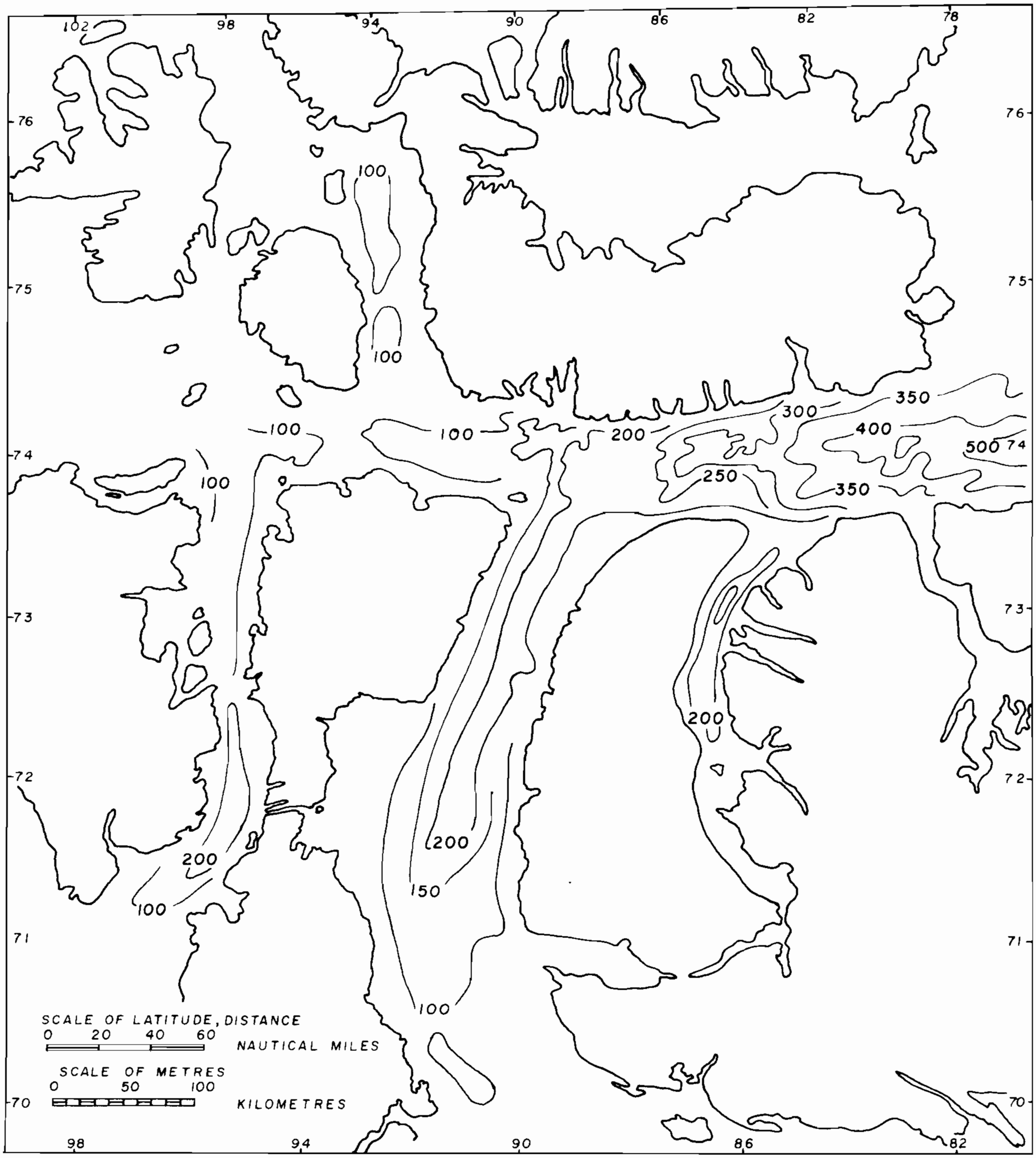


Fig. 5 Bathymetry of the Lancaster Sound system, depth in fathoms, contour interval 50 fathoms.

a slight shoaling of the bottom followed by a gradual deepening to a maximum of 180 fathoms in the head of the channel. This depression takes the form of an elongated, elliptical basin with the steepest slope on the sides and the headward end. The shape and even the size of the Wellington Channel basin, are quite similar to the depression which occurs in Franklin Strait.

Vertical Profiles

Within the study area the waterways of Lancaster Sound, Admiralty Inlet, Prince Regent Inlet, Peel Sound, and Wellington Channel form an angular pattern of deep-water passages that leads westward into Viscount Melville Sound, southward into Foxe Basin and northward to connect with the northern passages into the Arctic Ocean. The interesting configuration of the Canadian Arctic islands has led Fortier and Morley (1956) to investigate the concept that the channels of the archipelago represent the remnant pattern of the preglacial drainage system. The evidence which these authors present includes a discussion of the bedrock geology and the results of an aeromagnetic survey, and the conclusions drawn support the theory that these waterways do in fact follow the branching drainage pattern of a large, eastward flowing, pre-glacial river system.

An investigation of the bathymetry and the vertical profiles of the channels suggests a later glacial modification and tentatively identifies the position of the late ice margin in Prince Regent Inlet with indications of longitudinal faulting in some of the profiles.

The Lancaster Sound - Barrow Strait waterway is the main east-west passage in the eastern Arctic north of Hudson Strait. With its westward extension through Viscount Melville Sound this series of channels forms a direct oceanic link between Baffin Bay in the east and the Beaufort Sea to the west. East of Barrow Strait there are sufficient soundings to construct profiles of the channel but to the westward the lack of information makes this technique impossible.

Figures 6 and 7 show the transverse profiles and the longitudinal sections along the approximate centre-line of the passages and Fig. 5 shows the bathymetry of the entire region. The longitudinal sections will, in most cases, be found to follow the line of maximum depth; however, in Wellington Channel and Peel Sound, it is quite possible that the deepest sections have been missed because of lack of sufficient soundings. On the scale of the hydrographic charts the accuracy of the depth measurements depends at least as much on the uncertainties of the ship's position as on the accuracy of the sounding equipment.

Longitudinal Depth Profiles

The depth profile of Lancaster Sound shows an eastward sloping, undulating configuration which extends from Lowther Island in the western end of Barrow Strait to 75° west, 85 miles to seaward of the eastern entrance to Lancaster Sound. The total length of the profile is 380 nautical miles along which the average eastward slope of the sea bottom, between the Barrow Strait rise and the eastern end of the sound, is 0.1°. Within the profile there are several topographic irregularities which deserve mention.

As is characteristic of glacially eroded channels the longitudinal profile of Lancaster Sound is very irregular and uneven. The average relief of the bottom is 40 fathoms and the slopes of the submarine depressions and elevations are in all cases much steeper than the average slope of the channel. The depth contours form a very confused pattern, the characteristic feature being for the isobaths to cross the channel at right angles to the coast, a configuration that makes the plotting of a line of maximum depth, or thalweg, a rather tenuous undertaking. Depths of over 150 fathoms form a weak elliptical depression in the eastern end of Barrow Strait between 90°and 92° west. Here the depth is slightly greater than directly to the eastward but there is very little indication of a sill at this position. The slight rise which appears at 79°30' west on the profile is seen to be a longitudinal feature on the bathymetric chart, while the gentle shoaling of the bottom between 76° and 77° west is perhaps the nearest indication of a possible morainal sill. The sparse soundings to seaward from the end of this section reveal no prolongation of the channel in an easterly direction.

In the extreme eastern end of Lancaster Sound there are two narrow, longitudinal, troughs which are possibly remnant features of the previous drainage. One of these furrows passes southeastward out of the middle of the channel and joins with the deeper trench along the north and eastern coast of Bylot Island at a position about 10 miles off the northeast point of the island.

Fortier and Morley (1956) have postulated a single, eastward

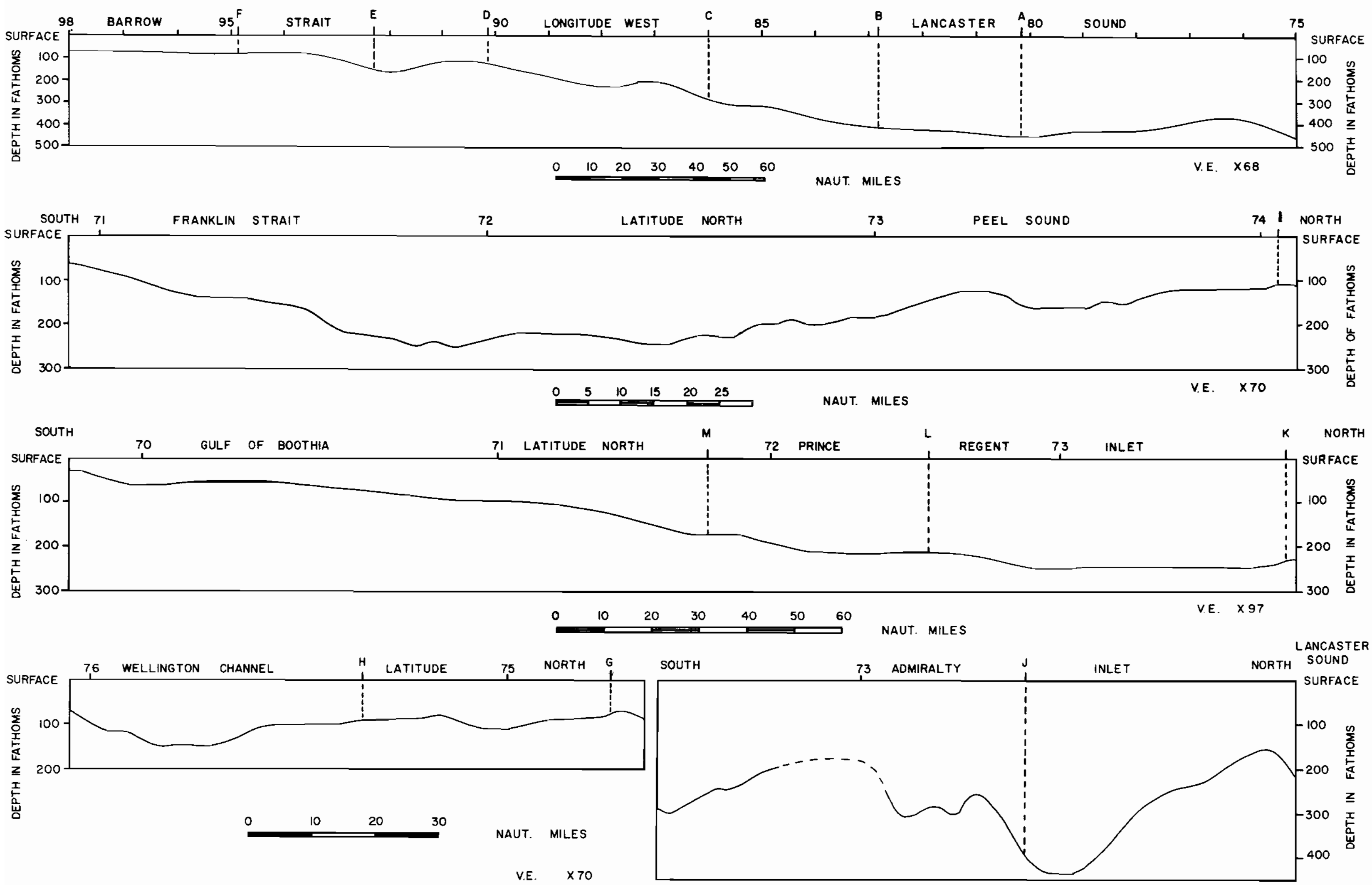


Fig. 6 Longitudinal profiles of the channels of the Lancaster Sound system.

drainage channel through Lancaster Sound which was joined on both sides by tributaries entering from the north and south. The recent soundings show that in the eastern end of the sound the line of maximum depth lies along the southern side of the channel and that in mid-channel there is a second longitudinal gulley which also passes southeastward to join with the southern one off Cape Byam Martin. It is interesting to note that this depression does not continue southward or eastward but appears to come to a definite end just north of Pond Inlet. Throughout Lancaster Sound the median channel can be traced as far west as Prince Regent Inlet and there is evidence of the southern channel as far west as Admiralty Inlet with indications of a tributary into Navy Board Inlet.

The longitudinal profile of Wellington Channel has been plotted from its southern entrance in Barrow Strait to the head of the channel and does not include Queens Channel and Penny Strait (Fig. 6). Soundings in Wellington Channel are few and far between, nevertheless, there are sufficient data to give a fair indication of the valley form. The profile is drawn along the sounded track and of necessity follows the centre-line of the passage. The shape of the channel exhibits several features which are common to the other inlets in the eastern Arctic and is similar, although on a smaller scale, to that of Lancaster Sound.

Contrary to the expected configuration, the general slope of this channel is northward, the deepest section being in the head of the sound where the maximum depth of 184 fathoms is recorded. Between the terminal basin and Barrow Strait to the south the profile takes the form of a series of rounded steps leading southward to a minimum depth of 75 fathoms approximately 6 miles north of the southern entrance. South of this position the depth increases gradually toward the main channel of Barrow Strait.

The depression at the head of Wellington Channel is a remarkable bathymetric feature in that it occupies a full third of the length of the passage and has a maximum depth 100 fathoms greater than the average depth at the southern end of the strait. The northern and southern slopes of the basin are almost equal at 0.3° but the bottom is nearly level over a distance of 10-15 miles.

Sporadic soundings north of Cornwallis Island indicate that the Wellington basin does not extend westward into Queens Channel, whilst further north, there is evidence of a detached depression in the northern section of Queens Channel and Penny Strait.

There is no definite sill in the southern end of Wellington Channel. The 75 fathom contour delineates a gentle ridge across the channel at its junction with Barrow Strait, but this structure is weakly defined and deeply indented. The slope on both sides of this ridge is moderate and there is no evidence of a true, fiord type, threshold. Throughout Wellington Channel the mean sounded depth is almost identical to that found in Barrow Strait directly to the south.

The longitudinal profile of Peel Sound has been constructed on the same scale and exaggeration as the other profiles and is equally limited in scope and accuracy by the paucity of soundings (Fig. 6). The form of the section is remarkably similar to that of other eastern Arctic passages and embodies the three significant features which have been noted in Lancaster Sound and Wellington Channel.

In Peel Sound, north of Bellot Strait, the slope of the bottom is not to the northward into Barrow Strait but to the south from the strait into a deep, narrow basin of over 250 fathoms off the western end of Bellot Strait. South of Bellot Strait the bottom shoals gently to slightly over 50 fathoms in the southern end of Franklin Strait. The steepest slopes in the Peel-Franklin depression are found on the western side of the passage where the basin wall lies at an angle 0.5°; to the north and south the bottom slope is 0.1°. Midway between the deep channel at the head of Peel Sound and its mouth on Barrow Strait there is a conspicuous elevation of the bottom to a depth of slightly over 100 fathoms. North of this rise the sea floor slopes gently to the mid-channel depth of 110 fathoms in Barrow Strait, and to the south the depth increases to the recorded maximum of 267 fathoms. There appears to be mo indication of a threshold of any form at the northern end of the passage. The few soundings suggest an irregular deepening off the eastern end of Baring Channel but no discontinuity is apparent in the bottom topography to the northward. Through Franklin Strait the slope is northward at 0.3°, however, the bottom is extremely irregular, the relief being of the order of 100 fathoms in the distance of 70 miles.

The longitudinal profile of Admiralty Inlet has been plotted along the line of maximum depth and so is perhaps more representative of the true configuration of the bottom than are the other bathymetric diagrams (Fig. 6). This section reveals, in an exaggerated form, the bottom topography common to the eastern passages of the archipelago.

South of the northern entrance to the inlet on Lancaster Sound the bottom slopes uniformly at an angle of 0.6° to the remarkable depth of 440 fathoms, 280 fathoms below the threshold depth at the mouth of the channel, and considerably deeper than the mid-channel depth of Lancaster Sound at that meridian. The north end of the passage is characterized by a sudden rise of the bottom to a minimum depth of 160 fathoms followed by a steep drop to depths of 400 fathoms in Lancaster Sound. From the bathymetric chart (Fig. 5), it can be seen that the isobaths of Lancaster Sound cut directly across the entrance to Admiralty Inlet with no evidence of a continuous channel through the sill which occurs at the mouth of the inlet.

Taylor (1956) in his study of the inlets along the south coast of Devon Island has found that these fiord-like channels have a longitudinal profile much like that already described in Admiralty Inlet, Wellington Channel, and Peel Sound, and Kurtz et al (1952) have described Dundas Harbour as an abandoned glacial valley although no soundings are available from this area. The typical profile of the Devon coast inlets shows that it is common for a trough-like depression of moderate depth to occur north of a rather complex threshold at the Lancaster Sound entrance. The maximum inside depth recorded on the recent charts is 110 fathoms, in Burnett Inlet, but there is little doubt that greater depths will be found in Croker Bay and Maxwell Bay.

The bathymetry of Prince Regent Inlet and the Gulf of Boothia is obviously different from that of the other passages under discussion. The longitudinal profile of the channel (Fig. 6) and the bathymetric chart clearly illustrate the topography of the sea bottom in this region.

The most striking feature is the gentle, uniform slope of the section. Unlike the channels of Wellington Channel and Peel Sound the longitudinal profile of Prince Regent Inlet and the Gulf of Boothia forms a smooth, almost regular curve dipping cautiously from depths of 50 fathoms at the southern end of the Gulf to 250 fathoms in the northern end of Prince Regent Inlet. The slope of the channel floor from Committee Bay to Lancaster Sound is less than 0.1° and irregularities of the bottom topography are not as frequent, nor are they as well defined, as the relief features in the other passages. In the northern sector of this channel there is indication of a weak, median, depression which extends intermittently for 65 miles but does not cross through the mouth of the inlet.

Transverse Sections

A selection of transverse profiles of the eastern Arctic passagesis shown in Fig. 7. Except for the Lancaster Sound drawings the sections have been constructed on the same scale and with the same vertical exaggeration as the longitudinal diagrams. At several locations there is not sufficient information available to warrant a definite interpretation of the bottom form; in these instances the sea floor is represented by a dashed line. The positions of the cross-sections are shown on the longitudinal profiles by dashed lines and a letter; on Fig. 7 they appear as a solid line marked by a letter.

The transverse sections of Lancaster Sound and Barrow Strait show a series of profile forms through the main passage of the archipelago. From east to west the sections reveal a modification of the deep, irregular, "U" shaped valley which occurs in the eastern end of the Lancaster Sound system. Towards the Barrow Strait rise the valley decreases in depth, the slope of the sides becomes more moderate and the longitudinal ridges are lower and weaker in form. At section "A", in the eastern end of Lancaster Sound the sides are steep and uniform for the full depth of the channel. The bottom, which is almost horizontal, with moderate relief, appears to be formed of two separate levels, one at 440 fathoms and the other at 380 fathoms. The shallower floor occupies the northern third of the section and a noticeable longitudinal ridge occurs at the break in slope between the two levels. The deepest channel, 470 fathoms, is on the southern side of the sound, but a secondary trough with a depth of 460 fathoms occurs in the exact middle of the section. Between the two depressions the sea floor is relatively flat and uniform at a depth of 440 fathoms.

The channels which have been recognized in section "A" are discernible in section "B" but cannot be definitely identified in the profiles west of Brodeur Peninsula. Between the positions of "A" and "B" the longitudinal trough become narrower and the general configuration of the sea floor appears more symmetrical. In the eastern end of Lancaster Sound the slope of the valley sides below sea level is 4°-6° with a maximum of 26° on the north coast.

West of section "B", Lancaster Sound narrows and the profile loses its broad "U" shape. At section "C", off Brodeur Peninsula, the average depth is under 300 fathoms and the southern margin appears as a more gentle grade of about 3°, at the base of which only a remnant of the mid-channel trough can be identified. On the northern side, a slight depression persists at the foot of the coastal slope that approaches Devon Island at a gradient of approximately 6°.

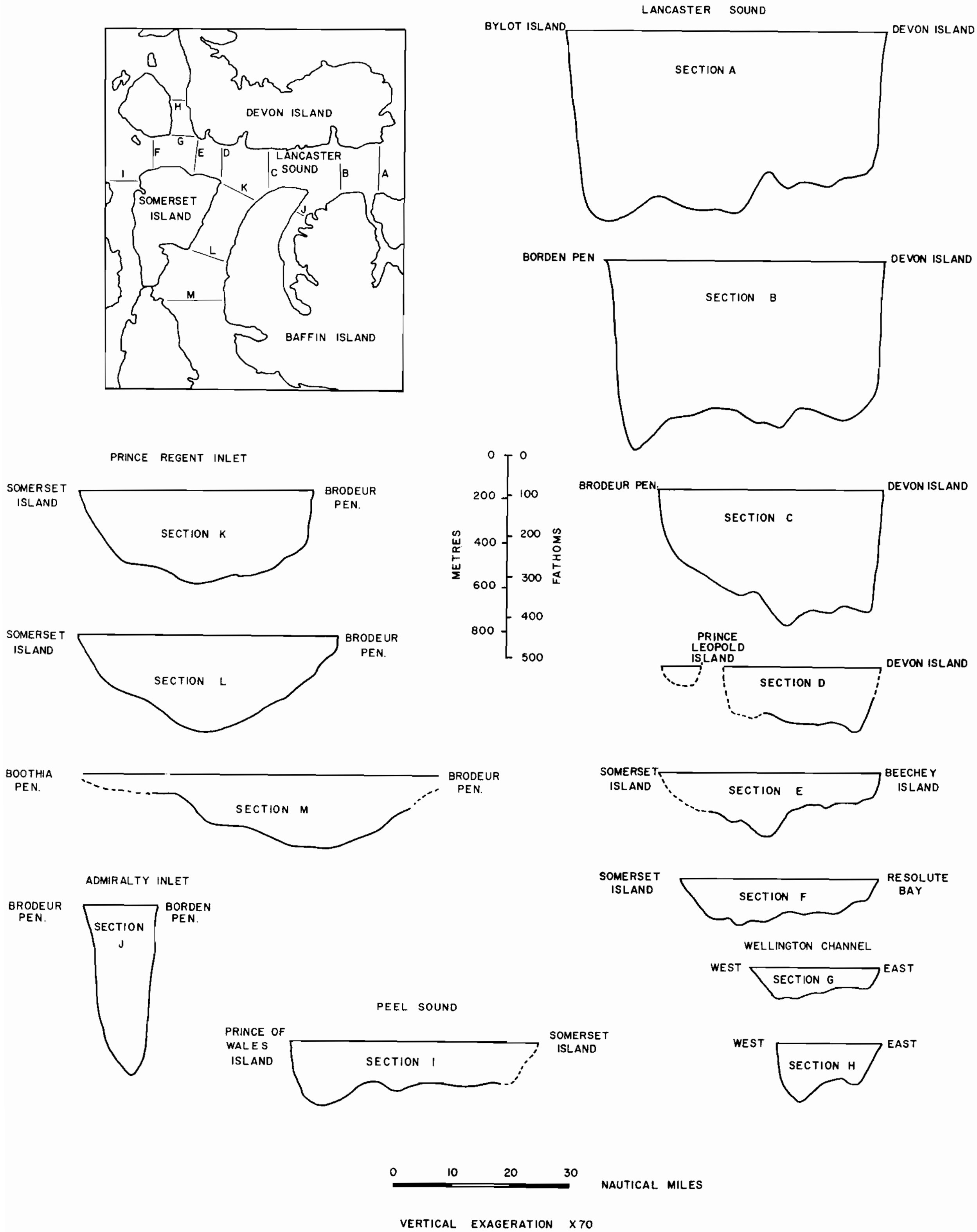


Fig. 7 Transverse profiles of the channels of the Lancaster Sound system.

Section "D" shows the valley form at the position of Prince Leopold Island where little remains of the configuration that characterizes the eastern sector of the sound. Here the northern shore has shoaled to a slope of slightly over 2° and the bottom is relatively level with only a minor depression along the north side. No soundings are available in the vicinity of Prince Leopold Island but oceanographic considerations suggest a depth of at least 40 fathoms in the pass between the island and the Somerset Island coast (Collin, 1958).

In sections "E" and "F" the depth at the valley sides has decreased considerably to under 100 fathoms and the slope has levelled to 2°. In section "E" a local basin occurs near the middle of the channel but does not continue westward to section "F", situated directly off Resolute Bay. In this area the channel attains its weakest form with a maximum depth of only 115 fathoms on the southern side of the passage and average coastal slope of 1.5°. Notwithstanding the modified form of the valley and bottom relief of about 30 fathoms, there still persists an indication of a weak trough along the south side of the passage.

Three transverse sections have been plotted in Wellington Channel. At section "G" across the southern end of the channel the maximum depth of 84 fathoms occurs along the Cornwallis side of the passage at the foot of the long, even slope of the western shore. At this location the channel floor is almost flat with only a slight grade toward the east. Profile "H" illustrates the typical headward deepening of the passage from its mouth on Barrow Strait. At this section the depression on the western side has deepened to 140 fathoms and a gentle elevation has formed along the centre-line of the trough. In addition, there is an indication of a second, minor deepening on the eastern side of the channel. The average slope of the valley sides between sections "G" and "H" is of the order of 3^{o}. The few soundings recorded in the northern end of Wellington Channel indicate that the depression continues to deepen to the northward and that in all probability the slope becomes weaker on the eastern side as is indicated by the land drainage pattern along the eastern coast. A maximum sounding of 184 fathoms is recorded in the northern section of Wellington Channel.

At only one location in Peel Sound are there sufficient soundings from which to construct a reliable transverse profile (Fig. 7). Section "I", at the northern end of the passage is based on recorded depths from coast to coast but even here several gaps in the data leave much room for interpolation. At this location the sides of the channel are uniform and even, with a slope of 3^{o} and, except for a shallow depression on the western side, the bottom is remarkably flat and regular at 110 fathoms. Insufficient soundings are available to construct further profiles in Peel Sound or Franklin Strait; however, the depths that are recorded indicate that in the deepest regions of the passage the valley walls steepen considerably and the cross-section assumes a more pronounced "V" shape rather than the shallow somewhat rectilinear form in the north. Soundings in Franklin Strait reveal a shoal, basin-like depression with little bottom relief.

The single profile drawn for Admiralty Inlet, section "J", crosses the channel at the deepest location, thus, the slope of the valley sides appears much steeper than that encountered in the other passages owing to the narrow width of the strait. Throughout Admiralty Inlet the sides slope at a uniform angle of approximately 7^{o} to a maximum depth of 440 fathoms. Average depth through the length of the passage is well over 200 fathoms, and the available soundings indicate a regular, flattened "U" shaped profile.

The three transverse sections that have been plotted for the Prince Regent Inlet - Gulf of Boothia seaway are reproduced in Fig. 7. Sections "K" and "L" are in Prince Regent Inlet and "M" is located in the northern end of the Gulf of Boothia just south of Bellot Strait. The two northern profiles are deeper and narrower than the Gulf of Boothia section; nevertheless, the shape of the sea floor throughout the length of this passage is remarkably different from that of the other eastern Arctic channels. The maximum depth at profile "K" is 230 fathoms and the bottom dips gently from both sides of the channel toward a weak depression along the middle of the trough. This feature cannot be recognized at section "L", 109 miles to the southward, at which position the bottom forms a basin shaped hollow with a maximum depth of 240 fathoms in the centre.

There is bathymetric evidence of a discontinuous, narrow, longitudinal, depression through the length of Prince Regent Inlet. This furrow appears to be outlined by the 250 fathom contour and, as such, does not continue through the north end of the inlet nor extend southward as far as the position of profile "L". At section "M" there is no trace of the mid-channel depression and the slope of the valley sides is considerably less than that measured in Prince Regent Inlet. On the western side of the channel there appears to be a series of two, or perhaps three, ill-defined terraces above which the foreshore shoals gradually from 50 fathoms depth toward the coast. South of Bellot Strait the passage is wider and the bottom becomes level and uniform at a depth between 40 and 60 fathoms with a slightly deeper area, 100-120 fathoms, apparent on the western side of the gulf. In Prince Regent Inlet the slope of the valley sides below sea level is about 1°; in the Gulf of Boothia the transverse gradient is barely half this figure, 0.5°.

Discussion of Channel Forms

As mentioned earlier the form of the Prince Regent Inlet, Gulf of Boothia depression is noticeably different from that of the other passages under discussion. Not only does the Prince Regent Inlet trough show little of the headward deepening found in all the other examples but it also has a much more regular and shallow transverse form. This obvious contrast has led to a brief exploration of the feasibility of using a detailed investigation of the bathymetry as a tool in the determination of the glacial limit.

The extent and northern boundary of the most recent glaciation in Arctic Canada has been the subject of numerous articles and discussions. Most authors are agreed that at one stage continental ice covered the entire Arctic Archipelago from Greenland to the Rocky Mountains, however, the margins of the last Wisconsin glaciation are still undetermined in many areas throughout the eastern Arctic and there is an expanding collection of evidence which suggests that a considerable area was exempt from the last glacial advance. The suggestion put forward by Shepard and Emery in 1941 that all the islands and the intervening channels had been covered with thick ice was based on the supposition that all the passages in the Archipelago were deep and of a fiord form. Flint (1943) substantiated the earlier views with further glaciological evidence of the merging of the Greenland and Ellesmere Island ice lobes and the continental extent of the ice cover. Two years later Hobbs (1945) suggested a northern boundary of the latest glaciation based on the areal distribution of lakes. The ice border according to Hobbs crossed Prince Regent Inlet just north of Creswell Bay and Bernier Bay and passed through Admiralty Inlet in the vicinity of Arctic Bay. From field investigations in the western Arctic islands Jenness (1952) has presented evidence that the southern part of Banks Island was covered by ice moving northward from the continent and that the most recent advance onto Victoria Island appears to have been initiated on the continental mainland south of King William Island. Jenness summarizes his findings as follows:

> "Several different lines of negative evidence suggest that northern Banks Island, northern Prince of Wales Island, and at least the northern part of Somerset Island lay beyond the limits of the advancing continental ice."

Recent investigations (Prest, 1957; Craig and Fyles, 1960) indicate that, even at the time of maximum glaciation, ice movement was controlled by the topography of the individual islands and that Baffin Island, Ellesmere Island, Melville Peninsula and Southampton Island had only local ice which, at its maximum stage, may have been contiguous. Prest concludes his discussion with the paragraph:

"At its greatest development the Queen Elizabeth Islands ice-sheet was probably confluent with that of Greenland on the east and with Baffin ice on the south. There is, however, no reliable evidence of this northern ice having pushed southward across Lancaster Sound and Barrow Strait, nor that Baffin ice pushed northward across these same waters. It seems logical to assume that the maximum glacier coverage of the Queen Elizabeth Islands was attained at about the same time as the glacier maximum on the mainland to the south, and that both bodies supplied ice to Lancaster Sound. Within the Queen Elizabeth Islands group ice movements appear in general to have remained individual to each island."

Since the evidence of recent glaciation in Prince Regent Inlet is lacking, or at best sparse, there is reason to suggest that perhaps the configuration of this water course, in contrast to others of the eastern Arctic, is a result of partial or weak glaciation.

The channels within the study area show unmistakable signs of glacial modification of which the headward deepening of the valleys and the flattened, "U" shaped form of the profiles are most obvious characteristics. Secondary evidence is supplied by the undulating, irregular slope of the longitudinal profile and the absence of the valley continuation out onto the continental shelf. Nansen (1904) presented this last factor as a strong point in the case for glacial erosion in the fiord-like troughs bordering the Arctic coast for he suggested that either the steep depressions through the shelf have been masked by glacial deposits or the fiords and similar channels are ancient river valleys sloping seawards, the outer parts of which have been filled with erosional debris.

The eastern Arctic inlets exhibit many fiord characteristics the most remarkable being the irregular topography of the bottom, the headward deepening, and the long narrow form. Nevertheless, if an accepted definition of the fiord form is reviewed in comparison it is apparent that these channels cannot be described as examples of fiord topography. Such a definition according to Guilcher (1958, p. 157) and Shepard (1959, p.105) must emphasize the importance of glacial overdeepening in a pre-existing valley sufficiently steepened by rejuvenation and only partially influenced, if at all, by structural faulting. It follows that a fiord is a long, narrow inlet of the sea bounded by steep slopes and of great depth. The form is characterized by a closed depression cut off by a sill of solid rock or moraine at the seaward end and the cross profile is "U" shaped, typical of a glaciated valley. The fiord is a submergent coastal form produced by valley glaciers cutting downward to a depth well below sea-level and drowned by the rise of sea-level following the decay of continental ice sheets.

The term "glacial trough" as defined by Shepard (1931) is a far more appropriate description for these passages. This classification is applied to a relatively wide depression with steep sides and an irregular longitudinal section. The depth in the inner parts of the valley is comparable with or greater than that in the outer regions and the sides are straight or smoothly curving. The glacial trough type of depression appears to terminate at the edge of the continental shelf, or even inside it, and most of the glacial trough type submarine valleys are seaward continuations of estuaries.

The objections to this definition as applied to the channels in question are the comparatively great width of the passages and the extensive areas of almost level bottom found in Lancaster Sound, Peel

Sound and Wellington Channel. These discrepancies can be overcome by comparison with the St. Lawrence River which, in its eastern end, flows in a channel over 70 miles in width and to the Great Lake depressions which are even wider. Even floors, which are typical features in the Norwegian fiords, are presumably caused by stream sedimentation and subsequent marine deposition. This type of marine topography can also be the result of longitudinal turbidity currents which pass from the head of the passage to the lowest part of the basin where the suspended material settles to form extensive areas of relatively level bottom. Kuenen (1950) has shown that the finer marine sediments can be transported by turbidity currents on only moderate slopes and Heezen and Ewing (1952) have presented a very strong case in support of the theory that a landslide converted into a turbidity current took place on the continental slope south of the Grand Banks in 1929 along a slope of $0^{\circ}35'$. It has been suggested by Pickard (1956) that remarkably flat areas in several of the British Columbia inlets, especially Bute and Kingcome, are the result of turbidity currents that originate as mud slides at the head of the inlet and travel the full length of the passage where the material is deposited in the lowest part of the basin. The longitudinal slope in the inlets where the level bottom is most pronounced varies from $0^{\circ}40'$ to $1^{\circ}0'$. More recent investigations by Laughton (1960 and personal communication) in the Bay of Biscay have shown that turbidity currents have taken place, or are presently active, on slopes of $0^{\circ}24'$. A similar discussion is presented by Ericson, Ewing, and Heezen (1951) for the level areas containing regions of stratified sand in the North Atlantic.

To substantiate the possibility of turbidity currents in the Lancaster Sound system the axial slopes of several of the passages were calculated. The general slope from the headward end of the valley to the most pronounced level region was found to be 0°20' in Wellington Channel, 0°36' in Admiralty Inlet and 0°12' over a distance of 132 miles in Lancaster Sound where local slopes of 0°18' are common at several locations along the profile. In this region sediment sources capable of supplying a sufficient load for mass movements, such as periodic turbidity or density currents, are supplied by the natural accumulation of marine deposits and the accelerated seasonal discharge of the rivers emptying into the channels of the eastern Arctic (Pelletier, personal communication). In addition, it is suspected that ice rafting has accounted for considerable deposition of coarse sands and gravels in the past and is at present an important agent in sediment transport in Arctic waterways, especially the Arctic Ocean. In the regions of steep coastal cliffs, landslides and slumps similar to the Cape Hotham landslide must provide significant contributions to the sediment load. Thus, it is possible, since source materials and slope conditions are propitious, that turbidity currents, capable of depositing substantial loads of marine and fine grained terriginous sediments, may take place along some of the more pronounced marine slopes within the Lancaster Sound system thereby accounting for the unusual flat areas of the sea floor within regions of generally uneven and irregular bathymetry. Charnock (1959) has recently presented a summary of the development and state of turbidity current research which further strengthens this suggestion.

From recent geological evidence (Fortier and Morley, 1956; Bird, 1959; Craig and Fyles, 1960) and this study of the bathymetry it appears that the present pattern of channels and islands of the eastern Arctic has been formed by a combination of early Tertiary, sub-aerial river erosion modified later by differential uplift that determined the original drainage outline at a time when the area was all above sea level, and by glacial erosion during the maximum ice stages of the Pleistocene which widened and deepened the existing valleys. Subsequent submergence and partial uplift of the entire region has resulted in a higher sea level, forming the present landscape. Admiralty Inlet and several of the inlets on the south coast of Devon Island are true fiords formed by streams of ice that moved through pre-existing valleys or fault zones into the main channel of Lancaster Sound. Bellot Strait also appears to be a fiord-type depression, the head of which has been scooped out by ice moving from east to west to form a continuous passage through the isthmus.

Within Prince Regent Inlet there is evidence of a late ice limit occurring in the vicinity of Bellot Strait. South of the strait the bottom forms a gentle slope from the southern end of the Gulf of Boothia to a point between Bernier Bay and Bellot Strait. At this position there is a distinct change in the slope and relief of the bottom. To the northward the sea floor is approximately 100 fathoms lower and slightly steeper and there is no indication of headward deepening in Prince Regent Inlet; a feature which is distinctly characteristic of the other passages under consideration. The bottom is relatively smooth and shows few irregular features with no evidence of steep breaks in the slope at the northern end of the inlet. The mid-channel furrow, which has been mentioned earlier, can be traced only as far south as Creswell Bay, whilst to the south there is no sign of this feature.

Guilcher (1958) has suggested that the reasons why an obviously glaciated submarine depression does not exhibit representative characteristics are twofold: (a) the ice at this location was not powerful enough to carry out erosion along its path; or (b) the pre-glacial valley which controlled the direction of flow was not steep enough to lead to the formation of glacial troughs. Neither explanation can account for the unusual form of Prince Regent Inlet. Throughout the length of the passage the slope is at least as great as that in Peel Sound and Franklin Strait and, if the distance from a centre of glaciation situated on the mainland south of King William Island is taken as an index of the erosive power of the ice, it follows that this force must, as far as glacial activity is concerned, have been equal on both sides of Boothia Peninsula.

A glacial margin across Prince Regent Inlet in the vicinity of 71°57' north would account for the contrast in the form of the bottom. A tributary presumably passed westward into Bellot Strait, and in Prince Regent Inlet glacial outwash spread northward and has since been blanketed with a thin coating of marine deposits to form the uniform sea floor that is found today.

As an alternative it can be argued that the geology of the region is responsible for the form of the depressions. Possibly glacial ice has exploited the weaker palaeozoic sediments of Prince

Regent Inlet to produce a valley form which differs from that developed by similar forces acting in the more resistant intrusives. However, since Wellington Channel and Prince Regent Inlet are in identical lithologic formations little confidence can be placed in this argument.

CHAPTER IV

ICE DISTRIBUTION

Schule and Wittmann (1958) have emphasized the limitations of an ice distribution chart produced from the observations of a single ship in a relatively large area. The track of H.M.C.S. "Labrador" in the eastern Arctic waters during 1956 and 1957 was of necessity meandering and irregular, a fact which permitted a great number of observations to be taken over a considerable area within a short period of time. The ice charts produced from these data are not as complete as those which could have been drawn from aerial reconnaissance, owing to the time lapse and the limited range of visibility enforced by ship-board observations. They are, nonetheless, probably more accurate for those waters along the ship's course. Ice distribution charts for September 1956, August 1957, and September 1957 are shown in Figs. 8, 9, 10.

Ice conditions in Prince Regent Inlet, the Gulf of Boothia, and Committee Bay are not well known owing to the relative unimportance of the passage as a supply route and also because most of the observations have been based on only occasional voyages in the area and infrequent aircraft reconnaissance flights.

Many of the early explorers and navigators, including Ross and Parry, left valuable accounts and descriptions of the ice conditions in these waters but these reports were based on the effect of ice on sailing ships that had no auxiliary power and as a result are difficult to convert to modern symbols of ice reporting.

Swithinbank (1960) has recently completed a most thorough ice atlas of northern Canada that shows, graphically, ice conditions as they affect shipping in Canadian Arctic waters. Logs of all types of ships were used for this analysis but the author notes the type of vessel with each observation thereby leaving the final appraisal to the reader. It is hard to imagine this form of research being presented under any other condition.

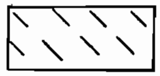
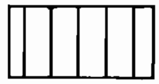
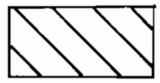
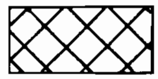
In September, 1956, Fury and Hecla Strait was free of ice except for light concentrations of 1-3 tenths winter ice while Committee Bay was completely ice covered with 8-10 tenths winter and polar ice. Presumably much of the heavier ice from Prince Regent Inlet and the Gulf of Boothia moves south to Committee Bay in the summer, keeping this area almost permanently ice-bound the year round.

West of Fury and Hecla Strait, "Labrador" encountered heavy polar ice of 7-10 tenths concentration that extended across the mouth of Committee Bay and as far north as Crown Prince Frederik Island. This ice was extremely heavy, varying in thickness from 1-3 metres, and was closely bound with new ice 10-20 cm. thick. Very little winter ice was encountered further north in the Gulf of Boothia.

North of the Committee Bay ice boundary, a wide band of young ice from 3-10 cm. thick extended across the Gulf of Boothia and along the eastern shore of Prince Regent Inlet. Between the new ice and the western shore of the gulf light concentrations of well weathered winter ice were encountered as far north as Bellot Strait while in Prince Regent Inlet, the winter ice remnants decreased in concentration and young ice was only sighted at one station on the

SEA ICE CONCENTRATION

LEGEND

CONCENTRATION	COVERAGE
0.1 TO 0.5	
0.5 TO 0.8	
0.8 TO 1.0	
NO WATER VISIBLE	

CONCENTRATION BY SIZE

EXAMPLE $\frac{9}{6\ 2\ 1}$

6 TENTHS SLUSH, BRASH AND BLOCK

2 TENTHS SMALL MEDIUM FLOES

1 TENTH GIANT FLOES AND FIELD

BOUNDARY

————————	KNOWN
— — — — —	ASSUMED

W	WINTER ICE
Y	YOUNG ICE
VY	VERY YOUNG ICE
PR	PRESSURE RIDGES
OW	OPEN WATER

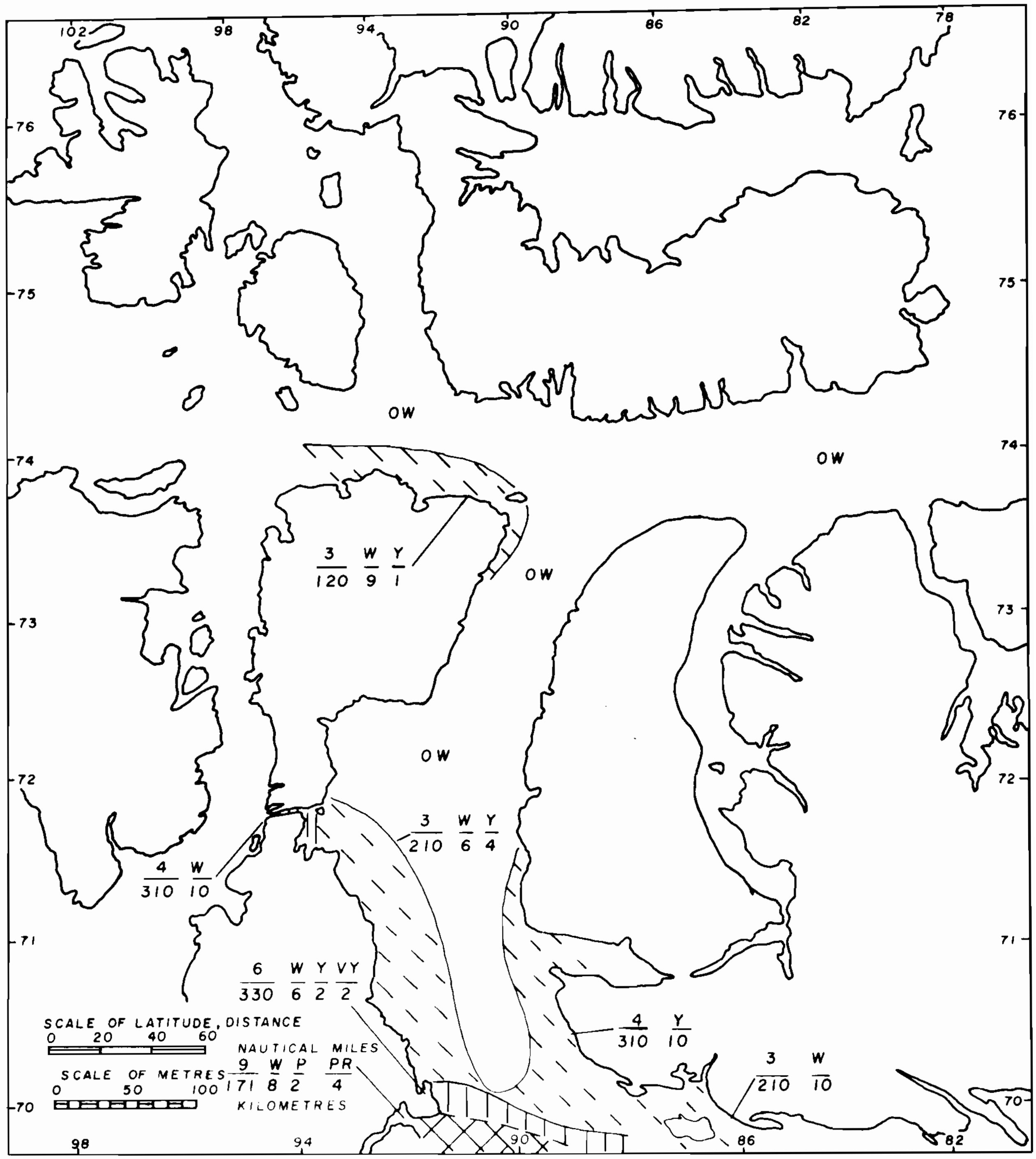


Fig. 8 Ice distribution, Lancaster Sound, September, 1956.

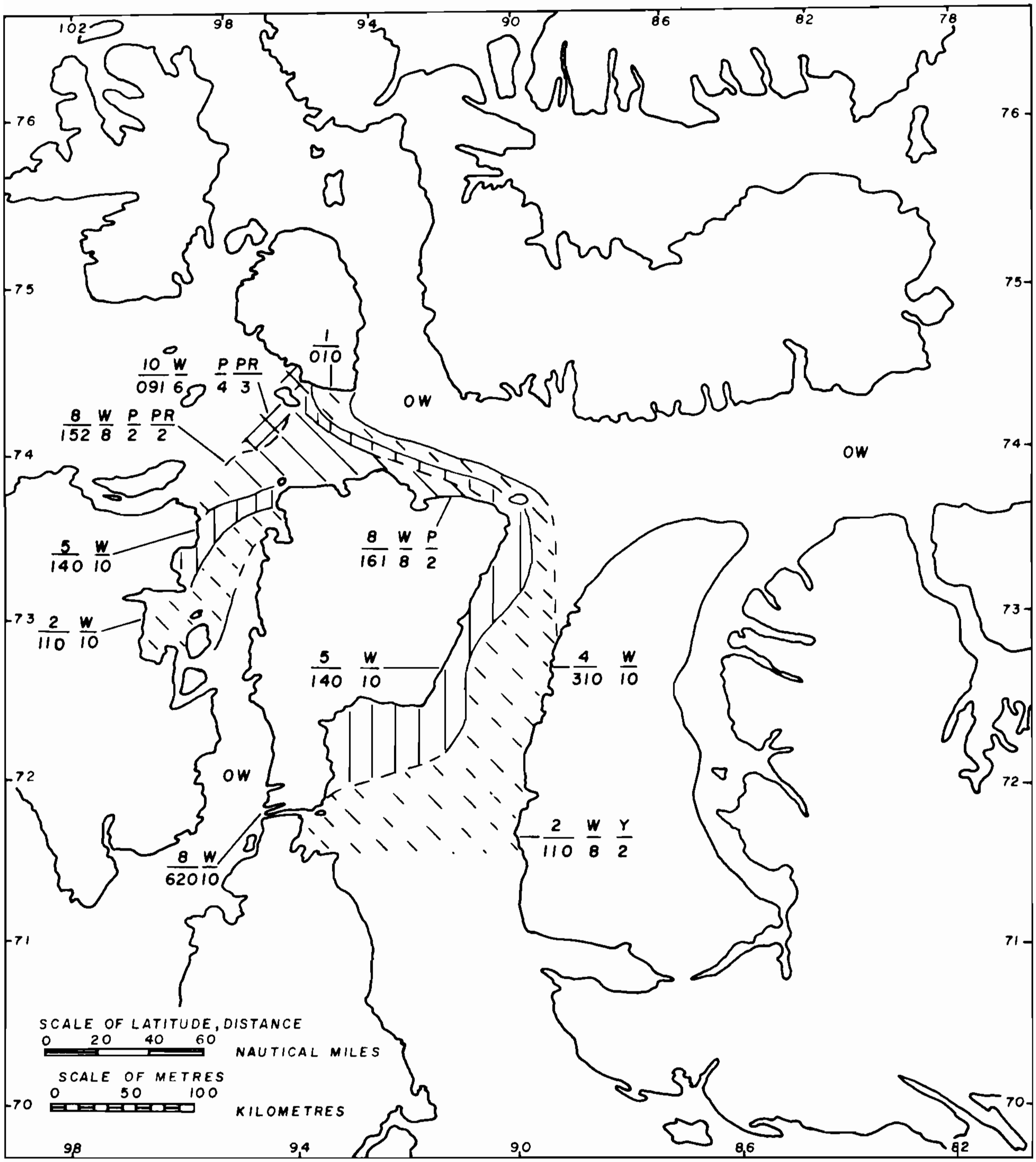


Fig. 9 Ice distribution, Lancaster Sound, August, 1957.

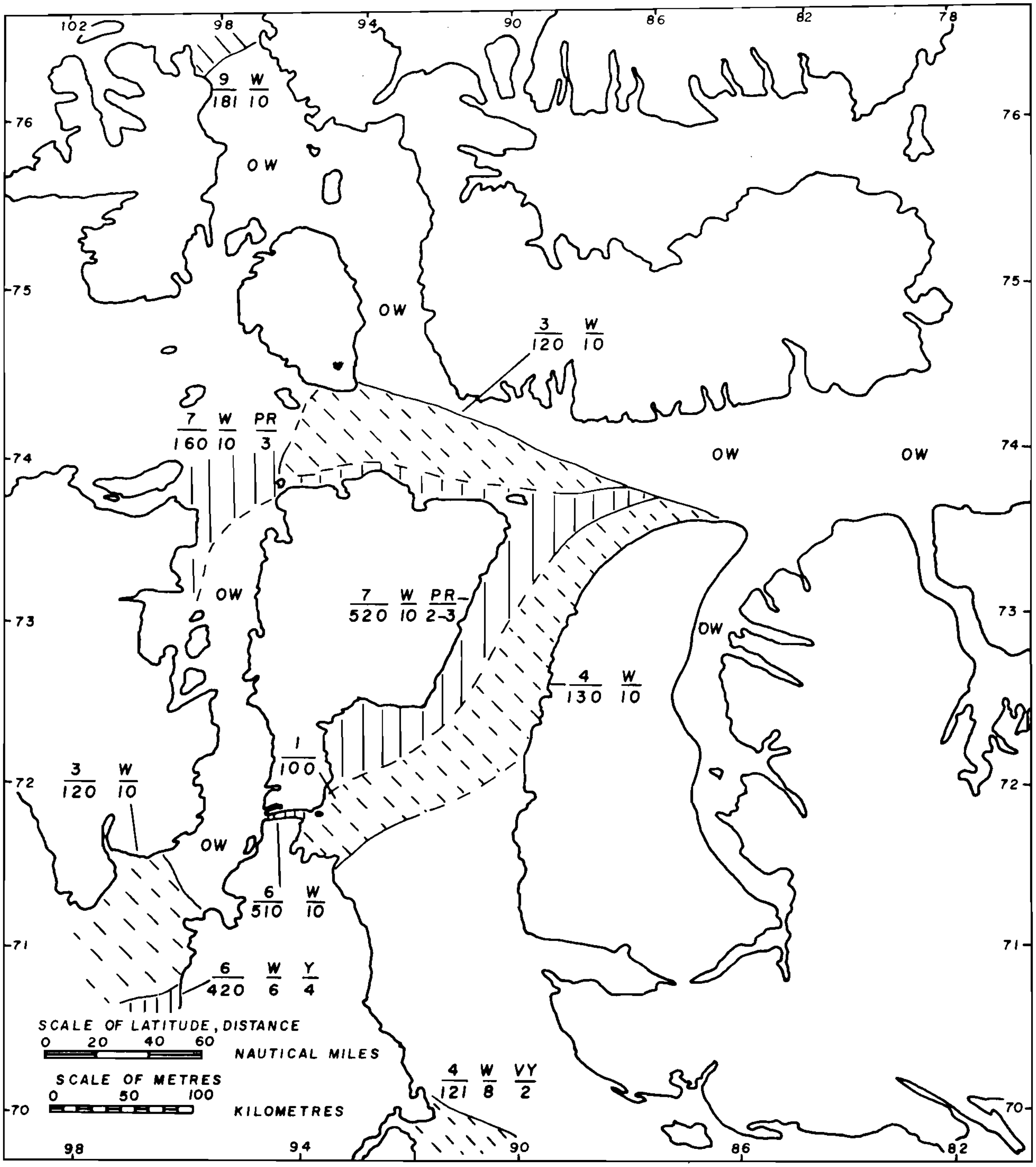


Fig. 10 Ice distribution, Lancaster Sound, September, 1957.

eastern shore. Greenaway and Colthorpe (1948) have reported that, contrary to the information regarding ice conditions mentioned in the British Admiralty Pilot, Vol. III, the ice in Prince Regent Inlet tends to pack more along the east coast than the west. A similar condition was encountered by "Labrador" in 1956.

Light concentrations of winter ice fragments were observed to extend in both directions along the south shore of Barrow Strait and Lancaster Sound but on no occasion was dirty ice, similar to that encountered in Foxe Basin, found west of Fury and Hecla Strait (Campbell and Collin, 1958).

The outstanding annual variation of sea ice conditions in the eastern Arctic is apparent from a comparison of the 1956 and 1957 ice distribution charts. Ice observations in August 1957 were confined to Lancaster Sound and the waters surrounding Somerset Island; in September the survey was extended into Franklin Strait, the Gulf of Boothia, and through Wellington Channel to Penny Strait.

In August 1957 open water extended through the length of Lancaster Sound and Barrow Strait as far west as Resolute Bay. Ice-free conditions were also observed in the southern end of Wellington Channel, along the northeast entrance to Prince Regent Inlet, and in Peel Sound between Prescott Island and Franklin Strait. The ice along the northern and eastern coasts of Somerset Island appears to have originated, for the most part, from a massive congestion of heavy winter and polar ice which had formed in the western end of Barrow Strait in the vicinity of Griffith and Lowther Islands. As this ice disintegrated during the summer it passed eastward along the south shore of Barrow Strait and entered Prince Regent Inlet along the western shore. In August 1957, the eastern boundary of the source area of 8-10 tenths heavy winter ice was found to extend roughly from Griffith Island across Barrow Strait and, for a short distance, along the north coast of Somerset Island.

Areas of lighter concentration were encountered along the fringe of this heavy ice mass in the northern end of Peel Sound and through the length of Prince Regent Inlet. In Prince Regent Inlet a narrow band of winter ice of 6-8 tenths concentration was restricted to the western shore as far south as Creswell Bay. The remainder of the Inlet had a light cover of 1-4 tenths winter ice.

The September 1957 chart shows a continuation of this ice-drift pattern. The area of maximum concentration in Barrow Strait presumably retreated to the westward but the increased rate of disintegration along the ice boundary resulted in the extension of the area of medium ice concentration across the northern end of Prince Regent Inlet. In Barrow Strait the area of light ice concentration enlarged to fill the strait, and in Prince Regent Inlet the coverage of ice of light concentration expanded in the northern end and decreased in the southern end of the passage. Except for an area of 4 tenths concentration in the southern end, the Gulf of Boothia was ice-free during September 1957.

Since Peel Sound was found to be open throughout both months of observation it is suggested that ice conditions in Franklin Strait are controlled by the ice situation in M'Clintock Channel and the adjoining straits to the west. In September 1957 the ice in Franklin

Strait was observed to vary from 3-8 tenths and to increase in concentration toward the south. Although in some areas this ice was closely packed it was in the last stages of disintegration and so presented the ship with little difficulty.

The most recent ice charts of the whole northern hemisphere show that Wellington Channel is relatively open in September and that the southern boundary of the semi-permanent sea ice in this area passes through Queens Channel in the region of 76° north latitude (U.S. Hydro. Office, 1958). In 1957 Wellington Channel and Queens Channel were found to be completely free of ice in mid-September. Infrequent small patches of ice were seen in Penny Strait but the southern edge of the heavy pack did not extend south of 76°40'. North of this position the ice, which was of 10 tenths concentration, appeared severely weathered and hummocked, indicating an age of probably two years or more.

A more general picture of ice conditions can be obtained from the prognostic ice forecasts of the United States Navy Hydrographic Office (U.S. Hydro. Office, 1958). These reports are based on past knowledge of the ice conditions and recent ice observations by ships and aircraft as well as current oceanographic data. Close checks are kept on the reliability of the reports so that by these precautions the monthly ice forecasts continue to be remarkably accurate.

According to the general forecast, by mid-August the ice in the Gulf of Boothia and Prince Regent Inlet is broken but of 8-10 tenths concentration. In Lancaster Sound and Barrow Strait the ice usually moves out by July and decreases in concentration to the middle of

August at which time, however, ice concentration in Lancaster Sound may increase with the influx from Barrow Strait. Ice from Wellington Channel may also contribute to the congestion in Lancaster Sound in August; nevertheless, Parry Channel is generally open for ice-strengthened ships as far west as Resolute from early August until late September. Bilello (1960) states that, for the nine years on record, freeze-up on Resolute Bay occurred between 12 and 26 September.

Ice surveys in the eastern Arctic conducted by the Department of Mines and Technical Surveys in 1958 and 1960 show that the cycle of ice coverage in Lancaster Sound and the adjoining passages is consistent in a general way and that the conditions described for 1956 and 1957 are typical of the sea ice situation in this region (Black, 1958, 1960).

The most recent ice observations in the Lancaster Sound area recorded by the Meteorological Service of the Department of Transport in 1961 reveal a similar pattern of ice decay throughout the summer. The first significant areas of open water were observed in Queens Channel and the eastern end of Lancaster Sound on May 21 and by mid-July a large area in Barrow Strait was clear of sea ice. Open water extended through Lancaster Sound as far west as Resolute Bay including the south end of Wellington Channel by late July and expanded rapidly to a maximum between August 4 and August 30. By late August new ice was beginning to form in Queens Channel but Wellington Channel, Barrow Strait and Prince Regent Inlet were completely ice-free. On September 23, 1961 open water was continuous as far west as Byam Martin Island in Viscount Melville Sound but in Wellington Channel and Prince Regent Inlet young ice covered extensive areas of the sea surface.

Centres of Weak Ice Formation

The evolution of ice conditions in the western end of Barrow Strait as depicted in the 1957 charts contributes further evidence to the discussion of comparative ice conditions in the American Arctic put forward by Schule and Wittmann (1958). It has been shown by these observers that within the eastern Arctic there are several areas of unstable ice conditions in which heavy ice is less likely to form owing to unique conditions of current or wind. These areas act as centres of sea ice removal and the boundaries of the spring break-up expand outward from these cores of weak ice formation.

Certainly the most familiar occurrence of ice weakness in the eastern Arctic is the historic "north open water" of Baffin Bay. Mention has been made of this remarkable condition by the earliest explorers and the succession of whalers and traders who have since travelled through this area (Kiilerich, 1933, translated in Dunbar, 1951, p. 59). The origin of this region of unstable ice has not been finally settled nor has its precise location been determined. The position of the "north open water" was originally thought to be in Smith Sound, west of the Thule-Etah coast of Greenland; in 1949 Hare suggested that from meteorological evidence the position should be considerably south of Smith Sound. Schule and Wittmann (1958) in their recent comparative study of ice conditions in the North American Arctic place the centre of the "north open water" directly in Smith Sound but show that by mid-June the area has expanded southward into the eastern end of Lancaster Sound.

Two other areas of weak or very unstable ice occur in Barrow Strait; one off the northeast point of Somerset Island and the other in the western end of the strait south of Griffith Island. Summer break-up in the Barrow Strait area expands outward from these two centres and intrudes northward and southward into Wellington Channel and Prince Regent Inlet. The 1957 ice distribution chart shows the maximum extent of open water during this particular year.

In March 1960 large cracks were observed in the western end of Barrow Strait and in early March 1961 a wide east - west lead was open in the strait approximately 18 miles south of Resolute. This lead was of such an extent that it was not possible to see how far it continued through the strait. During the last three years (1959-61) it has been observed that early break-up may also take place in the area north of the Grinnell Peninsula along the south coast of Belcher Channel. By late August the area of open water in this region is considerable and at its maximum extends from Bathurst Island to Cornwall Island. However, in 1957 and 1961 ice breakers were prevented from entering this are of weaker ice concentration by a congestion of very heavy winter ice which blocked the passage through the northern end of Penny Strait.

A summary of sea ice distribution data for the Lancaster Sound area indicates that optimum navigation conditions exist in Lancaster Sound and Barrow Strait as far west as Resolute Bay from August 15 to September 15 and in the channels leading into the Lancaster Sound system from August 20 to September 15.

CHAPTER V

AVERAGE CONDITIONS OF TEMPERATURE AND SALINITY, 1956-1957

Regional averages of temperature and salinity have been computed for all standard depths for 1956 and 1957, Tables I to VII. To facilitate these calculations the survey region was divided into seven areas, eastern Lancaster Sound, Barrow Strait, Prince Regent Inlet, Wellington Channel, Peel Sound, Franklin Strait, and Penny Strait. Average temperature and salinity profiles were determined for both sides of the four main passages. The standard deviation in each table is small, usually in the order of 0.5, thus accurate predictions of the primary physical conditions can be determined from these data.

Averages in Lancaster Sound show little variation of temperature between the north and south side of the strait in 1956 (Table I). There is also little difference in the salinity gradient; however, salinities below 100 metres are higher on the southern side by an increment of approximately 0.08‰ while at the bottom this property is constant at 34.41 - 34.42‰. The 1957 temperatures are considerably higher than the 1956 observations within the upper layers but, below 30 metres, the 1957 temperature averages in the south section of the strait are similar to, if not lower than the 1956 averages in the same location. Salinity values in the eastern end of Lancaster Sound for 1956 and 1957 show that in 1956 lower readings were found in the northern side of the passage, whereas in 1957 the lower salinity averages occurred at the southern stations.

The warm surface water that appears in eastern Lancaster Sound has been mentioned in Chapter IV and its origin has been attributed to the presence of the so-called "north water" described by Kiilerich (1933) and in English translation by Dunbar (1951). The fluctuating type of exchange through the eastern end of Lancaster Sound leads to a poorly defined stratification within the profile; nevertheless, the slightly lower salinities would be expected in the south side of the channel owing to the greater proportion of western water, i.e. Arctic Basin water, which passes eastward through this part of the cross-section.

The 1956 and 1957 averages in Barrow Strait show distinct transverse variations between the north and south sides of the passage (Table II). In 1956 lower temperatures and higher salinities were observed at all except the bottom depths in the north half of the strait. In 1957 the temperature gradient was directly opposite with the lower values occurring along the south side but, below the depth of 20 metres, the higher salinities remained confined to the northern half of the passage. Disregarding the surface observations the greatest cross-channel variation of temperature and salinity appears in the 1957 data at a depth of 10 metres at which level the range in properties between the north and south side of the strait is 1.47°C and 0.7‰.

Reversals of current along the northern side of Barrow Strait have been reported by observers at Resolute Bay and, as mentioned earlier, Winchester (1954) has carried out precise observations of this change. The surface current chart developed from the 1957 data (Fig. 28) shows westerly currents along both the north and south boundaries of the passage and indicates that variations in the cross-channel distribution of temperature and salinity are dependent on fluctuations of these westerly coastal currents.

The Prince Regent Inlet data show a similarity in the transverse distribution of these characteristics (Table III). The 1956 average temperatures indicate that, from the surface to 30 metres, lower values of the order of -1.4°C, can be expected in the western side of the channel, whereas below 30 metres the gradient reverses, the slightly higher temperatures being on the western side. Salinity values range from 30.06‰ to 33.92‰ through the entire section and there is evidence that salinities on the western side of the passage are generally higher by about 0.2‰. In 1956 the east-west salinity gradient was continuous from the surface to bottom.

The transverse surface temperature variation in Prince Regent Inlet is even more pronounced in the 1957 observations. During August 1957 east-west surface temperature differed by more than 1.7°C within the top 10-15 metres. A large proportion of this variation was the result of heavier ice concentrations in the western side of the channel as is indicated by the lower salinities, through the entire western profile, to a depth of 200 metres.

The 1957 temperature and salinity averages for Wellington Channel appear in Table IV. It is apparent from these data that lower temperatures and higher salinities may be expected within the upper 0-20 metres along the western side of the channel and that below 20 metres temperatures are slightly lower on the eastern side and salinities are almost uniform.

In August 1954 highest surface temperature, 1.27°C, in conjunction with lower salinity observations was reported along the western side of Wellington Channel (Bailey, 1957). This variation of physical properties again demonstrates the influence of ice and melt-water on the temperature and salinity structure in shallow, confined passages.

Temperature and salinity tables for Peel Sound and Franklin Strait have been computed from observations taken in this area in late August and September 1957 (Tables V and VI). The data show a decrease in temperature from surface values of -0.2°C to a minimum of -1.4°C at 75 metres. Between this level and the bottom, where temperatures are of the order of -1.3°C, there is little variation. Surface salinity values are slightly higher in Franklin Strait, increasing from 24.00‰ near the surface to 32.60‰ at 75 metres, while in the deeper water of Peel Sound salinities increase to a bottom maximum of 33.20‰.

The table of average water temperature and salinity for Penny Strait is representative of conditions at 76°40' north latitude in this passage (Table VII). At the time the observations were taken there was open water at this position, but within a few miles to the north a continuous cover of 10/10 winter ice extended across the entire width of the strait.

Average water temperatures in northern Penny Strait show a minimum of -1.48°C at 10 metres and a gradual warming to -0.79°C at the bottom; the salinity values increase with depth from 31.63 ‰ at the surface to 33.41 ‰ at 150 metres. The relatively high surface salinity in comparison with that recorded in Barrow Strait and Prince Regent Inlet and the strong salinity gradient within the surface layers are parameters typical of coastal Arctic Ocean winter conditions and indicate that little melt-water has been formed in this region.

Salinity of 33.40 ‰ or greater is typical of depths of 150 metres in Penny Strait but is not recorded in Wellington Channel where average bottom salinity values of 32.50 ‰ – 33.10 ‰ are reported. Thus, from consideration of temperature and salinity only, it appears that the limiting depth at the southern outlets of Queens Channel, that restricts the southward passage of Polar Basin water into the Lancaster Sound system, is about 100 metres.

Table I

Average Temperature and Salinity Conditions

Eastern Lancaster Sound

	Sept. 1956				Sept. 1957			
	North		South		North		South	
Depth m	Temp C°	Sal ‰	Temp C°	Sal ‰	Temp C°	Sal ‰	Temp C°	Sal ‰
0	-1.47	32.84	-1.33	32.37	0.85	31.73	0.50	31.29
10	-0.98	32.20	-0.78	32.47	0.81	31.78	0.33	31.05
20	-0.26	32.71	-0.73	32.55	0.94	31.99	0.17	31.31
30	-0.87	32.73	-0.56	32.86	1.19	32.42	-0.77	32.08
50	-0.58	33.01	-0.45	32.95	-0.18	32.98	-0.85	32.34
75	-1.21	33.28	-0.75	33.15	-1.06	33.23	-0.87	32.85
100	-1.29	33.45	-1.36	33.52	-1.06	33.45	-1.26	33.11
150	-1.33	33.68	-1.38	33.79	-1.12	33.77	-1.39	33.37
200	-0.98	33.87	-1.17	33.93	-0.82	33.93	-1.03	33.61
250	-0.73	33.99	-0.52	34.06	-0.21	34.12	-0.73	33.81
300	-0.43	34.09	-0.06	34.17	0.13	34.22	-0.51	33.99
400	0.45	34.31	0.36	34.33	0.27	34.36	0.14	34.23
500	0.41	34.41	0.56	34.42	0.37	34.41	0.56	34.38

Table II

Average Temperature and Salinity Conditions

Barrow Strait

	Sept. 1956				Aug. 1957			
	North		South		North		South	
Depth m	Temp C°	Sal ‰	Temp C°	Sal ‰	Temp C°	Sal ‰	Temp C°	Sal ‰
0	-1.79	31.31	-1.63	31.04	-0.74	29.28	-1.41	28.25
10	-1.73	31.45	-1.68	31.09	0.23	29.38	-1.24	30.18
20	-1.71	31.46	-1.69	31.19	-0.15	31.24	-1.21	31.42
30	-1.65	31.54	-1.62	31.44	-0.65	31.97	-1.43	31.75
50	-1.40	32.16	-1.53	32.17	-1.03	32.47	-1.51	32.11
75	-0.38	32.69	-1.52	32.43	-1.14	32.64	-1.42	32.47
100			-1.45	32.58			-1.45	32.67
150			-1.37	33.01			-1.38	32.82

Table III

Average Temperature and Salinity Conditions

Prince Regent Inlet

	Sept. 1956				Aug. 1957			
	West		East		West		East	
Depth m	Temp C°	Sal ‰	Temp C°	Sal ‰	Temp C°	Sal ‰	Temp C°	Sal ‰
0	-1.52	30.06	-1.40	30.07	-0.44	28.73	1.36	29.94
10	-1.46	30.59	-1.33	30.22	-0.68	28.72	1.37	29.88
20	-1.30	31.77	-1.23	31.30	-0.69	28.86	-1.19	31.63
30	-1.41	32.09	-1.33	31.91	-1.09	29.92	-1.30	32.02
50	-1.44	32.40	-1.60	32.21	-1.38	31.95	-1.32	32.33
75	-1.46	32.61	-1.53	32.46	-1.54	32.41	-1.48	32.52
100	-1.47	32.77	-1.53	32.68	-1.51	32.53	-1.51	32.63
150	-1.38	33.23	-1.46	33.03	-1.46	32.81	-1.53	32.88
200	-1.21	33.65	-1.27	33.47	-1.39	33.16	-1.42	33.21
250	-0.83	33.92	-0.93	33.68	-0.31	33.96	-1.31	33.35

Table IV

Average Temperature and Salinity Conditions

Wellington Channel, Sept. 1957

	West		East	
Depth m	Temp C°	Sal ‰	Temp C°	Sal ‰
0	-1.44	32.01	-0.24	31.79
10	-0.73	32.21	-0.33	31.86
20	-0.67	32.35	-0.42	31.93
30	-0.64	32.55	-0.71	32.10
50	-0.63	32.62	-1.09	32.55
75	-0.77	32.71	-1.33	32.79
100	-1.05	32.81	-1.38	32.88
150	-1.51	32.99		
200	-1.61	33.07		

Table V

Average Temperature and Salinity Conditions

Peel Sound, Aug. 1957

Depth m	Temp C°	Sal ‰
0	-0.24	27.91
10	-0.42	29.36
20	-0.65	30.51
30	-1.01	30.98
50	-1.35	31.70
75	-1.43	32.24
100	-1.41	32.52
150	-1.34	32.86
200	-1.33	33.01
300 *	-1.29	33.17

* Observations from one station only.

Table VI

Average Temperature and Salinity Conditions

Franklin Strait, Sept. 1957

Depth m	Temp C°	Sal ‰
0	-0.11	23.49
10	-0.75	29.43
20	-1.07	30.72
30	-1.21	31.23
50	-1.35	32.02
75	-1.43	32.61

Table VII

Average Temperature and Salinity Conditions

Penny Strait, Sept. 1957

Depth m	Temp C°	Sal ‰
0	-1.44	31.63
10	-1.48	31.69
20	-1.21	32.20
30	-1.16	32.43
50	-1.03	32.76
75	-0.96	32.95
100	-0.90	33.11
150	-0.79	33.41

CHAPTER VI

HORIZONTAL DISTRIBUTION OF TEMPERATURE AND SALINITY

The first synoptic measurements of temperature and salinity taken in Lancaster Sound were recorded by the Danish Godthaab Expedition under the supervision of Eigil Riis-Cartensen in 1928 (Riis-Cartensen, 1931). At this time seven oceanographic stations were occupied across the eastern end of Lancaster Sound and observations of temperature and salinity were obtained at all standard depths. The first oceanographic measurements to be completed through Lancaster Sound and Barrow Strait were carried out during the first "Labrador" cruise in 1954 (Bailey, 1955, 1957). In 1956 the Arctic oceanographic survey was continued from H.M.C.S. "Labrador" in Prince Regent Inlet and the Gulf of Boothia and in 1957 the programme was extended to include Peel Sound, Franklin Strait, and Wellington Channel (Collin, 1958). Dunbar (1951 a) has compiled a history of the scientific investigation and a discussion of the oceanographic conditions of the eastern Arctic waters south of Lancaster Sound. The following chapters contain an appraisal of the 1957 data and a comparison of the most recent observations, with the results of previous expeditions.

The 1957 measurements are unique in that the time interval between observations is reduced to a minimum, thus increasing the accuracy of the synoptic survey. This situation was made possible through the combined efforts and planning of the ship's officers and the fortunate vagaries of ice and weather. Table VIII shows the period of observations from which the summary has been compiled for each of the six regions.

Table VIII

Period of 1957 Regional Surveys

Prince Regent Inlet	Aug. 20-27
Barrow Strait	Aug. 28-30
Peel Sound	Aug. 30-Sept. 4
Gulf of Boothia	Sept. 8-9
Wellington Channel	Sept. 15-17
Lancaster Sound	Sept. 18-24

Surface distribution of temperature and salinity in Arctic waters exhibit many steep anomalies formed by local conditions of sea ice concentration, melt-water drainage off the ice and land run-off, the length of time the water has been exposed to solar radiation, that is, free of ice cover, and dominant wind. On numerous occasions surface temperature and salinity have been found to differ by as much as 3.0°C and 3.0‰ respectively, over a distance of only a few miles and several instances of this variation are apparent in the charts of horizontal distributions which are discussed in the following paragraphs. For these reasons the surface conditions of temperature and salinity in Arctic waters are not reliable indicators of the physical structure through the underlying water mass. In an effort to present a more accurate picture of the actual horizontal distribution, charts have been prepared for the surface and 20 metre levels and average conditions have been calculated for the 100 metre surface as being representative of the mid-depth through the channels under discussion.

The charts of surface temperature and salinity are presented in Figs. 11, 12 and 13.

Surface Temperature

The initial investigation of these figures makes it immediately apparent that the distribution of properties forms a general linear pattern parallel to the axes of the passages. The range of the 1957 summer surface temperature was 3.0°C; the highest, 1.3°C, occurred in the eastern end of Lancaster Sound and the lowest, -1.6°C, was recorded in the northern end of Penny Strait. Average conditions for each of the six regions at surface and depths of 20 and 100 metres are shown in Table IX.

The 1957 surface temperature chart (Fig. 11) shows several features which are common to the 1956 data; however, there are a number of differences which are outstanding. In the eastern end of Lancaster Sound the characteristic warm intrusion, as outlined by the 0.0°C isotherm, extends westward into the sound for a distance of almost 200 miles. It is obvious that this area, within which temperatures are greater than 0.0°C, is confined to the northern shore as it progresses westward and is not recorded to the west of Cornwallis Island.

This region appears to be one of extreme surface temperature variations as disclosed by the data of Riis-Carstensen (1931), Bailey (1957), and Collin (1958). In July 1928 Riis-Carstensen recorded a surface maximum temperature of 3.39°C at his station, number 123, on the northern side of the channel, and the average of the seven observations taken in the eastern end of Lancaster Sound, with no ice in the vicinity, was 1.3°C. In 1954 Bailey encountered surface temperatures of 5.8°C in the same area and the average of the eight observations taken in early August 1954 was 1.6°C (Bailey, 1955). The 1956 observations were taken in late September and show that, at that time, surface water temperatures

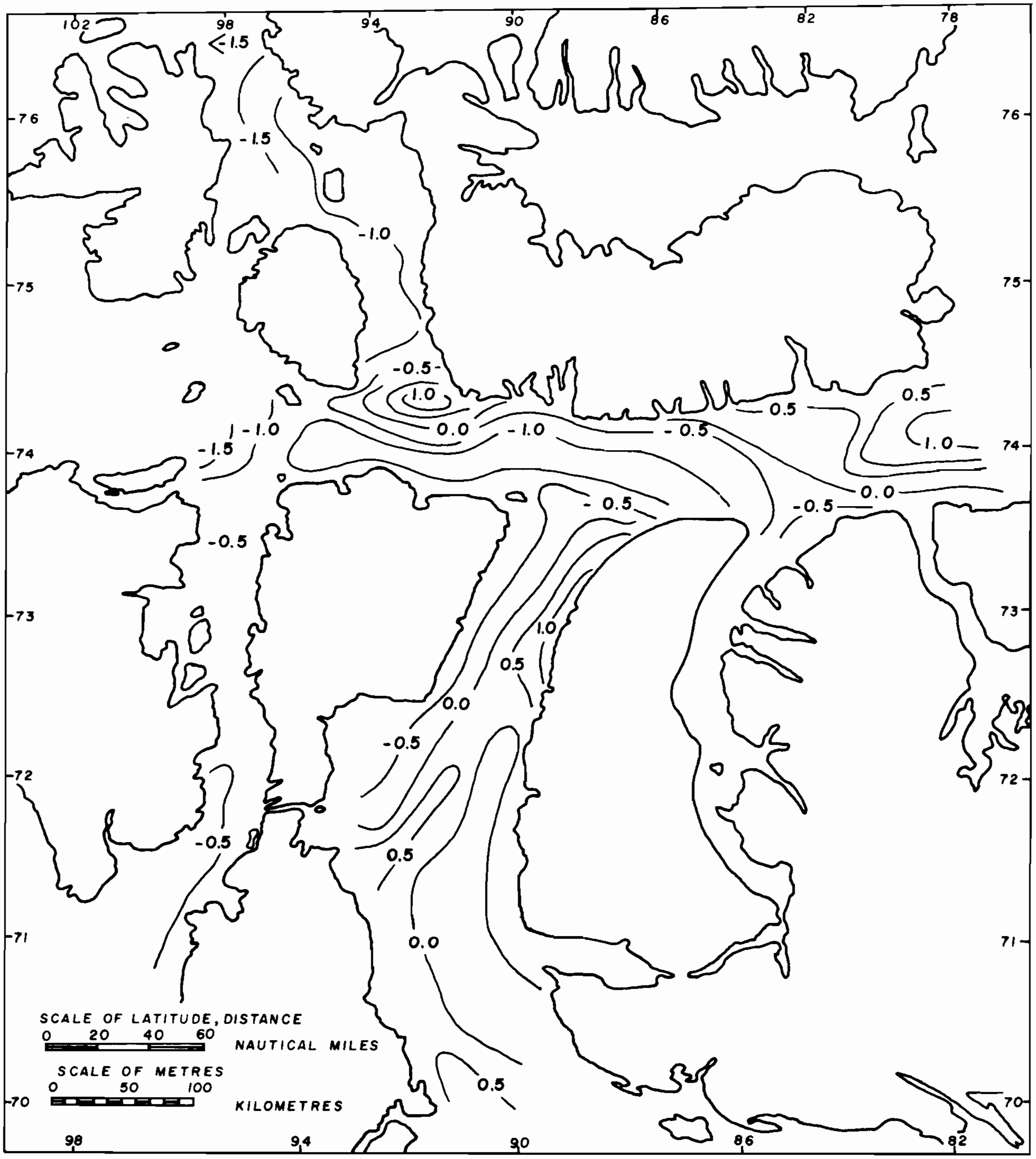


Fig. 11 Surface temperature distributions C°, August, 1957.

Table IX

Comparative

Average Temperature and Salinity,

Surface, 20 and 100 metres,

Aug., Sept. 1957

Temperature °C	Lancaster Sound	Barrow Strait	Wellington Channel	Peel Sound	Prince Regent Inlet	Gulf of Boothia
Surface	-0.22	-0.36	-1.12	-0.38	0.12	0.17
20 m	-0.05	-0.55	-0.88	-0.89	-0.85	-0.65
100 m	-1.34	-1.34	-1.10	-1.40	-1.60	-1.63
Salinity ‰						
Surface	30.64	29.50	31.84	25.85	29.29	29.28
20 m	31.51	31.23	32.16	30.69	39.94	30.60
100 m	32.93	32.77	32.93	32.65	32.54	32.51

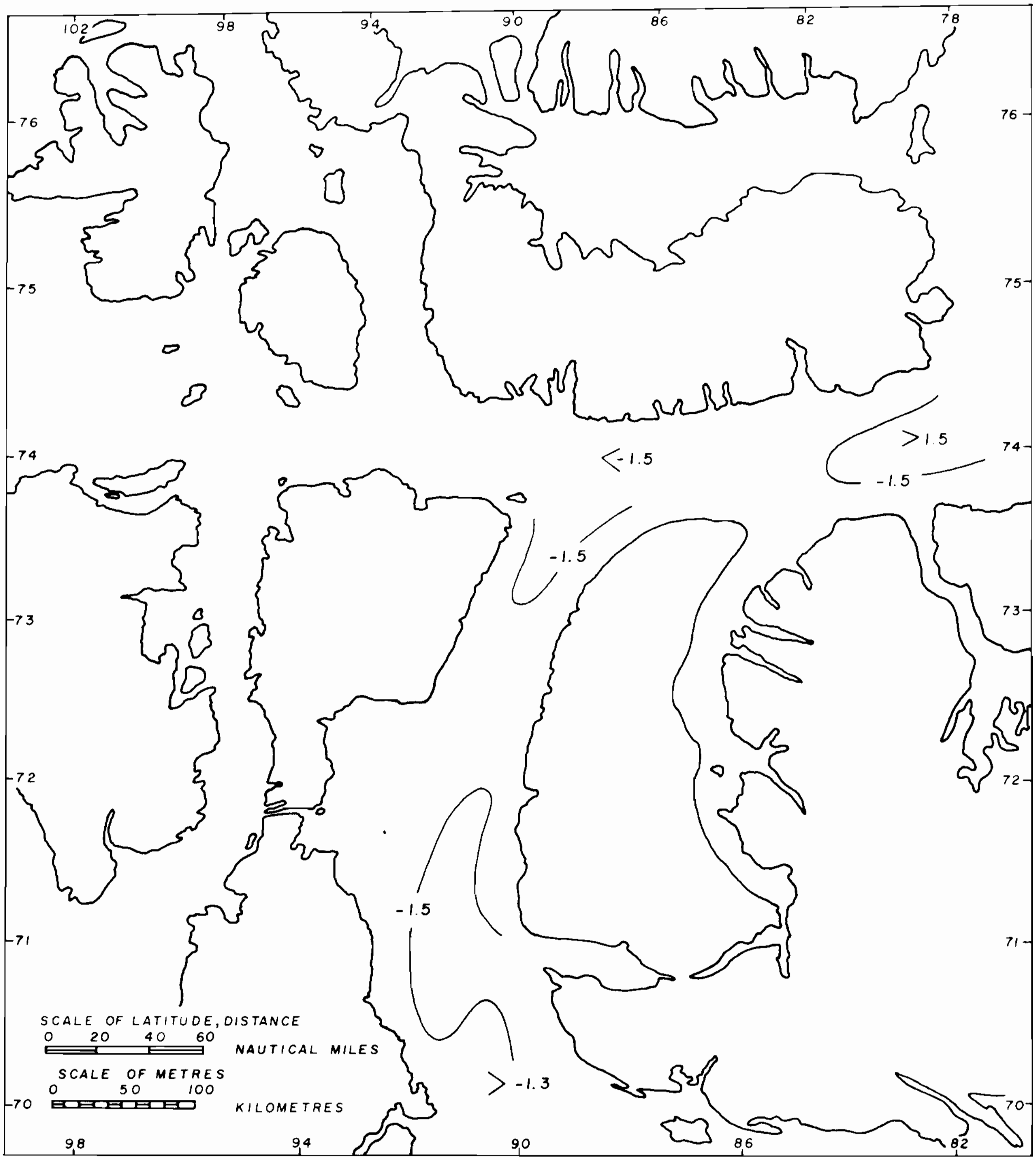


Fig. 12 Surface temperature distributions C°, September, 1956.

in the eastern end of the sound were markedly lower than those reported previously (Fig. 12). The average recorded in 1956 was -1.4°C and a minimum of -1.7°C was noted in the northern section of the channel. The most recent data, those of 1957, show that in mid-September surface temperatures in this region averaged 0.7°C with a maximum of 1.5°C. These values are consistently higher than those of 1956 but still considerably below the measurements taken in 1928 and 1954. A summary of surface temperature observations in the eastern end of Lancaster Sound appears in Table X.

Table X

Summary of Surface Temperature Observations

Eastern Lancaster Sound

Expedition	Date	Ave. Surface Temp. °C
Godthaab	VIII 1928	1.2
Labrador	VIII 1954	1.6
Labrador	IX 1956	-1.4
Labrador	IX 1957	0.7

On the evidence of surface temperatures alone it appears that unusual conditions existed in the eastern section of Lancaster Sound during the late summer of 1956, an observation supported by an investigation of the salinity data which follows.

To the westward, through Lancaster Sound and Barrow Strait, surface temperatures decrease regularly from 0.0°C to -1.5°C in the western end of Barrow Strait and in Wellington Channel the gradient is to the north where a minimum of -1.6°C is recorded at station 123, 76°40' north, in Penny Strait at the edge of the permanent pack ice.

Surface temperatures in Peel Sound and Franklin Strait appeared quite uniform at -0.5°C with only a weak indication of local warming occurring in the central section of Peel Sound. Slightly warmer conditions were also encountered at the western end of Bellot Strait where surface temperatures of -0.2°C were recorded.

Surface observations taken in Prince Regent Inlet and the Gulf of Boothia between August 20 and September 9, 1957, are consistently 1.5°C higher than those recorded in late September 1956. Average surface temperature in Prince Regent Inlet and the Gulf of Boothia in 1957 was 0.1°C while the mean for the same area in 1956 was -1.4°C; the seasonal time difference between the two surveys was no more than 10 days. On no occasion in 1957 were surface temperatures below -0.7°C reported in Prince Regent Inlet and the Gulf of Boothia. In 1956 temperatures in the northern end of Prince Regent Inlet were of the order of -1.5°C at the surface and a cold core extended through a considerable section of the channel in the region of Bellot Strait. Here temperatures of -1.6°C were common over a large area (Fig. 12).

During the 1957 survey the 0°C isotherm extended through the entire length of the passage and normal surface temperatures ranged from -0.6°C to 1.0°C in the northern end of Prince Regent Inlet and 0.8°C to -0.2°C in the southern end of the Gulf of Boothia.

In contrast to the 1956 findings warmer water of 1.0°C was found along the eastern side of Prince Regent Inlet, whereas, during the initial survey, a decrease in surface temperature was located in the same area. In the Gulf of Boothia there is an indication of southward warming in the 1957 observations that is also apparent in the 1956 data but is not as clearly distinguished.

A poorly defined region of slightly warmer water which occurred at the eastern end of Bellot Strait in 1956 was relocated in 1957 but at this time the axis of the warm surface area had assumed a different direction and a somewhat extended form (Fig. 11). A similar condition, which has already been mentioned, was found at the western end of the strait. The local temperature gradients in both cases are identical at 0.3°C, a comparison which suggests that the topography of the passage is the cause of the persistent deviation in water temperatures. Tidal currents through Bellot Strait are exceptional, 4-7 knots, and in both ends of the strait there are bottom obstructions which cause a violent mixing of the water as the current fluctuates through the narrow passage. Mr. Learmonth, who lived for a number of years at Fort Ross, has told me that at no time does Bellot Strait freeze over completely. Even during the coldest periods, two large areas in the eastern end of the strait remain open and are subject to strong surface currents (Learmonth, personal communication). Consequently, it is possible that early ice free conditions in the strait permit summer surface water temperatures to increase slightly above those of the surrounding area.

The central cold water region, enclosed by the -1.5°C isotherm, which appears so distinctly in the 1956 chart (Fig. 12) does not occur in the 1957 observations. In its stead a meandering area of slightly colder water extends northward through the eastern half of the Gulf of Boothia.

The most outstanding feature of the surface temperature distribution which appears on the 1957 chart is the large cell of relatively warm surface water found in Barrow Strait at the south end of Wellington Channel. This condition, which is obviously confined to the top 20 metres (Fig. 11), is bordered by the steepest surface temperature gradients encountered in the eastern Arctic and is not unique to 1957 but was also detected by Bailey in 1954. However, in 1956, the limited observations in the area give no indication of local warming of this extent.

In mid-August 1954 the average surface temperature recorded in the vicinity of the southern end of Wellington Channel was 0.6°C and the maximum and minimum were 1.3°C and 0.3°C respectively. The 1957 measurements produced an average of 0.7°C and maximum and minimum of 1.1°C and 0.1°C respectively. The vertical profile (Fig. 18) and the surface temperature chart (Fig. 11) show that this warm layer is confined to the upper 20 metres and thus must be of local origin or, as is indicated in the 1954 data, may be the remnant of a warm surface water influx from the east (Bailey, 1955).

If this area is of local origin it signifies that this section of Barrow Strait has been essentially ice-free for a period longer than that of the surrounding area and that the horizontal transfer is not sufficiently developed to compensate for the increase in heat. As is pointed out in the discussion of the ice situation in 1956 and 1957 this condition is not unusual, and according to Schule and Wittmann (1958) is a regular feature in this area. On the other hand, the 1954 observations show that warmer water, 1.0° - 3.0°C, was found in the central section of Lancaster Sound, a condition which suggests that the slightly higher temperatures about the southern end of Wellington Channel are merely an extension of this surface water. The 1957 temperature distribution could then be explained by a wind-driven westward movement of surface water which extended as far as Barrow Strait and a subsequent sudden eastward movement of colder surface water which cut off the western section of the warm intrusion.

Surface Salinity

The 1957 distribution of surface salinity (Fig. 13) is similar to the temperature distribution and emphasizes certain of the surface features. In Lancaster Sound there is indication of the typical high salinity surface intrusion in the eastern end of the passage and a broad intrusion of lower salinity water (29.0 ‰ - 30.5 ‰) extends northward out of Prince Regent Inlet. In the Gulf of Boothia the main features of the surface salinity pattern are aligned parallel to the axis of the channel and the salinity gradient is relatively weak. The remarkable warm water region at the junction of Wellington Channel and Barrow Strait is marked by an accompanying increase in surface salinity which reaches a maximum of 32.27 ‰ in an enclosed cell in the southern section of the channel. To the north of this nucleus of high salinity surface water the observations are relatively uniform with only a slight gradual decrease to 31.5 ‰ at the surface in Penny Strait. In Barrow Strait and Peel Sound the steep gradients are indicative of ice conditions in the northern end of the passage whereas off the western end of Bellot Strait the rapid change in surface salinity is the result of the mixing action that takes place in the strait.

The average 1957 surface salinity values within the Lancaster Sound passages, that are presented in Tables I-VII, appear to be very similar to observations taken in 1954 and 1956. Throughout Lancaster

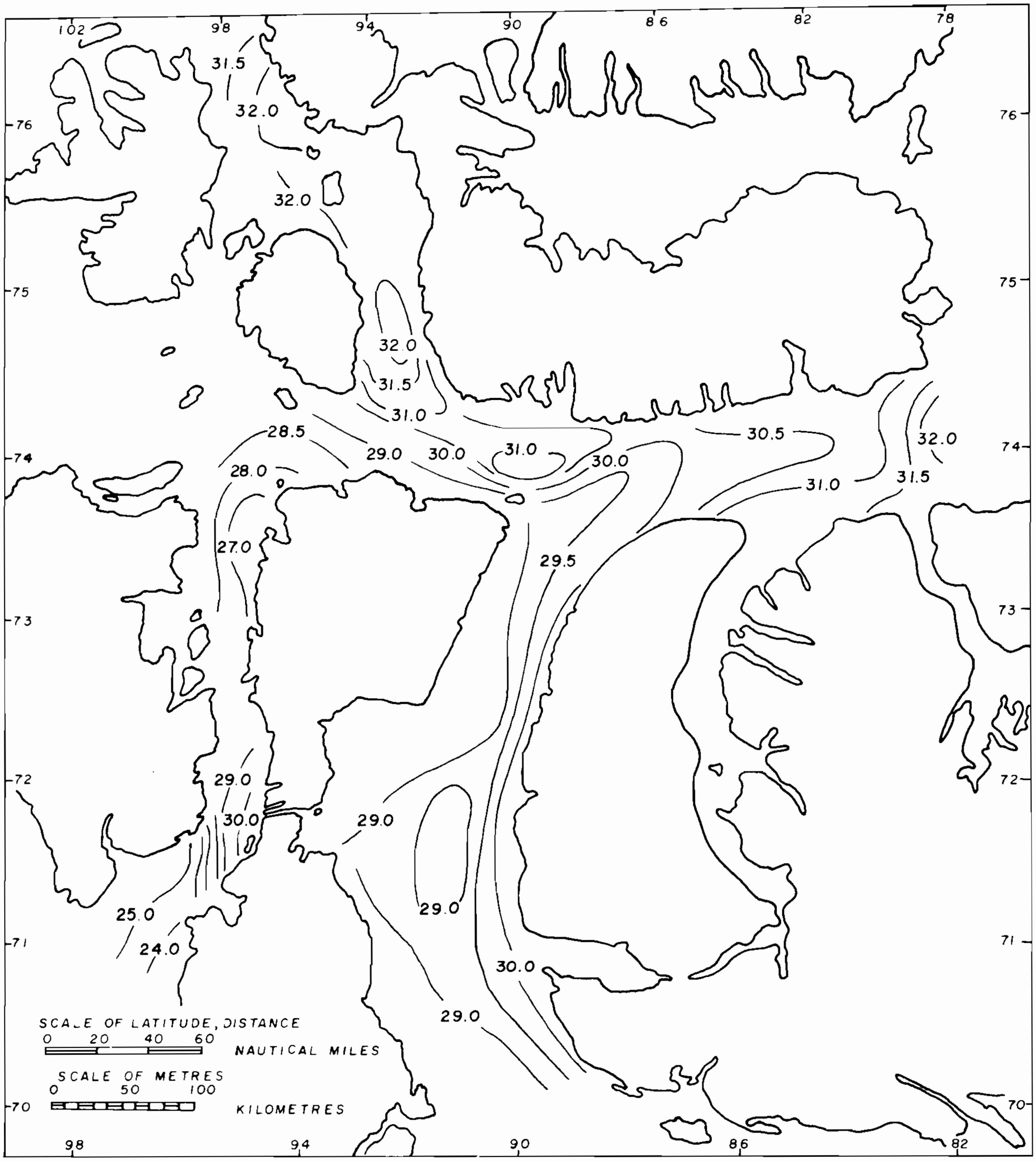


Fig. 13 Surface salinity distribution ‰, August, 1957.

Sound the range of surface salinity was from 32.12‰ in the eastern end to 28.30‰ off Resolute Bay (Fig. 13). The general trend, which is for a decrease in salinity toward the west, held true throughout Lancaster Sound and Barrow Strait except for the unusual area in the southern end of Wellington Channel which has already been mentioned. Normally the higher salinity values occur in the centre of the channel.

Averages computed for each of the four surveys which have taken salinity measurements in the eastern end of Lancaster Sound show moderate variation in this region. In 1928 the "Godthaab" Expedition recorded an average surface salinity of 30.86‰ during mid-August and in early August 1954 "Labrador" reported an average of 30.68‰ (Riis-Carstensen, 1936; Bailey, 1955). The highest values of surface salinity so far recorded in this region are those taken in late September from the "Labrador" cruise of 1956, at which time the salt content was found to be 32.60‰. The average measured in 1957 was 31.13‰ but the maximum, 32.12‰, was considerably less than the 33.01‰ maximum reported in 1956.

Throughout Lancaster Sound the major change in surface salinity occurred along the axis of the passage, while in Barrow Strait the situation was somewhat different in that the dominant gradient was across the strait with the higher values on the north side. This pattern appears to be cognate with the surface temperature distribution and presents strong evidence for the theory that the outstanding features of high surface temperature and salinity in this region were the result of a recent intrusion of warmer, more saline water from the east. In Wellington Channel the area of maximum surface salinity (32.27‰) was located slightly north of the position where the surface temperature maximum was recorded. However, the proximity of these two positions leaves no doubt that the unusual properties are representative of a single water mass.

Through Wellington Channel and Queens Channel surface salinity decreased slightly toward the north but not as decisively as might have been expected. In Queens Channel and Penny Strait the average value of the 9 observations was 31.76‰ and the maximum of 32.23‰ was reported in the northern end of the channel.

In Peel Sound and Franklin Strait the average surface salinity was 25.85‰. In the northern end of Peel Sound values as high as 29.49‰ were reported along the western side, whereas along the Somerset Island coast the average value was less than 27.00‰.

A steep salinity gradient was defined in Peel Sound at the western end of Bellot Strait in which surface values fluctuated from over 30.00‰ in the eastern side of Peel Sound to under 24.00‰ along the western side and to the south, in Franklin Strait, where average surface salinity was 24.49‰.

The distribution of surface salinity in Prince Regent Inlet and the Gulf of Boothia is similar to that of the surface temperature in that the pattern is parallel to the axis of the passage and variation is slight, the salinity range being of the order of only 2.00‰. The higher values, 30.00‰-31.10‰, are restricted to a narrow area that extends along the eastern side of the passage as far south as Fury and Hecla Strait, and the lower values appear along the Somerset Island coast and in the southwest region of the Gulf of Boothia.

There is no evidence of a salinity gradient in the eastern end of Bellot Strait similar to that which occurs in Franklin Strait. It is possible that this apparent difference is the result of tidal action through the strait and also that the sequence of the observations at the eastern end was such that the exchange characteristics were missed owing to unfortunate timing.

In the Gulf of Boothia the less saline water that extends northward along the east coast of the Boothia Peninsula presents a pattern similar to that encountered in 1956 and adds further evidence to the suggestion that in summer Committee Bay acts as a source of low-salinity water that influences temperature and salinity conditions to the northward (Collin, 1958).

Temperature Distribution - 20 metre level

The charts of the horizontal distribution of temperature and salinity at a depth of 20 metres minimize the surface effects of melt-water dilution and local warming and as a result portray a more accurate pattern of conditions within the upper layers. The temperature disposition at 20 metres (Fig. 14) forms a distribution similar to that found at the surface except that the values are generally lower and the gradients are weaker.

In Lancaster Sound and Barrow Strait temperatures at this level form a longitudinal pattern with the higher values in the eastern end of Lancaster Sound and the lower in the western end of Barrow Strait and along the northern coasts of Somerset Island and Brodeur Peninsula. In comparison with the surface observations there is more distinct evidence of a warm intrusion along the northern side of Lancaster Sound substantiating the theory put forward for the warm surface region in the southern end of Wellington Channel. An average difference of 0.8°C exists between the north and south temperatures in Lancaster Sound. This anomaly is consistent throughout the length of the passage and extends as far west as Barrow Strait, at which position it is masked by the cold water lying to the westward. In the eastern end of Lancaster Sound the north-south variation approaches 1.7°C and in Barrow Strait at the entrance of Wellington Channel there is a difference of 1.0°C at this level between the north and south sides of the strait. Previous surveys have revealed similar conditions at the 20 metre level. In 1928 the north-south difference across the eastern end of Lancaster Sound was 1.7°C and in 1954 the average variation was approximately 1.0°C. At the time of the 1956 survey, which is perhaps atypical in several respects, there was indication of an intrusion of colder water (-1.25°C) along the north side at the 20 metre depth, whereas under normal conditions the warmer water is found along the northern side of the channel.

In Wellington Channel temperatures at 20 metres are slightly higher than those at the surface and the warm core in the southern end of the passage is not as clearly defined at this level. In Queens Channel and Penny Strait the distribution of properties at the depth of 20 metres is almost identical to that at the surface.

Average temperatures at 20 metres in Peel Sound are lower than the surface temperatures but the regional distribution remains much the same. In the north, average temperature is -0.8°C and in Franklin Strait the mean is -0.9°C.

In Prince Regent Inlet and the Gulf of Boothia average temperatures

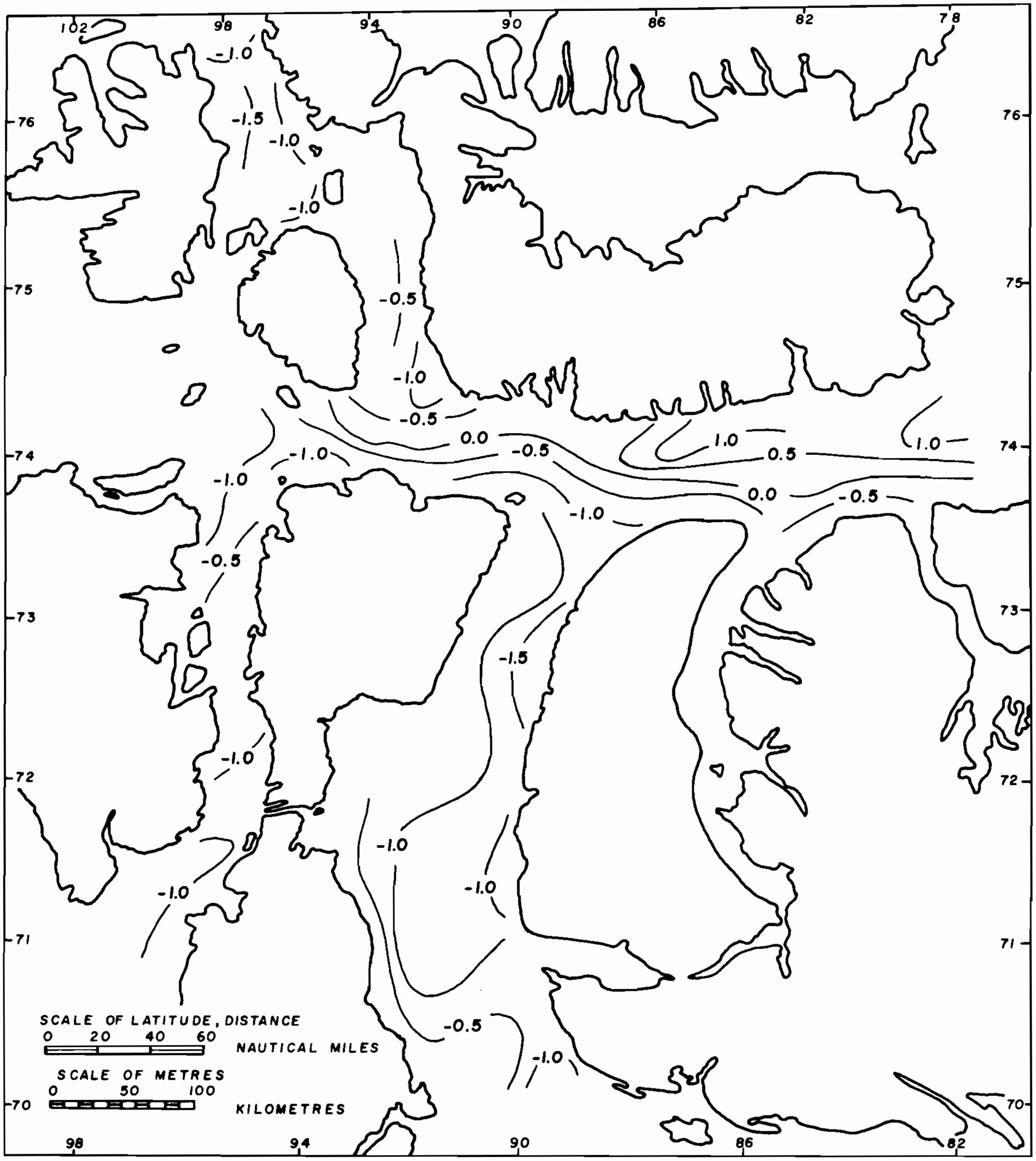


Fig. 14 Temperature distribution C°, 20 metres, 1957.

at 20 metres are 0.9°C lower than those recorded at the surface. The pattern, which is much the same as that of the surface temperature, shows that there is a reversal in temperature gradient at 20 metres depth; at this level the lower observations are found on the eastern side of the channel whereas on the surface the colder water occurs on the western side. Since the slope of the isotherms at 20 metres appears to be typical of the underlying water (Fig. 20) it can be assumed that the surface temperature pattern is a result of the local ice distribution and recent winds.

Salinity - 20 metres

The salinity distribution at 20 metres is shown in Fig. 15. The pattern appears similar to that found at the surface (Fig. 13); however, there are several variations which occur in the salinity gradient within the top 20 metres. Salinity values at this depth are in all cases higher than those recorded at the surface. Average values, which are shown in Table IX, indicate that through Lancaster Sound and Barrow Strait the salinity range is from 31.51‰ in Lancaster Sound to 31.23 ‰ in Barrow Strait. As is the case in the surface distribution an area of high salinity occurs in the southern end of Wellington Channel where the average salt content is 32.16‰; this region of relatively high values extends northward as far as Penny Strait and is confined in Barrow Strait to the area adjoining Wellington Channel. The maximum salinity at 20 metres recorded in the region is 32.66‰ in the northern end of Wellington Channel.

In Peel Sound more uniform conditions are encountered at

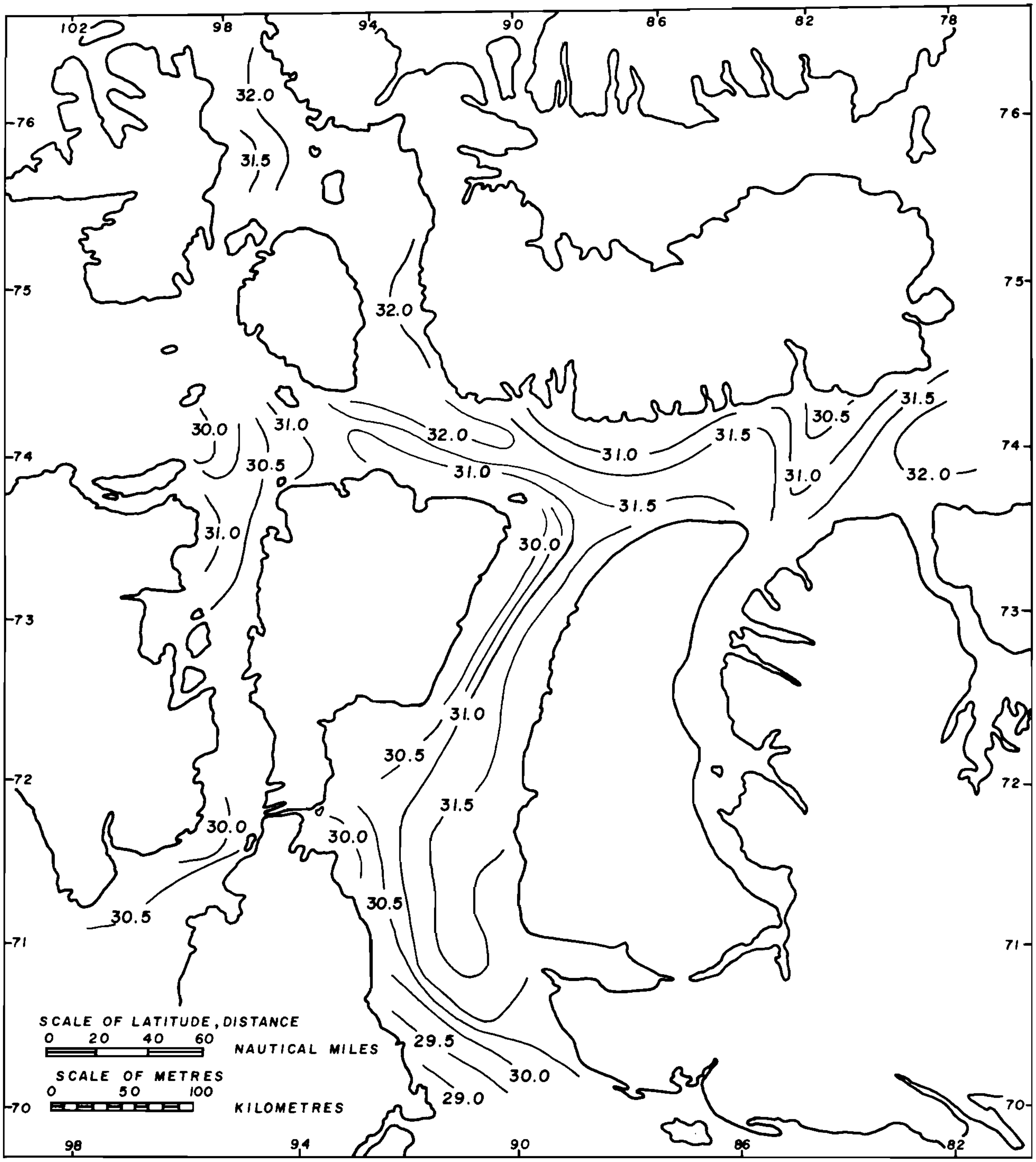


Fig. 15 Salinity distribution ‰, 20 metres, 1957.

20 metres with a variation of only 1.5 ‰, while in the vicinity of Bellot Strait the steep salinity gradient which is apparent on the surface chart has weakened considerably. In Franklin Strait salt content at the 20 metre level appears quite uniform at 30.0‰ - 30.5‰ . Salinity averages at 20 metres in Prince Regent Inlet show an increase of 1.65‰ over those at the surface and in the Gulf of Boothia the average increase is 1.32‰ . The distribution is similar to that at the surface, with the higher values occurring along the eastern side of the passage and extending into the Gulf of Boothia where the slope of the isohalines steepens slightly at the 20 metre level to a minimum of 29.00‰ north of Simpson Peninsula.

The surface chart shows a distinct example of melt-water dilution in the northern end of Peel Sound and along the northern coast of Somerset Island. In this region surface salinity decreases by 2.0‰ within a short distance, as melting ice is approached with an average gradient under these conditions of the order of 1.0‰ in five miles, decreasing in the direction of the heavy ice concentration. The distribution at 20 metres shows that at this depth the effect of surface melt-water is much reduced to the extent that, in the same area, the maximum salinity gradient at 20 metres is 1.0‰ in a distance of at least 10 miles.

Temperature and Salinity - 100 metres

The horizontal distribution of temperature and salinity at 100 metres shows a marked uniformity compared to the surface and 20 metre levels (Table IX). Throughout the survey area the average temperature and salinity at 100 metres is 1.4°C and 32.72‰. The maximum variation in temperature at this depth is less than 1.0°C and the greatest range of salinity is 1.3‰.

Comparison of Sub-surface Temperatures, 1928-1957.

With the accumulation of accurate scientific observations taken within the Arctic Basin during the last 50 years it has become apparent that there have been significant climatic variations within this region in the past and, within recent years, inconstancies of the temperature of coastal waters have been detected at several locations.

As early as 1937 Berezkin (1937) presented meteorological and oceanographic evidence of ameliorating temperatures within the Polar Basin. Dunbar (1946) has listed the periodic fluctuations of subsurface temperatures that have been recorded at Godthaab, Greenland, and from these data has shown that a cold period existed from 1908 to 1916 which was followed by a warmer period from 1928 to 1940. From 1942 to 1944 there have been indications of a weakening of the warmer Atlantic influence along the west Greenland coast. These findings have been substantiated by Lysgaard (1949) who has traced the evidence of surface warming back at least 150 years based on a study of meteorological records. In 1955 Crary, Kulp, and Marshall (1955) drew attention to the climatic significance of the dirt layers on the ice "island" T-3 and suggested, from these findings, that there have been successive periods of climatic fluctuation in the Arctic Ocean during the formation of the "island" ice. Recently, Emiliani (1958) has applied the relationship of oxygen isotope concentration to ambient temperature at the time of carbonate formation to the study of deep ocean sediment cores. This investigation has led to the correlation of radiocarbon analyses and oxygen isotope dating and has shown that there have been significant temperature variations in the oceans of the northern hemisphere.

In an effort to discover any trend of water temperatures in the Lancaster Sound area, the averages of all available measurements have been calculated and are listed in Table XI. Except for the eastern end of Lancaster Sound, for which the observations of the Godthaab Expedition of 1928 are included, the data are limited to the years 1954 to 1957.

From this summary it is apparent that the 1956 temperatures, especially in the surface and 20 metre levels, are consistently lower than those recorded in the other surveys. This difference may, in part, be the result of abnormal weather conditions during the summer of 1956. It is suggested that prolonged easterly winds in Lancaster Sound have a significant effect on the circulation and it is perhaps for this reason that the 1956 temperatures are conspicuously lower. The 1957 temperatures in eastern Lancaster Sound are slightly higher than those of the 1928 and 1954 surveys at the 20 and 100 metre levels resulting in a positive difference of 0.16°C between the two extremes.

In Barrow Strait the 1956 observations are lower at the surface and 20 metres, but at 100 metres the recorded mean temperature is considerably higher than that observed in 1954 or 1957.

Table XI

Comparative Temperatures at Surface, 20, and 100 metres

Derived from Previous Surveys.

Eastern Lancaster Sound

	1928 Aug.	1954 Aug.	1956 Sept.	1957 Sept.
Surface	1.24	1.64	-1.40	0.69
20	-0.46	-0.41	-0.66	0.56
100	-1.32	-1.45	-1.32	-1.16

Barrow Strait

	1954 Aug.	1956 Sept.	1957 Aug.
Surface	-0.10	-1.68	-1.08
20	-1.03	-1.70	-0.68
100	-1.40	-1.08	-1.42

Wellington Channel

	1954 Aug.	1957 Sept.
Surface	0.74	0.66
20	-0.32	-0.51
100	-1.29	-1.31

Prince Regent Inlet

	1956 Sept.	1957 Aug.
Surface	-1.47	-0.33
20	-1.25	-1.03
100	-1.49	-1.56

Gulf of Boothia

	1956 Sept.	1957 Sept.
Surface	-1.54	0.03
20	-1.27	-0.38
100	-1.57	-1.63

The mean temperatures in Wellington Channel, Prince Regent Inlet, and the Gulf of Boothia, do not reveal any yearly temperature variation over so short an interval; nevertheless, they do show that September temperatures are consistently lower than those for August and that in Prince Regent Inlet and the Gulf of Boothia this comparison does not extend to 100 metres. Obviously this variation between August and September water temperatures is a result of seasonal cooling that begins in late August. The contrast of the Gulf of Boothia data in Table XI is a good example of September cooling. The 1956 observations were taken on 21 and 22 of September and the 1957 measurements were recorded on 8 and 9 September. If the difference is in fact representative of the seasonal decline, a decrease of up to 0.8°C can be expected in the top 20 metres during the month of September.

The summary of oceanographic observations taken since 1954 in the eastern Arctic shows no evidence of a continuous trend in sub-surface water temperatures. There are indications that 1956 conditions were unusual in that water temperatures were consistently lower than those recorded in 1954 and 1957, and a comparison of the 1956 and 1957 observations at the surface and at 20 metres suggests that cooling starts about the end of August and continues with a rapid decrease of surface temperatures during the month of September.

CHAPTER VII

VERTICAL DISTRIBUTION OF TEMPERATURE AND SALINITY

Five cross-sections of temperature, salinity, and density have been selected from the 1957 data as representative of the vertical distribution of water characteristics in the Lancaster Sound area. Four of these sections are repetitions of sections which were occupied in 1956 and have been selected for purposes of comparison. The fifth section is situated across Wellington Channel midway between Lancaster Sound and Maury Channel. This profile illustrates the characteristics and distribution of water masses entering Lancaster Sound from the north. In addition to the cross-sections which appear in Figs. 16 to 20, longitudinal vertical profiles of Lancaster Sound and Barrow Strait are shown in Fig. 21. The 1957 profiles show many of the features identified in the earlier investigations and the longitudinal sections illustrate the distribution of properties along the long axis of the system.

The oceanographic diagrams for the eastern end of Lancaster Sound for 1956 and 1957 show a distinct similarity in the structure of the water masses and in the pattern of the isopleths (Fig. 16). Previous surveys conducted in this area by the "Godthaab" Expedition in 1928 and by the Fisheries Research Board of Canada in 1954 show that there are clearly defined characteristics within this section which may be considered representative (Riis-Carstensen, 1936; Bailey, 1957). These features, which are apparent in varying degrees in the data of each survey, include a range in temperature with depth from over 3.0°C at the surface to 0.5°C at 500 metres. Within the water column, higher temperatures (1.0°C) above the 50 metre level are typical of the northern side of the passage and a warm core with temperatures between 0.5°C and 0.7°C occurs in the 400-500 metre interval within the northern half of the channel. Salinity values at the surface show a variation similar to that of temperature with a range from 30.00‰ to 33.00‰. Usually the higher values occur in association with the warmer water along the northern side of the channel, but this is not always the case, as local ice conditions often cause steep surface salinity anomalies. Below 100 metres depth the salinity stratification through the section is remarkably constant with values of 34.00‰ at 200 metres and 34.45‰ at the bottom depth of 800 metres.

Eastern Lancaster Sound

The 1957 sections of temperature, salinity, and density through the eastern end of Lancaster Sound may be described as typical (September 23, 24). At the surface, temperature varies from 1.36°C to 0.85°C and the warmer surface water occurs along the northern side of the channel. Below the 0.0°C isotherm, which extends across the width of the sound at a depth of 25 - 50 metres, the temperature structure is uniform and similar to that which has been described by earlier investigators (Riis-Carstensen, 1936; Bailey, 1957; Collin, 1958). Between 50 and about 200 metres there is a gradual decrease in temperature to a minimum of -1.48°C between 100 and 200 metres but, in contrast to the 1954 observations, negative temperatures were found

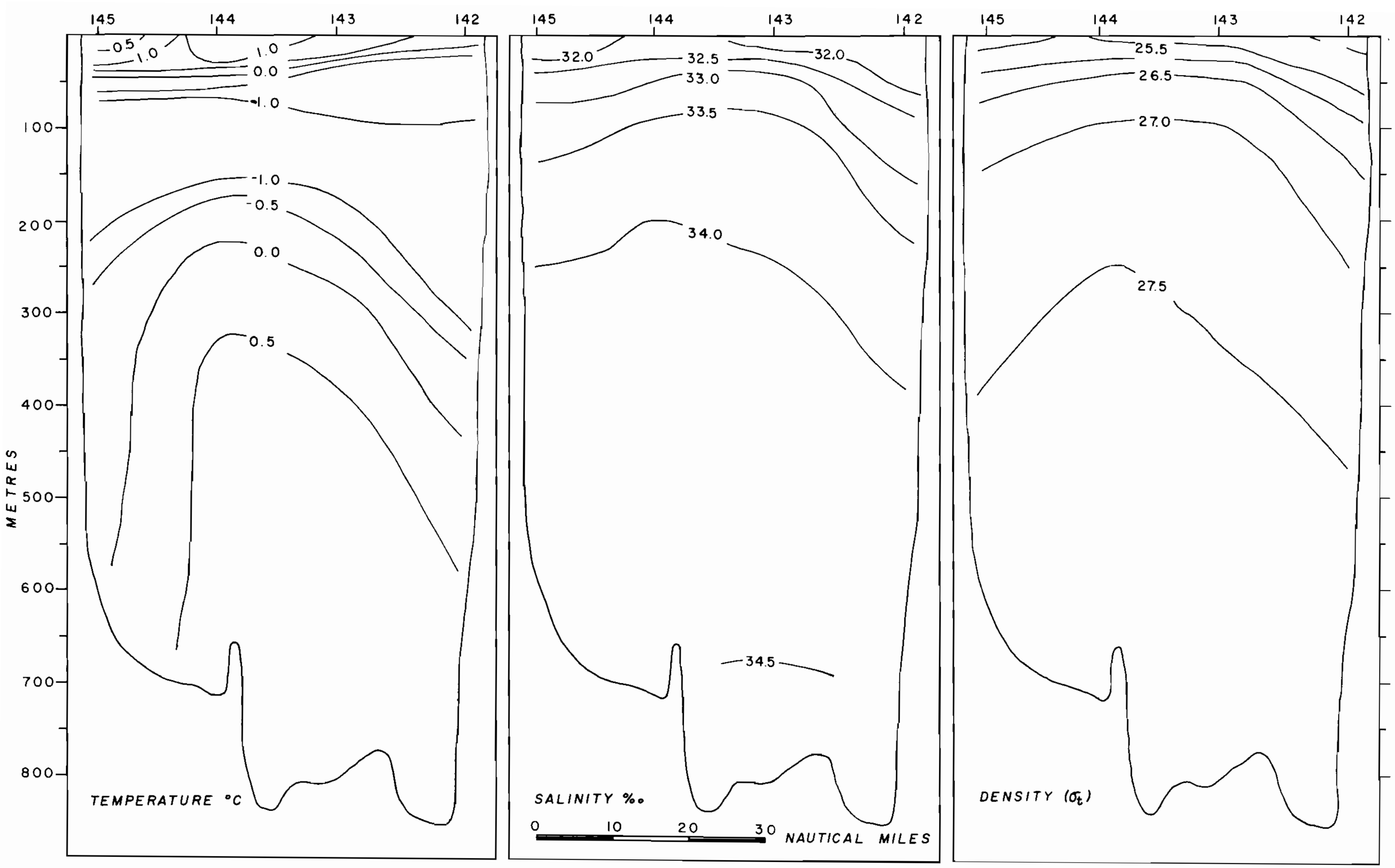


Fig. 16 Profile of temperature, salinity, density, east Lancaster Sound.

to extend to the bottom along the north side of the sound at station 145. Throughout the remainder of the section temperatures increase with depth below 200 metres to a maximum of over 0.5°C in the 400 to 500 metre level. As pointed out earlier, this maximum is usually found in the northern side of the passage; however, in 1957, positive bottom temperatures as high as 0.5°C only appeared at stations 142-144.

The salinity structure in the eastern section of Lancaster Sound as it appeared from the 1957 data is very similar to that which was encountered by the earlier cruises. Salinity diagrams of Arctic waters show a marked summer gradient within the top 20 metres as a result of local ice conditions and surface mixing. The largest surface salinity difference so far recorded in Lancaster Sound was reported by Bailey (1957); on this occasion surface salinity increased from 26.94 ‰ to 32.18 ‰ (stations 3, 4, 1954). In 1957 the extreme surface values were 31.04‰ and 32.12 ‰, while below the 50 metre level the salt content increased with depth until at the bottom values of 34.50 ‰ were almost constant.

The density profile across the eastern end of Lancaster Sound is similar to that of 1956. The slope of the isopynals indicates a westerly flow along the northern side of the channel with a flow in the opposite direction along the southern side. The form of the 27.5 (σ_t)* density surface shows that below 250 metres this current system becomes

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* For a water particle of salinity S, temperature t and at pressure p the density may be written $\rho_{S,t,p}$. Sigma-t (σ_t) is defined as 1000 ($\rho_{S,t,0}$-1), where $\rho_{S,t,0}$ is the density of water of salinity S, temperature t and at atmospheric pressure. Sigma-t is in fact very nearly equal to density *in situ* at depths less than 1000 metres and is much more convenient, for, to determine properties at a given potential density surface it would be necessary to convert all observed temperatures to potential temperatures.

more pronounced.

All investigators who have dealt with the oceanographic features of the eastern Lancaster Sound section have commented on the sinuous form of the isopleths of this model. Riis-Carstensen (1936) has shown that the time interval between the "Godthaab" stations bears a direct relationship to the tidal period in Lancaster Sound and from this deduction he has suggested that the wave-like form of the isopleths is a result of tidal action. This idea has been discussed by Kiilerich (1939) who has expressed the opinion that the tidal displacement in the eastern end of Lancaster Sound is too small to produce such a pattern. Instead he has intimated that an eddy formation in the outgoing current caused by some other factor determines the temperature and salinity pattern. Such a condition was reported in September 1956 at which time a weak eddy system existed within the upper 50 metre level, centred about station 188 (Collin, 1958). There is no trace of a subsurface counter current within the section in the 1957 data (Fig. 16); nevertheless, it appears that the undulating form of the isopycnals is a typical feature of the region and is a result of the natural reversal of current direction across the passage.

Western Lancaster Sound

The western section in Lancaster Sound (Fig. 17) drawn from stations 130 to 133, shows that significant changes in temperature and density exist throughout the length of the channel.

The temperature gradient within the upper 50 metres is similar to that found in the eastern end of the passage while below

100 metres there is a noticeable decrease in subsurface temperature with increasing depth. A temperature minimum of -1.5°C that is only weakly defined in the eastern section (Fig. 16) at station 142 at 150 metres is well formed in the western section in the 50 to 100 metre interval and the warm core at 450 metres that was recognized at the eastern end of the channel is completely absent.

The salinity pattern of this section shows that considerable freshening of the water column occurs from east to west and that the slope of the isohalines becomes more uniform (Fig. 17). Within the western profile the salinity gradient in the upper layer is from 30.00‰ at the immediate surface to 32.00‰ at 50 metres; below this depth salinity increases gradually to a maximum of 34.50‰ at the bottom.

The density profile in Fig. 17 reveals a weakening in the slope of the density surfaces and indicates a general easterly movement between the depths of 50 and 350 metres. Within the upper 50 metres there appears to be a weak westward set to the current.

Barrow Strait

The Barrow Strait section which appears in Fig. 18 is located directly off Resolute Bay, stations 71 to 74. At the time this work was under way there was very little ice on the northern side of the strait but a concentration of about 5/10 remained along the northwest coast of Somerset Island. To the west, ice concentration increased to 10/10 in the region of Griffith Island and extended throughout the width of Barrow Strait.

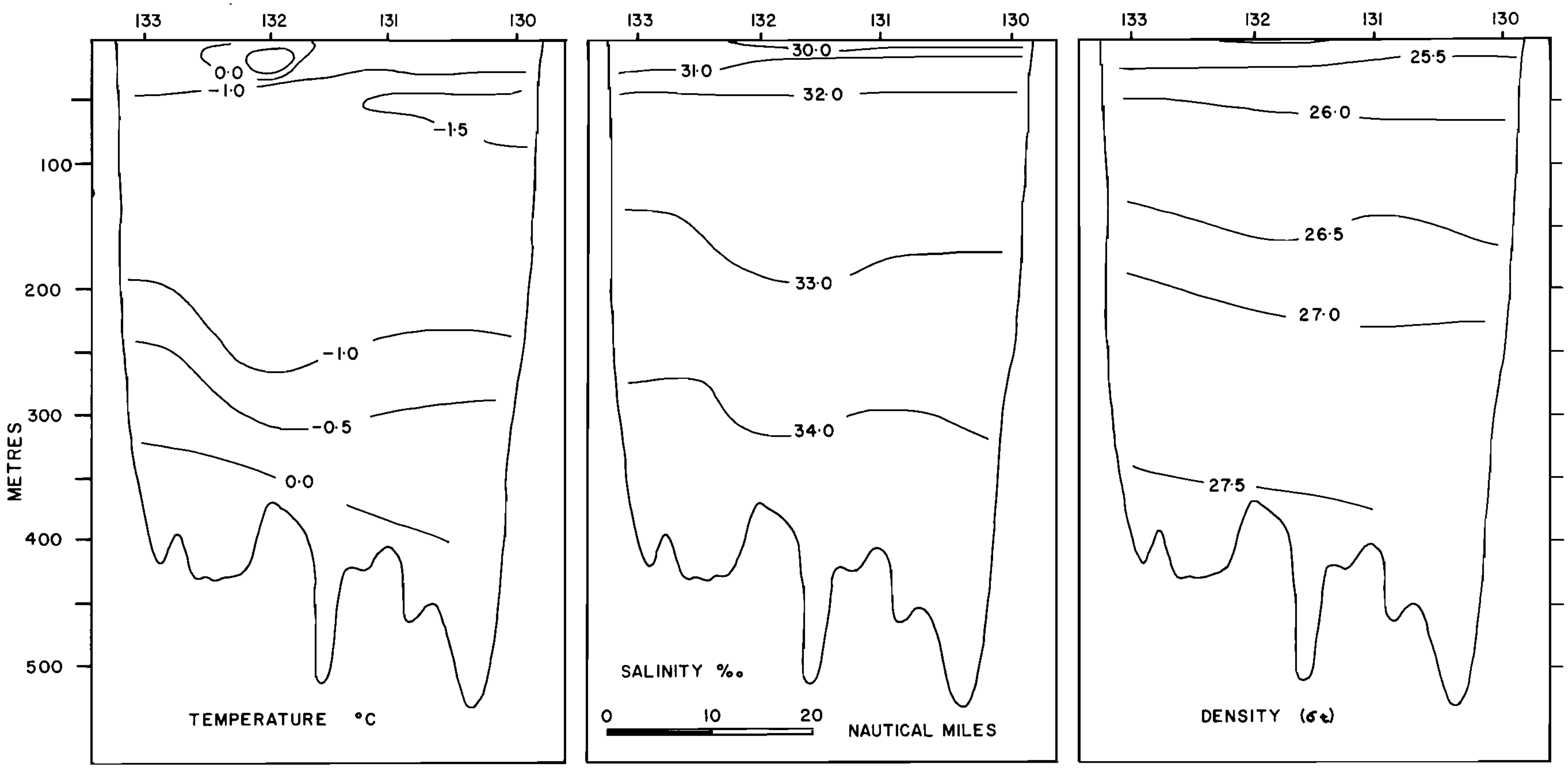

Fig. 17 Profile of temperature, salinity, density, west Lancaster Sound.

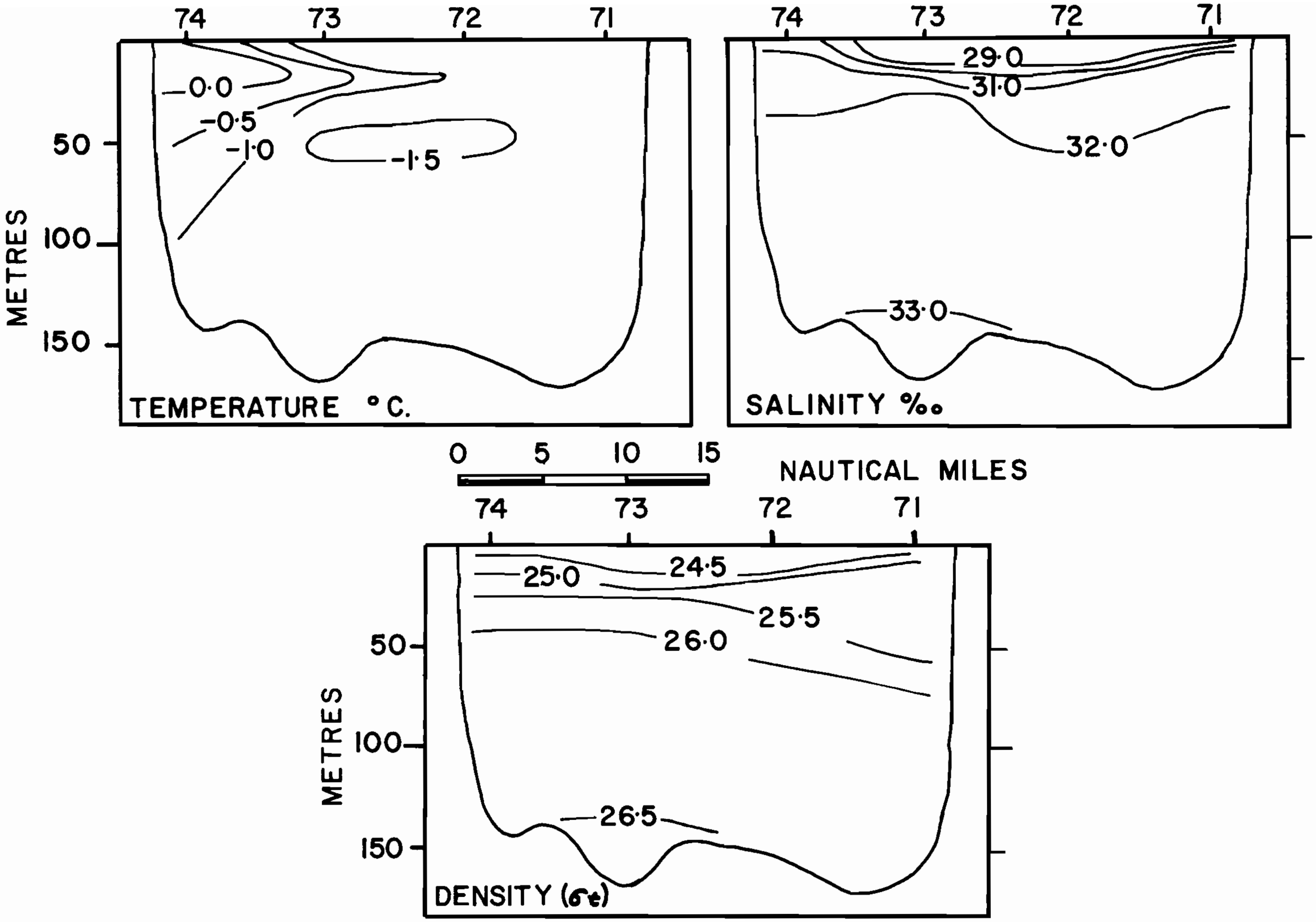

Fig. 18 Profile of temperature, salinity, density, Barrow Strait.

The temperature profile at this section reveals an interesting feature in the form of a deep wedge of slightly warmer water along the north side of the passage. This condition does not appear in the few scattered stations in western Barrow Strait but shows up at several locations in the southern end of Wellington Channel and also at station 132 in the west Lancaster Sound section (Fig. 17; Table XII).

Table XII

Barrow Strait Sub-Surface Temperature Anomaly, August, 1957.

Station	74	69	67	64
Depth m		Temp °C		
10	-0.14	1.06	1.06	0.61
20	0.62	0.63	0.38	0.47
30	-0.07	-0.16	-0.76	-0.88
50	-0.56	-0.66	-0.82	-1.26

As pointed out in the discussion of the surface temperature distribution in Barrow Strait and Wellington Channel this cell of positive temperatures is confined to the region off the southeast coast of Cornwallis Island. The vertical distribution indicates that the depth of warmer water is about 25 metres and that its greatest depth is in the vicinity of station 69. The local nature of this anomaly suggests that these temperatures, which are approximately 1.0°C higher than the surrounding temperatures at the same depth, are the result of an early removal of ice and consequently a longer period of solar heating.

The regularity of this condition can only be estimated. Observations taken in the area in late September 1956 do not show similar surface warming, whilst in August 1954 even higher temperatures (1.27°C) were recorded at the surface in the same region (Bailey, 1957; Collin, 1958).

Schule and Wittmann (1958) have stated that ice jamming and prevailing winds are the factors mainly responsible for the Barrow Strait Polynya which, in turn, results in the restricted area of warmer surface water reported in the same region in August. Ice surveys show that the earliest evidence of the Barrow Strait open water area appears in late March when extensive tracts of broken ice form along the north coast of Somerset Island and to the west of Resolute. By mid-June the ice-free region spreads eastward into Lancaster Sound and is completely open. Obviously this expanse of open water will have surface temperatures above freezing and, as the seasonal spring heating continues, with daily mean surface air temperatures above 0.0°C by the middle of June, the surface water temperature will become increasingly higher than that in the surrounding ice-covered areas. It would appear from the oceanographic data that the period of maximum intensity of the anomaly is mid-August and that the structure weakens rapidly after this date. If such an explanation is in fact the case, similar reasons apply for early higher surface temperatures in the eastern end of Lancaster Sound. A comparable situation is recorded by Grainger (1959) who maintained a hydrographic station throughout the winter of 1955-56 at Igloolik, in northern Foxe Basin. At this station the seasonal increase of subsurface water temperatures began in mid-June and increased from a winter mean of -1.67°C at 10 metres to the summer maximum of 1.55°C recorded on September 2. Further to the south, in Foxe Basin, no positive temperatures were reported at the surface or at the 20 metre level in October 1955 (Campbell and Collin, 1956), and in mid-September 1959 surface temperature greater than 0.0°C (1.44°C) was noted at only one inshore location in northern Foxe Basin.

The salinity pattern of Barrow Strait shows little relationship with the temperature distribution. The normal summer salinity gradient occurs within the upper 50 metres where slightly higher values are associated with the temperature increase along the northern side of the passage. Below the 32.00 ‰ isohaline at 50 metres the increase is uniform to 33.00 ‰ at the bottom.

The slope of the density surfaces in this section indicates a general easterly movement in all except the surface layers along the southern side of the channel. At stations 71 and 72 there is evidence of a weak westerly movement within the top 30 metres that is confined to the southern half of the channel and does not extend below a depth of 40 metres.

Wellington Channel

The vertical sections for Wellington Channel have been constructed from stations 110, 111 and 112 with a maximum depth of 250 metres (Fig. 19). At the time the stations were occupied, September 15, there was no ice in the passage and the weather had been calm for several days.

The vertical distribution of temperature and salinity in this profile reveals a far more homogeneous situation than that observed in Lancaster Sound. The seasonal surface gradient is not nearly as well defined as that in the other sections, and the density profile indicates a considerably weaker gradation with depth. The entire water column has a temperature range of less than 1.5°C and a variation in salinity of only 1.5‰. The maximum salinity of 33.10‰ and the minimum temperature -1.6°C, occur at the bottom at a depth of 200 metres. The water in this section below the 50 metre level is identified as Arctic Cold water with features similar to those of the waters to the west the limiting properties being temperature from -1.2°C to -1.6°C and salinity from 32.20‰ to 33.50‰ respectively (Sverdrup et al, 1942, p.658).

The density distribution throughout this profile shows that there is a dominant southward movement through the deeper western section of the channel while a weak northerly flow occurs along the eastern side and within the upper layers.

A comparison of the 1957 and 1954 sections which have been occupied in Wellington Channel shows that the subsurface conditions were more uniform in 1957. The 1954 observations indicate a steeper surface gradient of temperature and salinity and a distinct variation from the anticlinal temperature structure encountered in 1957. Current direction in the 1954 section is similar to that recorded in 1957 except that, at the time of the 1954 observations, the northerly flow appeared at a depth of 50 metres along the eastern side of the passage

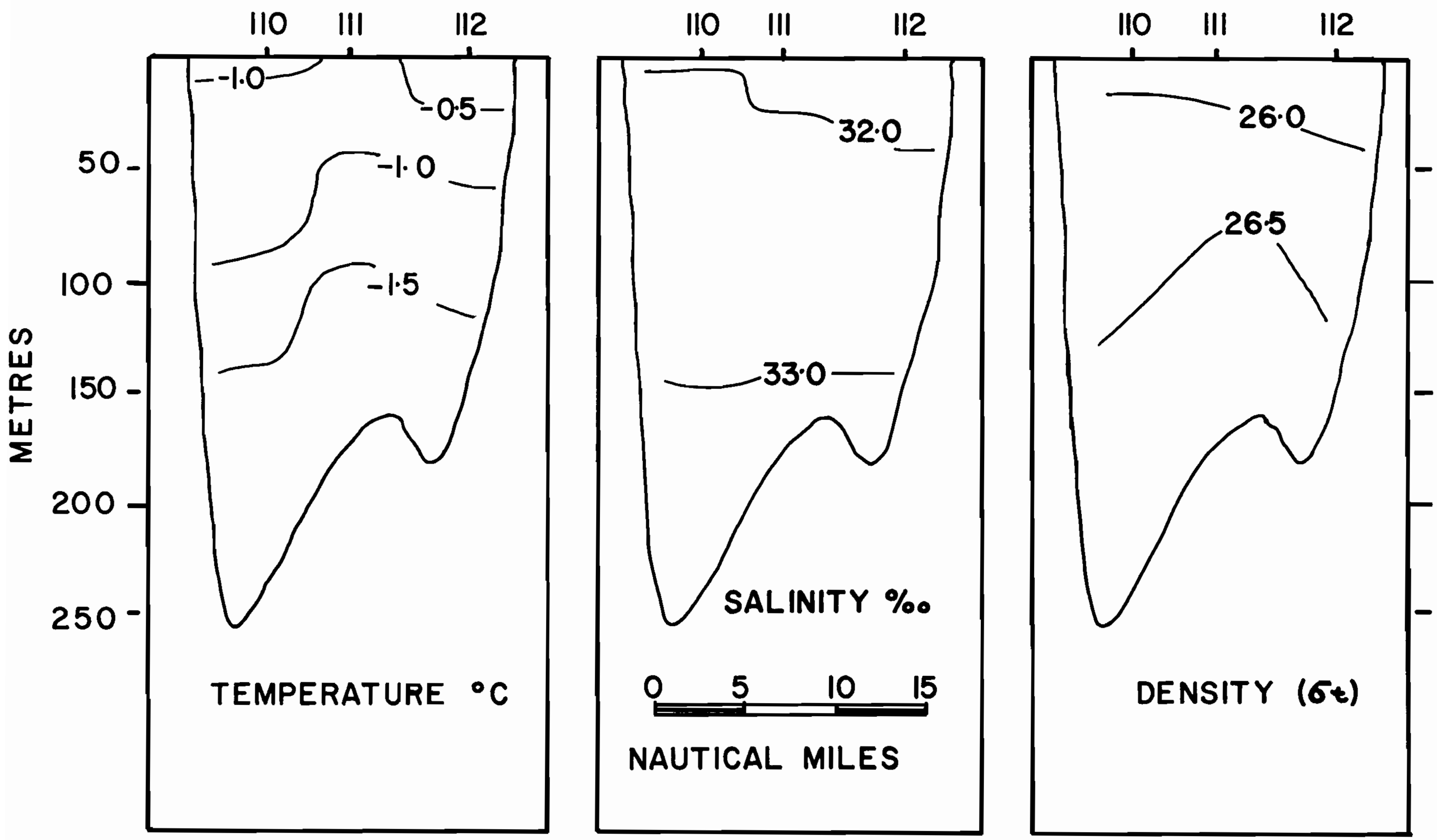

Fig. 19 Profile of temperature, salinity, density, Wellington Channel.

and was not recorded at the surface.

Prince Regent Inlet

The Prince Regent Inlet section is situated directly across the northern end of the channel at right angles to the long axis of the passage. The stations (38, 39, 40) were occupied on August 20 at a time when ice concentration was 3/10 or less.

The temperature and salinity distributions both show surface fluctuations of property within the upper 50 metres (Fig. 20). The temperature section, which is typical of this region, shows a marked shallow warming along the eastern side of the passage where temperatures reach a maximum of 1.36°C at a depth of about 20 metres in a narrow coastal strip confined to the eastern half of the channel (Fig. 11). The cause of this anomaly appears to be local surface warming, a result of calm, ice-free conditions for a short period of time previous to the observations. Below 50 metres, temperatures decrease to a minimum of -1.54°C at about 200 metres, then increase uniformly with depth to 0.0°C at the bottom.

In contrast to the surface temperature distribution the salinity gradient increases towards the western edge of the profile. In this region minimum surface salinity is 28.13 ‰ in contrast to values of 29.92 ‰ at the opposite side of the passage. Below 50 metres the salinity pattern becomes uniform with a range from 30.50 ‰ at 50 metres to a maximum of slightly over 34.00‰ at 400 metres.

The slope of the isopycnals indicates that a weak southward movement occupies the full width of the strait above the 70 metre

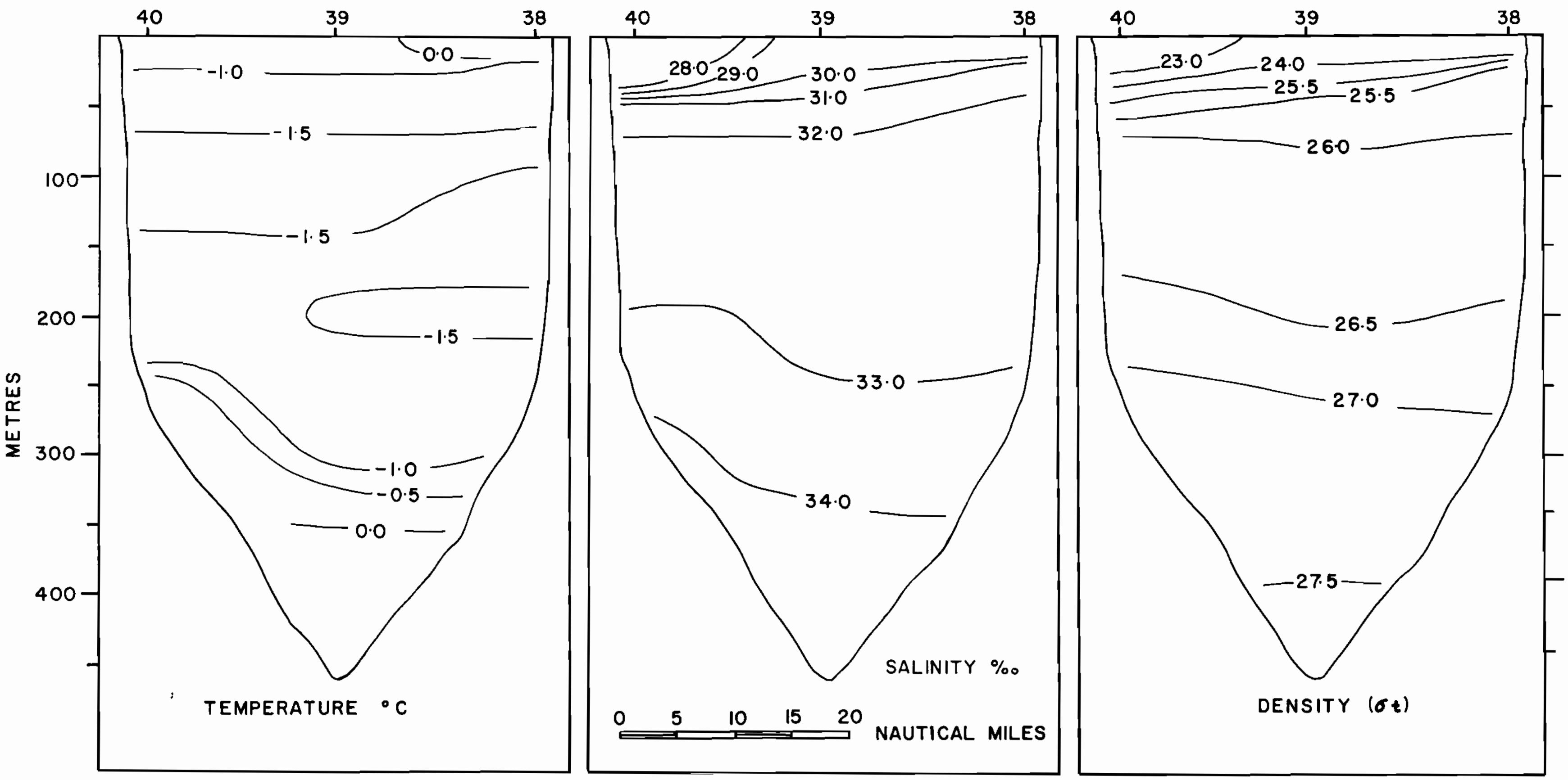

Fig. 20 Profile of temperature, salinity, density, Prince Regent Inlet.

level while below this depth the resultant movement is to the north. A comparison of Fig. 20 with the observations taken in the same area in 1956 reveals only two noticeable differences. Surface observations of temperature and salinity recorded in 1956 do not show the warming along the east coast or the salinity minimum on the west coast, both of which appear in the 1957 results. Other than these two discrepancies the profiles are almost identical.

Longitudinal Section, Temperature, Salinity

The longitudinal profiles of temperature and salinity for Lancaster Sound and Barrow Strait have been drawn as separate sections since the difference in time between the two surveys is 20 days (Fig. 21). The Barrow Strait investigation was completed in 11 days between August 28 and September 8; the Lancaster Sound programme, which was interrupted on two occasions, took a total of 6 days from the 18 to the 23 of September. The profiles were drawn through those stations which lie nearest to the centre-line of the passage.

The longitudinal sections for Lancaster Sound and Barrow Strait show further evidence of the strong summer stratification and the extensive intrusion of Baffin Bay water which takes place in this passage.

The surface layer, which shows distinctly the influences of seasonal warming and westward movement, with temperatures above 0.0°C, appears as a thin wedge extending from the eastern end of Lancaster Sound as far as Prince Regent Inlet. In several instances there are signs of cooling at the immediate surface; this is apparent at stations 132 and 136 and is the result of local ice conditions and decreasing surface air temperatures. The depth of the seasonal layer in the eastern end of the channel is about 60 metres, whereas at station 128 in the western end of Barrow Strait the surface layer is almost insignificant, owing to the dominance of the colder surface water.

Below the surface layer the Arctic Cold water that enters Lancaster Sound by way of Barrow Strait and Wellington Channel occupies the major portion of the channel. This layer, which is deeper in the Barrow Strait region, thins towards the east and eventually forms a series of lenses as it becomes mixed with warmer Baffin Bay water. The characteristics of this water mass are extremely low temperatures of -1.2°C to -1.5°C and salinity from 32.20‰ to 33.50‰. The cold high salinity water, temperature -1.0°C to -1.3°C, salinity 33.00‰ to 33.50‰, which occurs between 150 and 200 metres is formed by mixing of the Arctic Cold water that enters by way of Barrow Strait and Wellington Channel and the warmer Baffin Bay water from the east. The front representing the junction of these two water masses is marked by the 33.00‰ isohaline at a depth of 150 metres in the Barrow Strait section.

The underlying water is identified by slightly higher temperatures that increase with depth to a maximum of 0.76°C and salinity greater than 33.50‰. From the longitudinal profiles it is seen to extend from the eastern end of the passage to the western end of Barrow Strait where the steeply shoaling bottom forms a barrier below 200 metres.

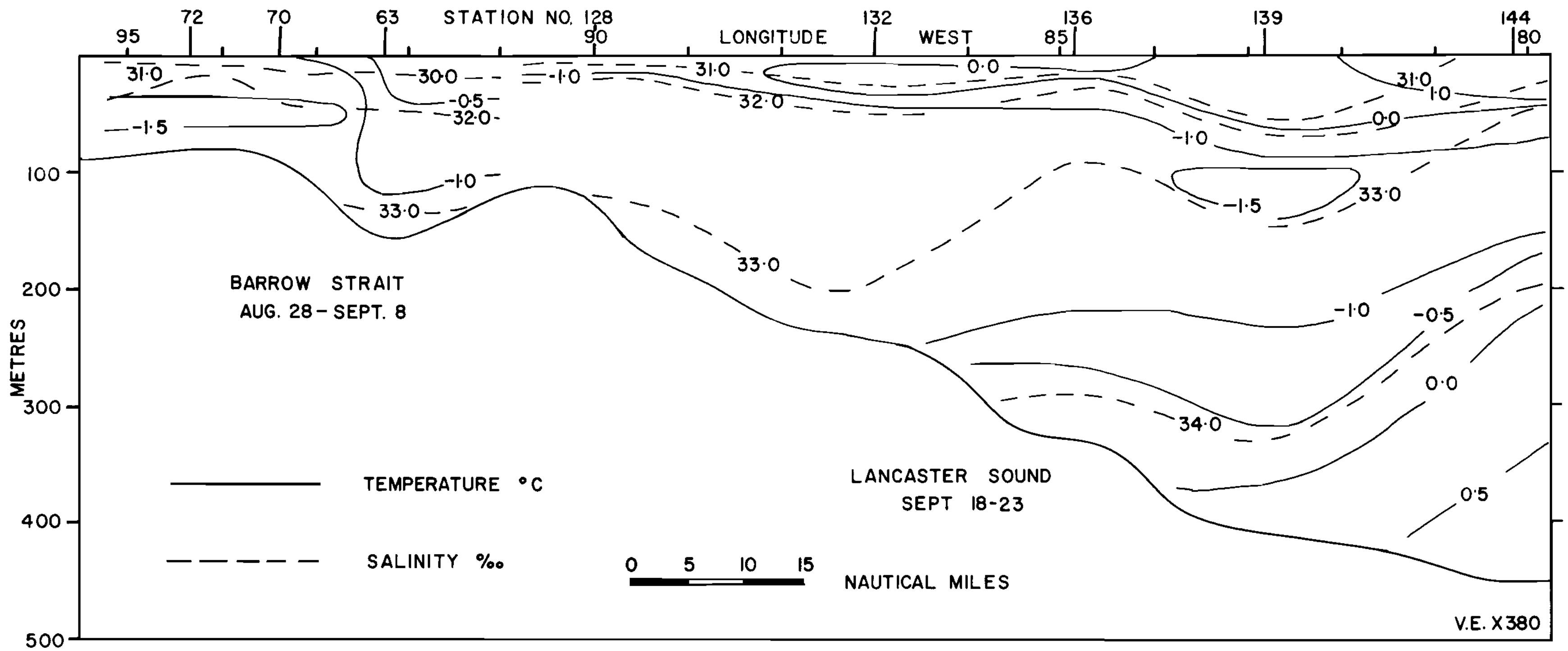

Fig. 21 Longitudinal profile of temperature and salinity, Lancaster Sound - Barrow Strait.

The upward slope of the $-1.0^{\circ}C$ isotherm in the eastern end of Lancaster Sound below 150 metres marks the upper boundary of the Baffin Bay extension into Lancaster Sound. The upper surface of this intrusion can be identified by temperatures of $-1.0^{\circ}C$ and salinity of over 33.50 ‰ and, in the eastern end of Lancaster Sound appears between 100 and 150 metres, while in the vicinity of Prince Regent Inlet it is defined at about 250 metres.

The wave-like form of the isopleths stands out as an interesting pattern in the longitudinal profiles. No concrete explanation can be offered for this distribution except to point out that Winchester (1954) has determined that the Lancaster Sound tide is of the standing wave type. If this is the case and if the oceanographic data from which the profiles were constructed are correctly spaced in time, then it is possible that a regular wave-like pattern would result. The time interval between stations is as follows:

128 to 132	26 hours
132 to 136	35 hours
136 to 139	7 hours
139 to 144	71 hours

It is apparent that these times are close to an even multiple of 6 and that, when computed, starting from a high water stage at station 136, the time intervals will result in a pattern of low stages at stations 139 and 132; however, this concept does not hold true for station 144. It appears therefore that the vertical, wave-like form of the isopleths in the longitudinal profile is partially the result of a coincidental timing of oceanographic stations that were occupied at extreme stages of the tide, whereas the slope of the isopleths in the eastern entrance of Lancaster Sound possibly represents a permanent boundary condition between the waters of Baffin Bay and those of Lancaster Sound.

CHAPTER VIII

CHARACTERISTICS OF THE WATER MASSES

The Parry Channel system forms a zone of transition between the waters to the west, characteristic of the Polar Basin, and those to the east that are formed through an interchange of Arctic water with that of the west Greenland current in Baffin Bay. The western water which passes from the Beaufort Sea into M'Clure Strait is identical in structure to that which has been described further off-shore in the Arctic Ocean. However, as this water moves eastward into Parry Channel it is obstructed by decreasing depth in Barrow Strait, so that only water of the surface layer (0-200 metres) passes eastward into Lancaster Sound. The water structure in Baffin Bay in the vicinity of the eastern end of Lancaster Sound is formed through a mixture of Arctic Ocean water that enters through Smith Sound and Jones Sound, and the warmer, more saline water of the west Greenland current that passes northward along the Greenland coast as far as Upernavik, in latitude 73° and possibly as far as Thule (Dunbar, 1946).

In Lancaster Sound the character of the water column is determined by a combination of these water masses and, as such, varies accordingly as the proportion of each contribution changes.

The water masses of the system are shown graphically in the temperature-salinity diagrams in Fig. 22. In each case only the data below 50 metres have been plotted, thus, seasonal surface fluctuations are reduced to a minimum. Nevertheless, seasonal warming is apparent in the Lancaster Sound and Baffin Bay curves. The information from which the T-S curves have been constructed has been taken from several sources and is of necessity limited in some areas. The plots for Lancaster Sound and Barrow Strait are based on data of the 1956 and 1957 "Labrador" cruises and the Viscount Melville Sound graph has been constructed from information collected during the "Labrador" cruise of 1954. The Baffin Bay and Smith Sound curves are drawn from results of the Danish "Godthaab" Expedition of 1928 and the "Labrador" cruises of 1954 and 1957. The Arctic Ocean information was collected from the I.G.Y. drifting station, T-3, during the months of August and September 1958, at which time the "ice island" was just to the north of the entrance to M'Clure Strait and additional observations have been used from project Ski Jump, station 6, 1952, and P.C.S.P.* stations 14 and 15, 1960. The T-S curve for the western end of M'Clure Strait is drawn from information collected at P.C.S.P. stations 1-4, 1961. In each case the representative curve shown in Fig. 22 has been determined from study of the graphs of several oceanographic stations taken in the area.

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* Polar Continental Shelf Project, Department of Mines and Technical Surveys.

TABLE XIII

Oceanographic stations used in T-S analysis.

T-S Curve	Vessel and Station	Source	Publication Date
Arctic Ocean	Ski Jump, 6, 1952	Worthington	1953 a
	T-3, 16-21, 1958	Collin	1959
	P.C.S.P., 14-15, 1960	Collin	1961
M'Clure Strait	P.S.C.P., 1-4, 1961	Collin	
Viscount Melville Sound	Labrador, 60-64, 1954	Bailey	1955
Lancaster Sound	Labrador, 135-140, 1957	Collin	
	Labrador, 187-190, 1956	Collin	1958
Baffin Bay	Godthaab, 130-133, 1928	Riis-Carstensen	1936
	Labrador, 29-30, 1954	Bailey	1955
	Labrador, 147, 151, 1957	Collin	

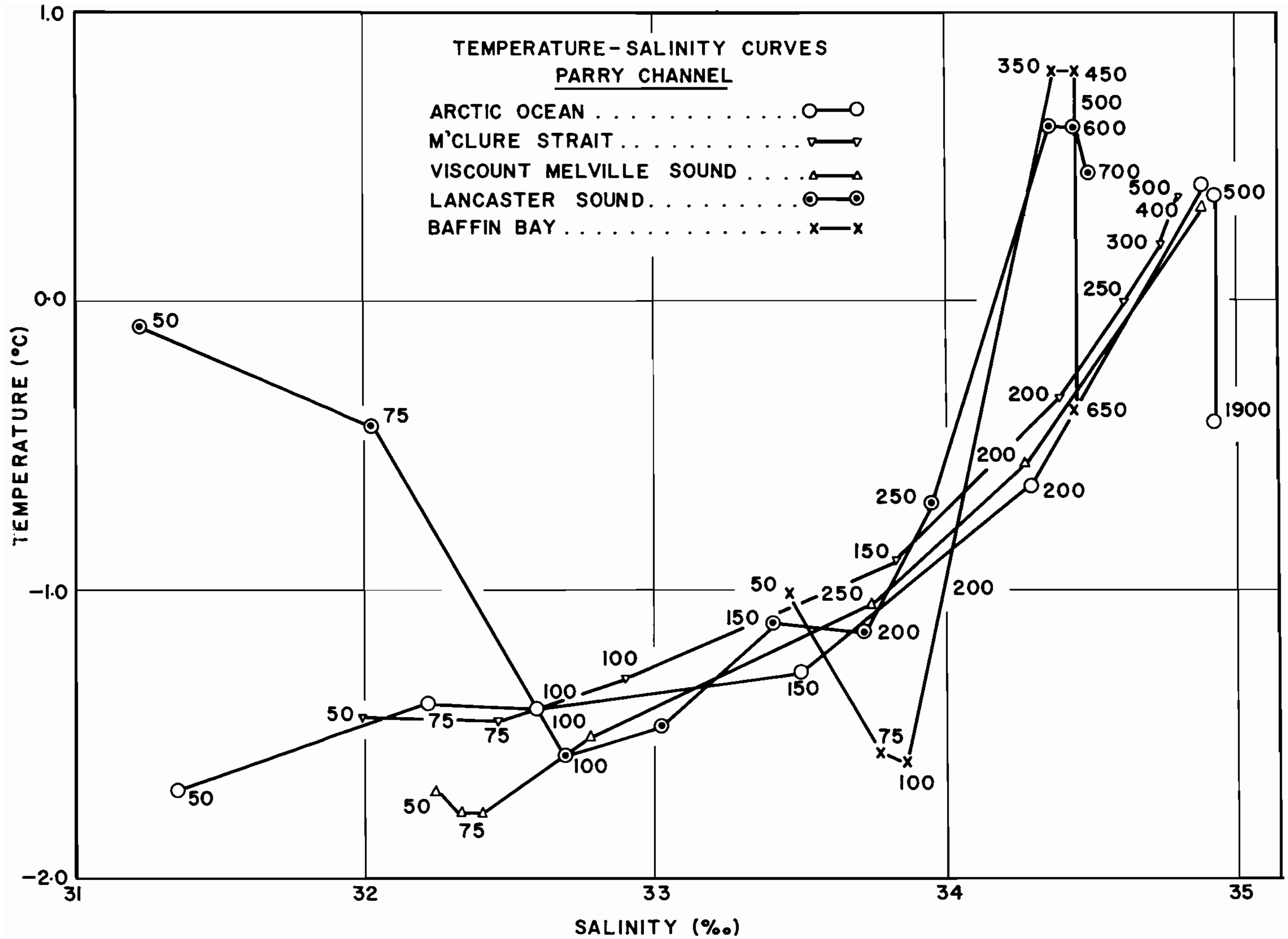

Fig. 22 Temperature - Salinity diagram.

T-S Analysis

The Arctic Ocean T-S curve represents the typical temperature and salinity structure of the offshore water in the region of the western Arctic Ocean. Measurements obtained in the Beaufort Sea in 1952 by Worthington (1953a) show that in the same area and to the north, in the vicinity of 82° north and 145° west, the T-S curve is identical to that shown in Fig. 22 and further observations taken from I.G.Y. station "Alpha" at 83° north and 151° west indicate that similar conditions were recorded at that position in April, 1958 (Farlow, 1958).

The T-S curve for the Arctic Ocean is therefore representative of the western source region of the Parry Channel and defines the characteristic column of four water masses.

The Arctic surface water, to a depth of 75 metres, is identified by temperatures below -1.40°C with a summer minimum of -1.72°C at 50 metres. The salinity within this layer is extremely variable, ranging from surface salt content of less than 10.00 ‰ to a maximum of 32.20 ‰. Below about 50 metres the salinity increases sharply with depth.

Within the surface layer a pronounced seasonal temperature variation takes place. In regions of permanent ice cover a remarkable thermocline develops at the base of the ice caused by the run-off of relatively fresh melt-water that collects between the bottom of the ice and the surface of the more dense, saline oceanic water below. This fresh water becomes trapped in the depressions of the lower surface of the ice and on occasion a second thin, almost fresh, ice layer develops at the interface between the fresh melt-water and the cold (-1.6°C) underlying ocean water. In April, 1961, the lower ice layer was discovered on two instances in M'Clure Strait under 71 cm. of winter ice. The second ice layer, which was 4-6 cm. thick, was separated from the bottom of the surface ice by about 50 cm. of water. Untersteiner and Badgley (1958) have described a similar condition recorded at the drifting station "Alpha" in 1958 and Sir Charles Wright (personal communication) has mentioned an identical situation which was reported in the Antarctic.

On T-3 the development of this fresh water layer was measured and a record kept of the seasonal temperature anomaly (Fig. 23). It was found that in the summer of 1958 (79°N., 121°W.) the layer began to accumulate about June 17 and reached its greatest depth of only 150 cm. at the end of July. At the time of maximum development the thermal gradient at the salt water interface was 1.5°C in 20 cm. but on no occasion was a seasonal temperature variation apparent at the 10 metre level. By early September the thermal gradient had weakened considerably and about the middle of the month a second ice layer formed at the interface. By the end of September little remained of the thermocline, and the salinity anomaly at the depth of 5 metres had weakened considerably; at the same time, little seasonal change was recorded in the salinity profile at a depth of 10 metres.

In the region of M'Clure Strait the Arctic Cold water layer lies between 70 and 140 metres. This water mass is identified by a range of temperature from -1.25 to -1.40°C and salinity that increases with depth from 32.20 ‰ to 33.50 ‰.

Within the upper 100-150 metres a cold intermediate layer is typical of Arctic waters (Fig. 24). This layer results from cooling

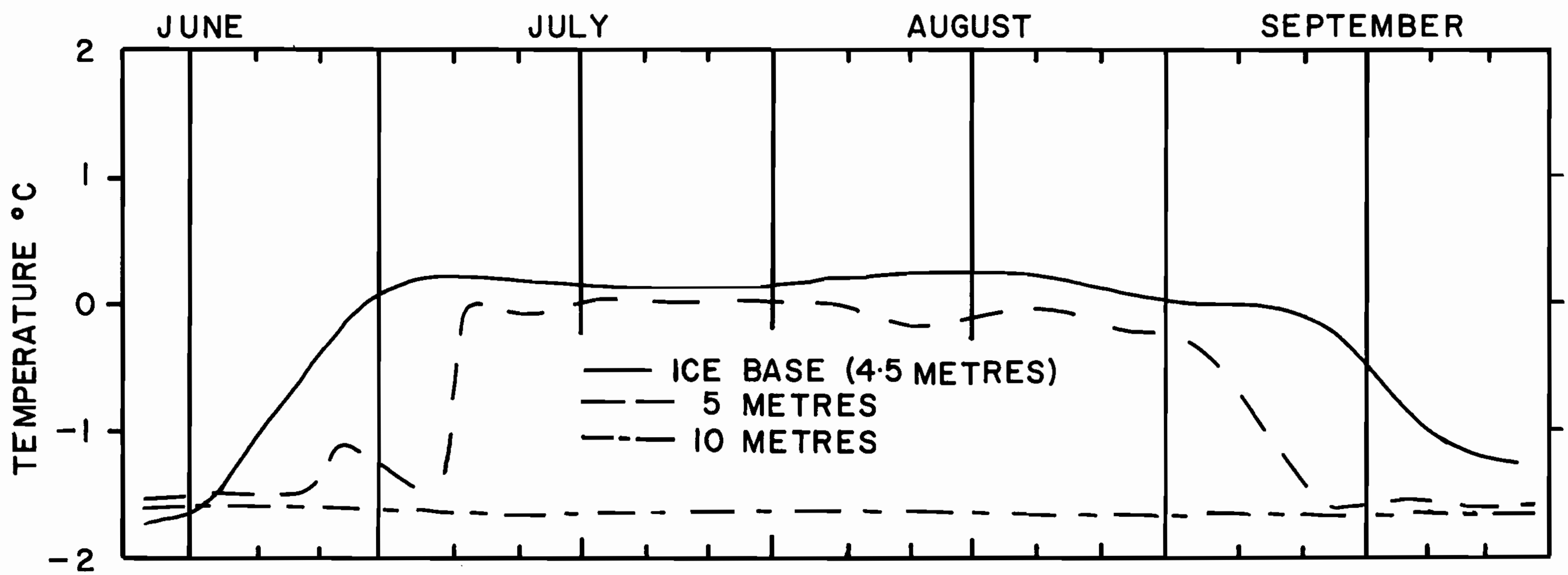

Fig. 23 Development of seasonal thermocline, permanent ice cover.

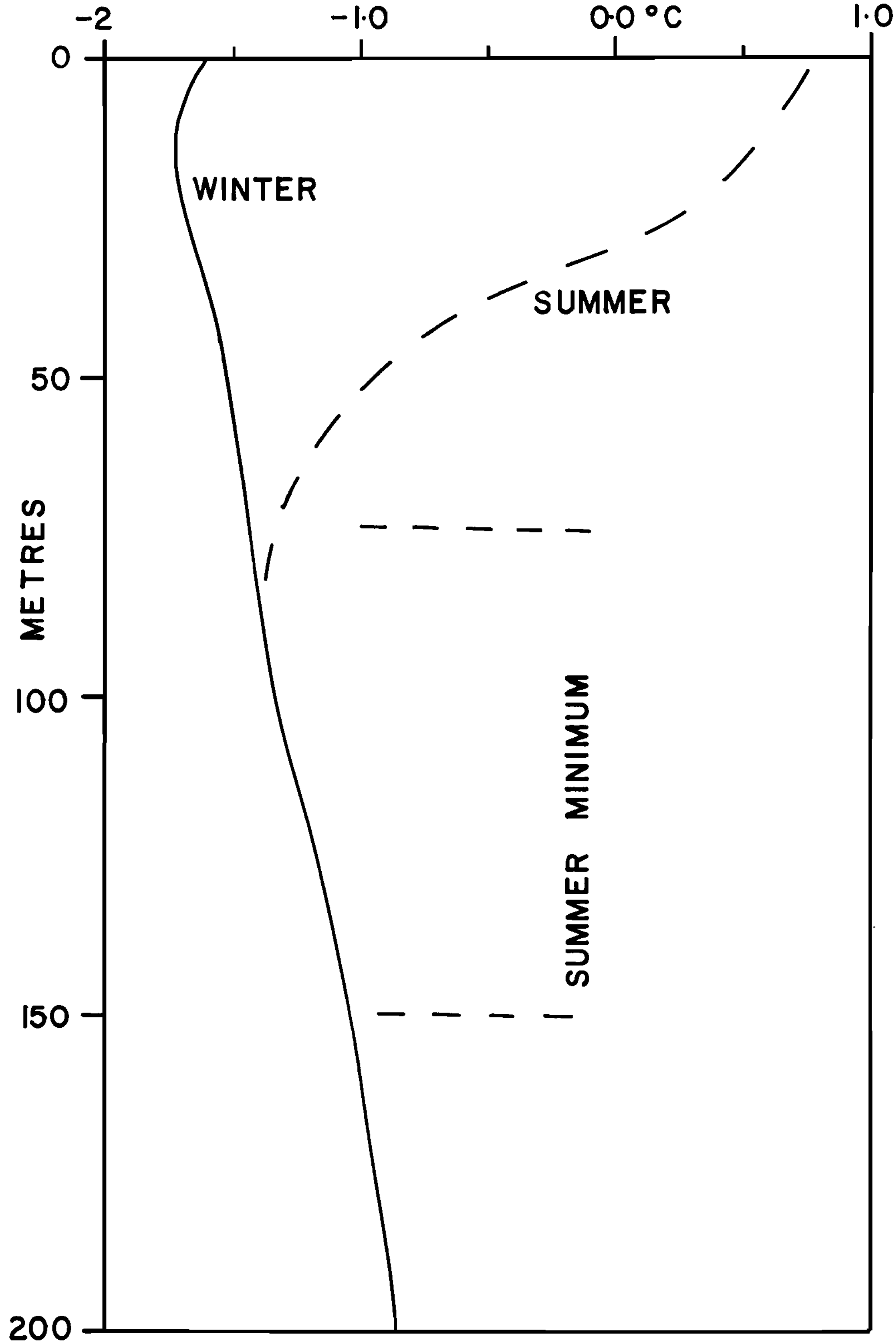

Fig. 24 Development of seasonal thermocline, ice-free summer.

of the surface water during winter and summer heating which penetrates throughout the course of the warm season, to a depth of 75-100 metres in the Lancaster Sound region. The result is a characteristic summer temperature minimum (-1.30 to -1.55°C) within the depth range 75-150 metres. Defant (1961, p. 135) has proposed that this feature is a natural result of winter cooling which, this thesis maintains, will be most pronounced in areas where winter ice formation occurs and the surface water is exposed in summer to above freezing temperatures for a considerable time.. The summer heating on the other hand does not develop in regions where the ice cover is permanent, except as explained above, for a very shallow melt-water layer which may form at the base of the ice. Coachman and Barnes (1961) have suggested that the sub-surface temperature minimum may, to a degree, be formed and maintained by mixing of Bering Strait water with Arctic shelf water and English (1961, personal communication) has offered substantial support to this theory in his description of the vertical distribution of dissolved oxygen and inorganic nutrients observed from Drift Station "Alpha". Since little evidence is found for the shallow water temperature maximum in the western region of the Parry Channel, indicative of the Bering Strait influx, it is probable that the 100 metre temperature minimum in Lancaster Sound is a result of seasonal surface temperature fluctuations.

Between about 150 and 250-400 metres there is a uniform transition zone below which lies the Polar Atlantic water first described by Nansen in 1902. This water of Atlantic origin (Timofeyev, 1957a) forms a definite stratification that has been encountered at all stations in the Polar Basin. At the T-3 stations the Polar Atlantic water occurred between 270 and 1,000 metres and was identified by temperatures greater than 0.0°C with a maximum of 0.4°C and salinity of 34.90‰. Within the Polar Atlantic layer the maximum conditions of temperature and salinity appear at about 500 metres.

Below 1,000 metres deep Polar water with negative temperatures and uniform salinity (34.93 - 34.99‰) forms the bottom water off the edge of the continental shelf in the region of M'Clure Strait. This water has also been shown to be of Atlantic origin but is formed only during winter in restricted geographic areas in the Norwegian Sea (Sverdrup, 1956; Timofeyev, 1957b; Metcalf, 1960).

The evidence for the shallow temperature maximum or Pacific interlayer initially described by Worthington (1953a) and Godkovich (1955) does not appear to any degree in the waters in the western end of M'Clure Strait. Barnes and Coachman (1961) have shown that this feature is weakest in the region along the western coast of the Arctic Archipelago and in the southeastern Beaufort Sea.

The T-S graph for Baffin Bay is representative of the water structure found in the vicinity of the eastern end of Lancaster Sound. Unlike the water column of the western Polar Basin which has been formed through the prolonged effects of severe surface temperature on waters of varying characteristics originating in remote areas of the earth's surface, the subsurface structure in north Baffin Bay is the result of an interchange of different water types within the immediate area. The sources which contribute to the formation of the

Baffin Bay water mass are the Polar Surface and Cold waters to a depth of 200-250 metres that enter through Lancaster, Jones, and Smith Sounds and the northern extension of the West Greenland Current, a relatively warm and saline water mass (0.0°C, 34.10 ‰ at 250 metres) at the latitude of Lancaster Sound. The Labrador Sea Intermediate water in combination with the colder Arctic water forms a warm water type (0.5°C, 34.30-34.50 ‰) which is characteristic of the 350-500 metre level.

From the Baffin Bay T-S curve in Fig. 22 it is apparent that the water structure in this area is remarkably different from that of the western Arctic. At the 50 metre depth there is evidence of surface warming and at 100 metres there is a distinct temperature minimum which must be caused by the influence of the cold Arctic Surface water as it enters Baffin Bay. The characteristics of this water type are, temperature -1.6°C, and salinity 33.85 ‰. Kiilerich (1939) recognized this temperature minimum at intermediate depths at several stations in Davis Strait; however, at that time it was considered an anomaly and explained as an accidental feature of local origin. Recent observations show that this water type is indeed typical of central Baffin Bay. Off the eastern end of Lancaster Sound the Baffin Bay warm water occurs at a depth of 400-500 metres and is defined by temperatures as high as 0.8°C and salinity about 34.40 ‰. Below the warm water layer the water structure is recognized by an almost constant salinity of 34.45 ‰ and decreasing temperature with depth.

From considerations of temperature and salinity data Bailey (1956) has shown that the deep water of Baffin Bay originates in the Arctic Ocean at depths of about 250 metres. Figure 22, which clearly illustrates these conditions, shows that the deep Baffin Bay water in the region of Lancaster Sound, which in this case is plotted at 650 metres, is similar in physical characteristics to the bottom water in Smith Sound and also to the 230 metre layer of the western Arctic and Viscount Melville Sound.

It is obvious that this water type must enter Baffin Bay through Smith Sound since Barrow Strait restricts all but the surface cold layers from passing through from Viscount Melville Sound into Lancaster Sound. An investigation of the available oceanographic data from Jones Sound and Wellington Channel shows that no water of this type enters Baffin Bay through these passages.

From a comparison of the T-S curves for the Arctic Ocean and Viscount Melville Sound it is apparent that these water structures are identical except for the fact that the subsurface column in M'Clure Strait and Viscount Melville Sound is limited to a depth of 500 metres. Observations conducted in the western end of M'Clure Strait in 1961 indicate a limiting depth across the passage of 398 metres on the northern side and a maximum of 525 metres on the southern side of the channel.

The water which passes through Barrow Strait is confined to the surface and upper section of the Cold Water layer, typical of the waters to the west. Below 50 metres depth this water has a temperature range of -1.2 to -1.5°C and salinity of 32.20‰-32.90‰.

The T-S curve for Lancaster Sound (Fig. 22) has been checked with all the oceanographic observations taken in the area during the 1957 cruise and is representative of summer temperature and salinity conditions in Lancaster Sound east of Prince Leopold Island. It is apparent from the T-S curves that the Lancaster Sound graph depicts an interesting combination of western and eastern oceanographic conditions.

From the surface to 250 metres the Lancaster Sound T-S curve has typical western characteristics. Large surface variations extend to a depth of 100 metres and from 100 metres to about 250 metres the T-S gradient is markedly similar to that of the Arctic Ocean, M'Clure Strait and Viscount Melville Sound. Within this depth interval the range of temperature is between -0.7°C and -1.6°C and salinity increases with depth from 32.70 ‰ at 100 metres to 33.95 ‰ at 250 metres.

Water that passes eastward over the Barrow Strait rise has a maximum salinity of the order of 32.90 ‰ at the bottom, approximately 150 metres, and that which moves southward through Wellington Channel has a high salinity of 33.30 ‰ at a depth of 250 metres. Therefore, it is suggested that the increase in salinity which occurs in Lancaster Sound between 100 and 250 metres is a result of mixing with the more saline Baffin Bay water which must intrude into this passage.

Below 250 metres the Lancaster Sound T-S curve takes on the characteristics of the Baffin Bay graph. Between 250 and 400 metres there is a steady increase in temperature and salinity with depth to a maximum of over 0.6°C and 34.40 ‰ at about 500 metres. In the eastern end of Lancaster Sound, where there are depths in excess of 500 metres, a sudden decrease in temperature occurs within the bottom layers. At this depth the typical negative gradient is approximately 0.1°C to 0.3°C between 500 and 700 metres. A similar anothermic condition is even more pronounced in the Baffin Bay curve.

In summary, there are four main points of this analysis which deserve mention. It has been shown by a study of typical T-S curves for each area of the Parry Channel that the water structure of the western Arctic in the vicinity of M'Clure Strait is significantly different from that of Baffin Bay near the eastern end of Lancaster Sound. Attention has been drawn to the similarity of properties which exist between the deep Baffin Bay water, the bottom water in Smith Sound, and water at 230 metres in the western Polar Basin. This condition, first described by Bailey (1956), leads to the suggestion that the deep water in Baffin Bay originates in the Arctic Ocean and enters Baffin Bay through Smith Sound. The temperature and salinity data for Barrow Strait show that the shallow depth of this passage restricts the complete interchange of the eastern and western water masses. This blocking action results in the dual structure of the Lancaster Sound water column. From the surface to 250 metres the temperature and salinity features of Lancaster Sound are identical to those of Viscount Melville Sound and the adjacent Arctic Ocean, whereas below 250 metres, the physical properties of Lancaster Sound are quite similar to those of Baffin Bay.

Discussion of Baffin Bay Intrusion

To further illustrate this relationship the T-S curves for Lancaster Sound and Baffin Bay have been treated in the manner described by Sverdrup et al (1942, p. 143) and Defant (1961, p. 204) in an attempt to determine the proportion of Baffin Bay water which enters Lancaster Sound. It appears from the T-S diagrams (Fig. 22) that at depths in excess of 200 metres the Lancaster Sound curve is, within the limits required for this procedure, coincident with that of Baffin Bay. Although the similarity of physical properties does not necessarily prove that water masses are of the same origin it is suggested that in this case, since the depressions of Lancaster Sound and Baffin Bay are directly connected and since current considerations indicate a well developed exchange between these two water bodies, the obvious similarity of physical properties defines the extent of the intrusion of Baffin Bay water into Lancaster Sound. The method assumes the simple T-S consideration that all temperature and salinity combinations resulting from the mixing of two water types will, when plotted on a T-S graph, fall along a strait line joining the co-ordinates of the two source regions and the ratio of mixing of the two original water types will be inversely proportional to the distance of any point along the line from the two end-points. It follows, that if the line joining the source regions, defined as subsurface Lancaster Sound, t=-1.2°C, S=33.80°/oo, and intermediate Baffin Bay, t=0.9°C and S=34.40°/oo, is divided into ten equal parts, the ratio of mixing between these two water types can be read directly off the graph (Fig. 26). In this way any portion of a T-S curve passing between the source points can be identified and the mixing ratio and depth read from the diagram.

This procedure was carried out for 24 stations occupied in Lancaster Sound in 1957 and the results are presented schematically in Fig. 25. The depth at which the T-S curve intersected the mixing line joining the co-ordinates of the two water sources was identified

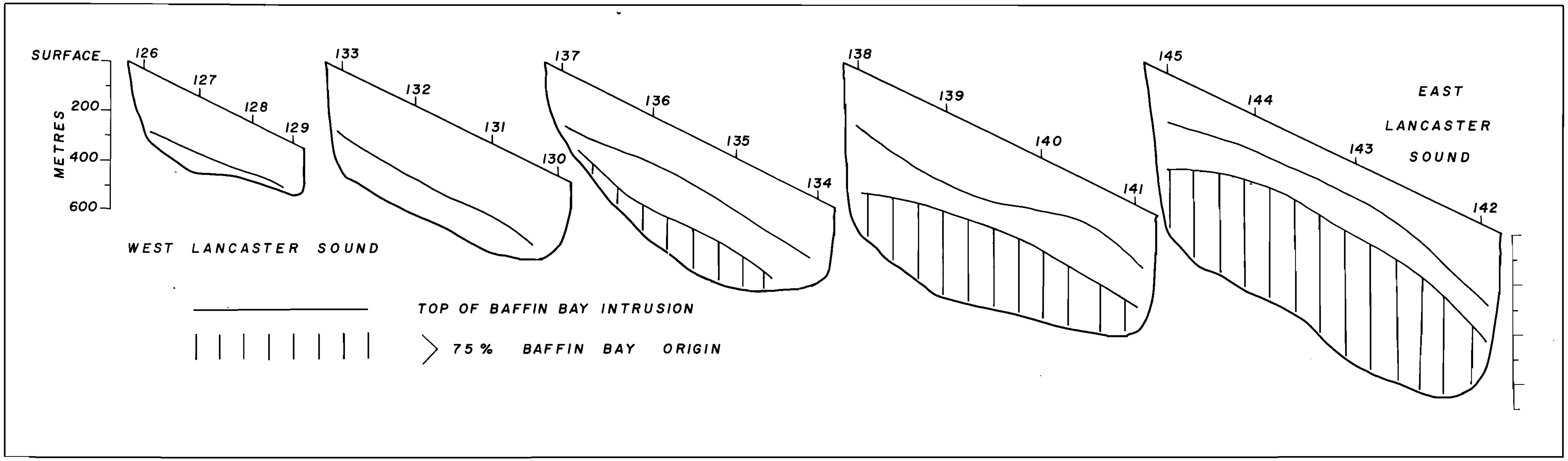

Fig. 25 Schematic representation of Baffin Bay intrusion into Lancaster Sound.

as the top of the Baffin Bay intrusion. The shaded area in the profile depicts the proportion of water through the section, below the line marking the top of the Baffin Bay influence, in which the ratio of Baffin Bay water (0.9°C, 34.40 ‰) typical of the depth interval 350-500 metres, makes up 75% or more of the water mass.

The greatest proportion of Baffin Bay water was calculated to be in the eastern end of Lancaster Sound where a maximum contribution of 92 percent was determined at the depth of 500 metres. Figure 25 shows that in the eastern end of the channel the Baffin Bay intrusion occupies at least two thirds of the section, while toward the west, the proportion decreases until, at Barrow Strait, there is only a weak indication detectable at the bottom. No evidence of Baffin Bay water was recorded further to the west since the decreasing depth of the channel restricts this water from penetrating into Barrow Strait. There is, however, indication of Baffin Bay water entering Prince Regent Inlet at a depth of 400 metres.

Determination of Equivalent Thickness of Baffin Bay Intrusion

Additional analysis of the equivalent thickness of Baffin Bay water has been carried out on all the data available for the eastern end of Lancaster Sound in the manner described by Jacobsen (1943) and the results listed in Table XIV.

For this inquiry it was accepted that the water type, t= -1.2°C, S= 33.80 ‰, defines subsurface characteristics in the eastern end of Lancaster Sound at a depth of about 200 metres and t= 0.9°C and S= 34.40 ‰ are representative of conditions at approximately

500 metres depth in northern Baffin Bay. Accordingly, the curve joining these points on a T-S diagram will form a line on which all water types consisting of a combination of these two components will lie when plotted on the diagram, and the distance from any point on this grid to the end points of the line will be inversely proportional to the percentage of participation of each source type.

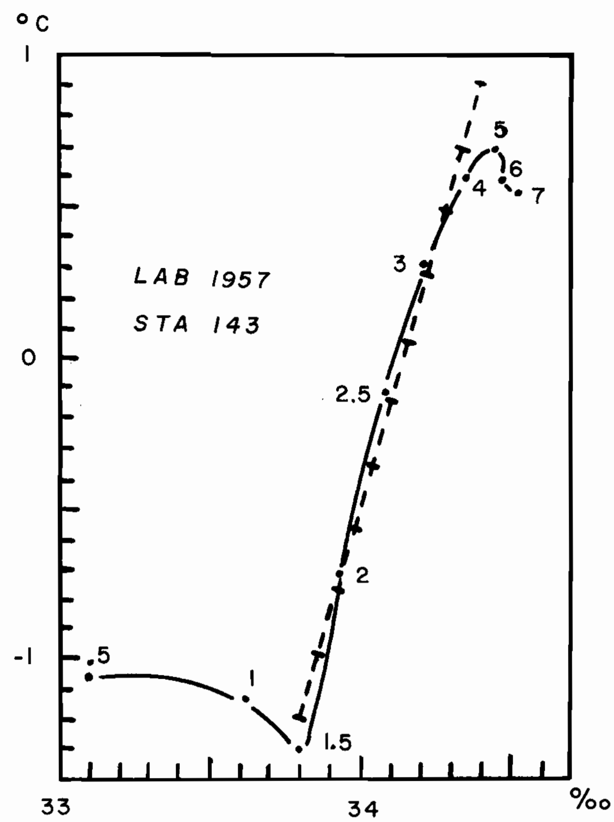

Fig. 26 Calculation of equivalent thickness of Baffin Bay type water in Lancaster Sound.

The water column at any place in eastern Lancaster Sound below a depth of 200 metres is formed by a mixture of intermediate Baffin Bay water with other water types so that at each station the proportion of Baffin Bay water, if separated from the remainder, would have a definite thickness; this calculation Jacobsen called the "equivalent thickness".

The line joining the co-ordinates of the mixing components was plotted on the T-S diagram and divided into 10 equal intervals indicating the proportional participation of each source type. The T-S curve for each station was then plotted on the same diagram and the ratio of Baffin Bay water read off the grid for each standard depth; the graph for station 143 is presented as an example in Fig.26. The T-S curves for eastern Lancaster Sound follow the dash line joining the mixing components closely and the participation of Baffin Bay water at each depth was read directly off the diagram. The following values were obtained for station 143:

Depth in m	200	250	300	400	500	600	700
Participation Baffin Bay component	0.22	0.51	0.70	0.85	0.91	0.86	0.85

The equivalent thickness of Baffin Bay water at this station was then calculated in this way:

.5 (0.22x200) +50x0.36+50x0.60+100x0.77+100x0.88+100x0.89+100x0.85= 409 metres.

The resultant figures do not describe a specific water column which can be identified on a T-S diagram or in a vertical profile. The equivalent thickness represents the total thickness of Baffin Bay water, which would exist in the eastern end of Lancaster Sound in one or more layers, if this water was separated from the rest of the water in this region and there was no horizontal displacement.

From Table XIV it is apparent that the equivalent thickness of Baffin Bay water within the eastern entrance to Lancaster Sound was significantly greater in 1957 than at the time of the earlier cruises. At the "Godthaab" stations taken during August 1928, the thickness was at a minimum and at the time of the "Labrador" investigations in 1954 and 1956 the equivalent thickness of Baffin Bay water was almost identical for both years. If the results obtained from the 1954 and 1956 data are used to determine an average, or perhaps normal situation, (equivalent thickness, 212 metres) the 1957 average of 259 metres represents an increase at that particular time of 22 percent.

Table XIV

Equivalent thickness, Baffin Bay water, eastern Lancaster Sound.

	Godthaab 1928 19-20/VIII						Labrador 1954 2-4/VIII				
Station	123	124	126	127	128	(Ave.)	9	10	11	12	(Ave.)
Equivalent thickness, m	22	131	58	204	134	(110)	140	223	281	227	(218)

	Labrador 1956 30/IX					Labrador 1957 23-24/IX				
Station	187	188	189	190	(Ave.)	142	143	144	145	(Ave.)
Equivalent thickness, m	115	248	229	233	(206)	116	409	350	159	(259)

CHAPTER IX

CIRCULATION AND VOLUME TRANSPORT

The general characteristics of the surface currents in Lancaster Sound and the adjoining passages have been the topic of much informed discussion. Early records show that under normal conditions ships were set to the eastward through the main section of the Lancaster Sound passage and that within a short distance of the northern shore a permanent westerly current could be traced as far as Wellington Channel. In several areas within the Lancaster Sound system the surface current has been observed to fluctuate with changes in tide and surface wind (Winchester, 1954). Kiilerich (1939) has made precise calculations of the volume exchange through the eastern end of Lancaster Sound based upon the results of the "Godthaab" expedition of 1928 and Dunbar (1951) has summarized and discussed the data which are available for this area. The observations taken during the 1954 cruise of H.M.C.S. "Labrador" have been analyzed by Bailey (1957) and further studies have been carried out by Collin (1958).

It is now known that the main circulation in the Lancaster Sound system is from the Arctic Ocean eastward to Baffin Bay. Water contributing to this budget enters through Barrow Strait and Wellington Channel and passes out of the circulation pattern by way of Prince Regent Inlet and Lancaster Sound.

The circulation in each of these passages is disturbed by frequent eddies and return currents which reduce the net volume exchange through any particular section. Examples of this circulation appear in the eastern end of Lancaster Sound where a persistent, westward flow occurs along the northern side of the channel and in the southern end of Wellington Channel where a periodic northern current occupies the eastern margin of the passage.

The following discussion of the circulation is based on a technique first suggested by Rossby (1936) and employed by Montgomery (1938) in an analysis of the flow pattern in the southern North Atlantic. The calculations of volume transport and current velocity have been carried out in the manner described by LaFond (1951) and are based upon the results of preliminary computations of the observations undertaken by the data processing centre of the United States Hydrographic Office.

Surfaces of uniform density, (sigma-t or σ_t), were contoured for Lancaster Sound and the tributary passages. The observed values of temperature and salinity for each station were plotted on depth diagrams and smooth curves were drawn through the resultant points which were usually close to or at standard depths. Sigma-t curves for the 26.0, 26.5 and 27.0 levels were drawn on the same diagrams and from a comparison of the curves the values of depth, and salinity were read off for each sigma-t surface. These values were then plotted on the standard plotting sheet of the region and the isolines drawn. The 26.5 sigma-t surface extended throughout the entire area and was selected for isentropic analysis.

For this study the customary sigma-t calculations were used instead of the more correct potential density. The difference between density <u>in situ</u> and sigma-t is very slight at depths less than 1,000 metres and it is generally customary to study the density stratification from the sigma-t values. In the calculation of sigma-t only the effect of pressure acting on the water mass is not taken into consideration thus, only the adiabatic temperature effect is neglected.

Defant (1961) has pointed out the ambiguity of the word "isentropic" as it refers to this type of data treatment. Since in oceanic water the entropy per se is very difficult to define, a more appropriate description of the technique would be simply an analysis of the oceanographic factors on a surface of constant sigma-t. Thus, by definition, changes in potential temperature, salinity or dissolved oxygen content within such a surface must take place without alteration in potential density. Therefore, variations of oceanographic properties along a specified sigma-t surface are the result of mixing along the surface and to a much smaller degree to movement in the vertical direction, normal to the sigma-t surface.

The numerical range in sigma-t within the region was limited to a minimum of 17.00 at the surface in Franklin Strait and a maximum of 27.50 at the bottom in the eastern end of Lancaster Sound. The depth of the 26.5 sigma-t surface varied from 50 to 200 metres while the range of salinity along this surface was 31.98‰ to 33.11‰, the higher values being in the eastern end of the passage. Although these are small differences to contour, the salinity distribution is related in form and shows features in harmony with the topography of the surface. The depth of the 26.5 sigma-t surface and the distribution of salinity at this level are shown in Fig. 27.

Depth of σ_t = 26.5 Surface

In Fig. 27a the depth of the 26.5= σ_t level is recorded in metres measured from the surface and from inspection of the general features of the topography it is possible to gain a preliminary indication of the current pattern at this depth.

In the eastern end of Lancaster Sound a steep dome in the centre of the channel indicates a pronounced cyclonic circulation within this area. About this "high" the strongest slope occurs along the southern side of the channel suggesting a dominant eastward movement at this depth. A weak depression extends for a short distance along the axis of the passage in which the flow is anticyclonic with the movement directed eastward in the northern section of the sea-way and westward through the southern section.

Throughout the length of Lancaster Sound and Barrow Strait there is a fairly uniform downward slope of the σ_t= 26.5-surface toward the south which indicates a uniform current running from west to east. In Wellington Channel the slope indicates a southern movement through the western section while along the Devon Island coast there is little evidence of a western current in Lancaster Sound.

In Barrow Strait the southern slope of the density surface is interrupted by a narrow area along the north side of the channel in which the slope is to the northward signifying a weak westward movement continuous with the southward flow through Wellington Channel (Fig.18).

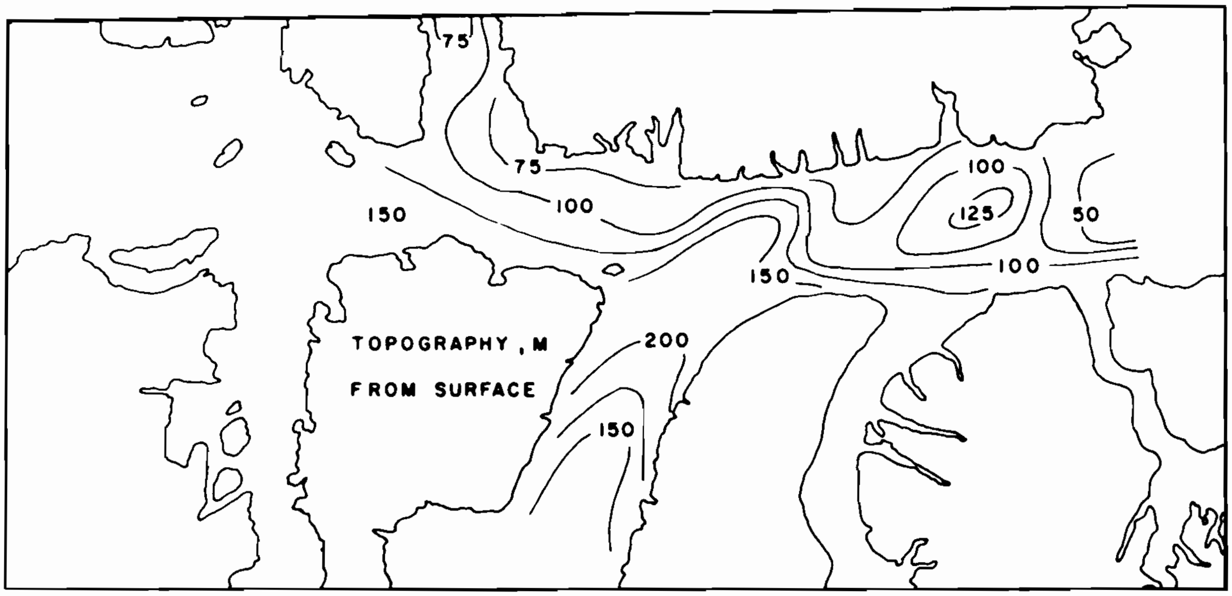

Fig. 27a Depth of $\sigma_t = 26.5$ surface in metres, contour interval 25 metres.

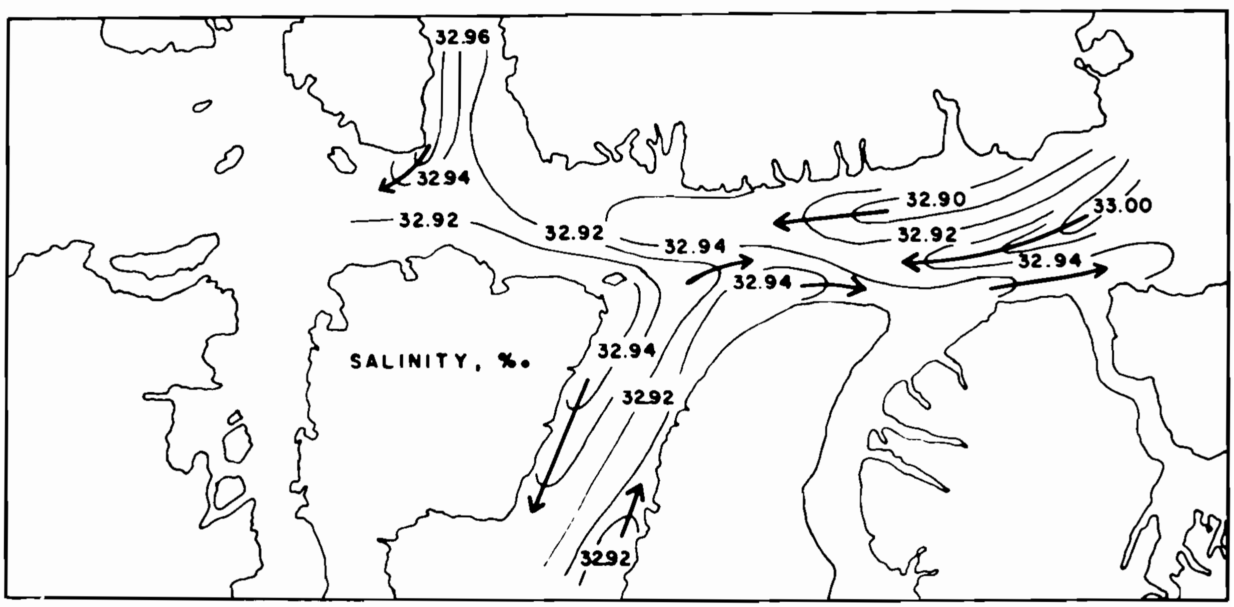

Fig. 27b Salinity distribution on $\sigma_t = 26.5$ surface.

In Wellington Channel the topography of the surface is moderate but the slope is constant to the westward, except for a narrow, ill-defined section along the western coast of Devon Island (Fig. 19). Thus, the resultant flow at this level is divided being primarily to the south with the exception of a tenuous, coastal movement to the north along the eastern side of the channel.

The maximum depth of the 26.5 sigma-t surface occurs in the northern end of Prince Regent Inlet. At this location the steep gradients along each side of the channel indicate a strong southern movement through the western section and a weaker northern movement along the eastern side at a depth of approximately 200 metres. In the southern end of Prince Regent Inlet the moderate westward dip of the density surface denotes a general southward current at the 140 - 200 metre level.

Salinity Distribution $\sigma_t = 26.5$-Surface

Although the range of salinity values on this sigma-t surface is small the salinity distribution corroborates the results of the topographic analysis and adds additional detail (Fig. 27b).

The highest salinity values recorded at this level are 33.12 ‰ and 32.99 ‰ in the eastern end of Lancaster Sound. In this area the distribution of relatively high salinity forms the axis of a well defined tongue of similar property which occupies the greater part of Lancaster Sound and extends through the eastern entrance of the passage in a southwesterly direction and westward as far as Prince Regent Inlet. Along the eastern side of Prince Regent Inlet and the south coast of Lancaster Sound a narrow eastward flowing current appears as a continuation of slightly lower salinity values from 32.92 ‰ to 32.94 ‰. The transfer through Wellington Channel and Prince Regent Inlet shows up remarkably well in the pattern of the salinity distribution at this level. In Barrow Strait the continuity of the 32.92 ‰ isohaline indicates a strong southerly movement in Wellington Channel and the continuation of this flow across Barrow Strait into Prince Regent Inlet, with only partial divergence eastward into Lancaster Sound and westward along the south coast of Cornwallis Island.

The distribution of salinity at this depth is an acceptable indication of the general circulation through the Lancaster Sound system. The inflow from Baffin Bay into Lancaster Sound is revealed as a pronounced feature and the north to south transfer from Wellington Channel into Prince Regent Inlet appears as a well defined pattern in the western end of the passage. The northward currents in Prince Regent Inlet and Wellington Channel do not appear to be dominant characteristics of the general circulation at this depth.

It is interesting to note that the position of the maximum transverse salinity gradient in the eastern end of Lancaster Sound coincides with that of the greatest calculated current speed.

Surface Currents

The chart showing surface currents relative to the 200 decibar level was compiled from calculated data based upon the dynamic computations (Fig. 28). The selection of the 200 decibar level is arbitrary

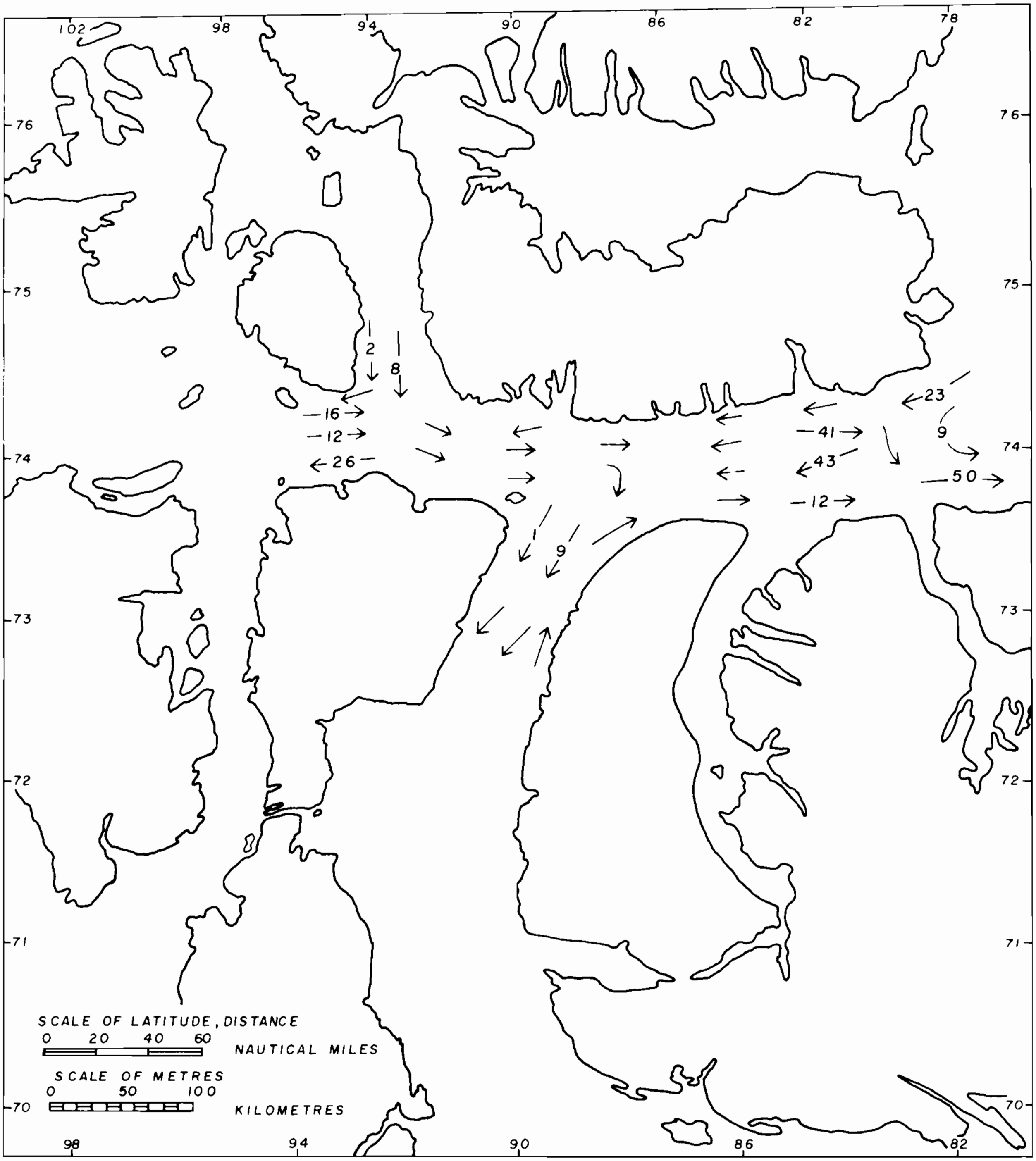

Fig. 28 Computed surface currents, Lancaster Sound system, figures represent speed in cm. per second.

since there is little evidence of a surface of no motion through the system. This surface was chosen because it is the greatest depth that is continuous through the area of investigation and because it represents the probable limiting depth over the Barrow Strait rise.

The surface current pattern is characterized by a dominant easterly movement through the Barrow Strait - Lancaster Sound passage. This pattern is disturbed by a large permanent eddy circulation located in the eastern end of Lancaster Sound and by an extensive wave-like intrusion which occurs in the entrance to Prince Regent Inlet. These interruptions cause the easterly current to become constricted in the region of Prince Regent Inlet and Brodeur Peninsula.

A permanent, westward moving current is confined to the northern side of Lancaster Sound and is continuous from Baffin Bay to Barrow Strait. In 1954 Bailey (1957) found this current to be about 6 miles wide and in 1956, Collin (1958) reported the width of the current to be 8 miles. The recent data indicate that the west-flowing current in Lancaster Sound may be considerably wider than reported and, in certain instances, occupy more than half the width of the passage. In addition, there is evidence that this current on occasion passes northward along the eastern side of Wellington Channel.

In Wellington Channel the major portion of the southward surface current combines with the general eastward movement through Barrow Strait but, at the time the 1957 observations were recorded, a narrow, west-flowing current was indicated along the south coast of Cornwallis Island. This coastal current has been detected previously and can now be considered a permanent feature. In 1956 the surface westward current along the northern side of Barrow Strait was found to be approximately 11 miles in width and from dynamic calculations the speed was determined at 25 cm./sec. The 1957 observations showed that at that time the width of this current was less than 5 miles and the speed was negligible.

A stronger westerly current has been detected along the south shore of Barrow Strait. In 1956 this current extended for about 10 miles off shore and its speed was calculated at 15 cm./sec., while in 1957 the width of the surface westerly current along the south shore was 10 miles and the speed was calculated at 25 cm./sec.

It is interesting to note that without exception vessels passing through Barrow Strait have found best ice conditions for navigation to be along either coast, that is, in the areas of westerly currents. When this evidence is considered with the assumption of a clockwise circulation in Viscount Melville Sound as reported by Stefansson and Larsen, it appears that the reverse circulation in southern Barrow Strait is a result of a surface extension of this circulation pattern (Sailing Directions for Northern Canada, 1951).

The surface current pattern in Prince Regent Inlet shows a more pronounced southern movement than was encountered in 1956. In this passage the southern current extends almost across the entire width of the channel and the weak northerly current is limited to a narrow sector along the eastern side.

Surface current velocities in cm./sec.* are shown for selected sections in Fig. 28 and are listed for standard depths in Table XV. These figures are generally higher than those recorded by Bailey (1957) but are similar in direction in all but a few cases.

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* Velocity of 1 nautical mile per hour (1 knot) = 51.5 cm. per second.

TABLE XV

Calculated everage velocities at selected depths in channels of the Lancaster Sound system.

Lancaster Sound

Stations:	144-145	143-144	142-143	140-141	139-140	138-139
Depth m	cm./sec.	cm./sec.	cm./sec.	cm./sec.	cm./sec.	cm./sec.
0	-22.9	9.4	50.0	12.0	-42.6	41.0
30	-18.2	6.1	46.0	16.5	-39.3	38.7
50	-16.6	6.4	6.0	23.3	-34.5	26.8
100	-13.2	6.4	12.1	21.4	-25.7	17.8
200	-8.3	5.5	3.0	5.6	-14.5	10.0
300	-5.0	3.7	7.6	0.6	-7.4	4.0
400	-2.9	2.0	2.7	1.0	-4.0	1.7
500	-1.8	0.9	0.9	0.6	-2.0	0.7

Reference level 600 db.

The negative sign (-) indicates a current flowing to the west.

Barrow Strait

Stations:	74-73	73-72	72-71
Depth m	cm./sec.	cm./sec.	cm./sec.
0	16.2	12.3	-26.2
10	9.7	12.4	-21.9
20	4.8	12.5	-16.3
30	9.4	11.6	-14.4
50	-1.7	8.0	-1.5
100	0.1	4.5	3.6
150	1.0	2.5	0.9

Reference level 200 db.

The negative sign (-) indicates a current flowing to the west.

TABLE XV (continued)

Wellington Channel

Stations:	107-108	108-109
Depth m	cm./sec.	cm./sec.
0	1.5	8.0
10	1.2	9.6
20	0.7	11.1
30	0.4	12.3
50	0.5	13.3
100	1.3	—
150	1.5	7.0

Reference level 200 db.

All directions are to the south.

Prince Regent Inlet

Stations:	38-39	39-40
Depth m	cm./sec.	cm./sec.
0	-9.4	-1.0
10	-9.4	1.1
20	-8.1	3.6
30	-5.8	7.2
50	-3.6	11.7
100	-1.8	10.9
150	-1.1	9.5
200	-0.7	8.3

Reference level 300 db.

The negative sign (-) indicates a current flowing to the south.

A maximum calculated current speed of 50 cm./sec. was recorded in the eastern end of Lancaster Sound along the north coast of Bylot Island and similar high speeds, in the order of 20 to 40 cm./sec., were determined for the central section of Lancaster Sound. In Barrow Strait the strongest flow was 26 cm./sec. to the westward along the north coast of Somerset Island but generally surface speeds in this passage were from 10 to 15 cm./sec. to the eastward. In Wellington Channel and Prince Regent Inlet the speed of the surface current was within the limits 1 to 10 cm./sec. to the southward.

The results listed in Table XV show that, in general, current speeds are highest at the surface and decrease rapidly with depth. Two exceptions occur in Wellington Channel and Prince Regent Inlet where the current velocities between stations 108 - 109 and 39 - 40 increase with depth to a maximum of 13.3 cm./sec. and 11.7 cm./sec. respectively at 50 metres.

Volume Transport

The net volume transport has been calculated for the Lancaster Sound system and the results listed in Table XVI. The initial calculations were based on the assumption that there is no well defined level of no motion through the system and, therefore, calculations for volume transport were carried out to depths as close to the bottom as possible. In many instances the depth of sampling was sufficient to give an accurate estimate of transport to bottom; in several cases sigma-t values were extrapolated downwards to the next standard depth in order to give the deepest possible profile. The final results were treated with a correction factor of from 1.0 to 1.2 for the side and bottom error depending on the proportion of the total cross-section included within the end stations of the oceanographic line.

Compared with the figures for the net easterly transport through Lancaster Sound arrived at by Kiilerich (1939) and Bailey (1957) the 1957 results are slightly lower than might be expected; however, the transport balance within the system appears to be satisfactory and suggests that 200 metres is an accurate assumption for the limiting depth through Barrow Strait. The data also show that Wellington Channel provides a far greater contribution to Lancaster Sound than does Barrow Strait; a situation that cannot be explained by the slight difference in the threshold depth of the channels but must indicate a very small west to east volume transfer through M'Clure Strait and Viscount Melville Sound. To check this assumption the volume transport through the western end of M'Clure Strait was calculated from observations recorded at four stations occupied in April, 1961. The resultant figure of 0.17 (10^6) m^3/sec. eastward tends to verify the calculated transport for Barrow Strait at 0.10 (10^6) m^3/sec.

The remarkably large southern flow through Prince Regent Inlet presents more serious difficulties in that it appears improbable that the volume of water passing southward through this channel is as great as that moving eastward through Lancaster Sound. Possibly the flow calculations for Lancaster Sound were based on data recorded at a period in which, owing to the state of the tide, the net eastward flow was at a minimum and a feed-back situation was produced in Prince Regent Inlet similar to the eastern Arctic examples discussed by Dunbar (1950). This condition could conceivably account for a temporary, unusually large influx into Prince Regent Inlet and under the same conditions a lower than normal easterly flow through Lancaster Sound, with the result that a balance would be maintained but an abnormally large proportion would appear to move southward through Prince Regent Inlet.

The possibility of such a substantial flow passing out of Prince Regent Inlet through Fury and Hecla Strait and Bellot Strait has been considered. A maximum tidal current through Bellot Strait has been recorded at over 7 knots but little is known of the residual current through this passage. Current measurements taken in the strait in August 1957 indicate that current speeds up to 6 knots occur at each successive tide but there is little evidence of a dominant westerly flow. Consequently, it seems most improbable that the flow through Bellot Strait has much, if any, effect on the volume transfer within Prince Regent Inlet. If, for the sake of comparison, a residual current of 1/2 knot to the westward is assumed, Bellot Strait can account for a volume transfer of not more than 0.02 (10^6) m^3/sec. out of Prince Regent Inlet.

The possibility of a substantial eastward flux through Fury and Hecla Strait seems to be more likely. Calculations made of the cross-section of the strait at 84°20' west longitude show that a volume of 0.50 (10^6) m^3/sec. could be transported through this section in a constant residual current moving at a speed of slightly less than 1 knot. Of course this result implies that current speeds will be much greater in the restricted eastern end of the passage, but since surface flow of up to 2 knots has been reported in the wider parts of the channel it is plausible to assume that a transfer of this magnitude could take place through Fury and Hecla Strait. It is stated in volume 111 of the Pilot of Arctic Canada, on page 128:

"In the wider parts of Fury and Hecla Strait, H.M.C.S. LABRADOR experienced moderate currents, with a maximum of 2 knots to the eastward."

Thus, in spite of the remarkable comparison between the volume transport figures for Lancaster Sound and Prince Regent Inlet it appears, in the light of substantiating information from the tributary passages, that these results are generally valid.

TABLE XVI

Calculated volume transport through channels of the Lancaster Sound system, September 1957.

Inflow from Arctic Ocean	Volume transport, $10^6 m^3/sec.$
Wellington Channel	0.90
Barrow Strait	0.10
	1.00
Outflow into Baffin Bay, Foxe Basin	
Lancaster Sound	0.49
Prince Regent Inlet	0.51
	1.00
Annual southward transport, Lancaster Sound system	31,536 km^3/year
Annual eastward transport, Jones Sound	8,515 km^3/year
Total annual southward transport, Canadian Archipelago	40,051 km^3/year

Calculated Volume Transport - Arctic Archipelago

Current measurements were successfully recorded in Eureka Sound in May 1961 and from the data it has been established that the mean southward current velocity through this passage at a point where there is no evidence of anomalous circulation is 15 cm./sec. This estimate has been used to calculate the possible annual southward transport through Eureka Sound to be 9,461 km^3/year. Assuming that perhaps 10 per cent of this discharge is carried westward and eventually passes to the south through Wellington Channel and thus is already accounted for, 90 per cent of the Eureka Sound volume transport, that moving through Jones Sound into Baffin Bay, has been added to the total already determined as passing through the Lancaster Sound system. The final figure of 40,051 km^3/year as the total annual southward transport through the Canadian Archipelago agrees well with that proposed by Timofeyev (1956, 1960), Antonov (1958) and most recently Dunbar (1960). The results presented here compare favourably with the work of Kiilerich (1939) who estimated a total of $1.40(10^6)$ m^3/sec. for the net southward transport over the Davis Strait ridge. If Kiilerich's average of $0.44(10^6)m^3$/sec. is used for the contribution through Smith Sound, the estimated net transfer across Davis Strait with reference to the calculations described in this thesis would be $1.23(10^6)m^3$/sec. to the south, a figure which is also comparable to the total transport of $0.67(10^6)m^3$/sec. suggested by Bailey (1957).

Estimated Volume Transport Budget, Arctic Ocean

Recent translations of Russian studies of the mass balance of the Arctic Ocean present information which may be applied to the solution of the exchange budget between the Arctic Ocean and the Pacific and Atlantic Oceans; hence the resultant volume transfer through the Canadian Arctic Archipelago is inferred from the data.

Passages through which oceanic waters enter the Arctic Basin are the Norwegian Sea, primarily through the Faeroe-Shetland Strait and to a very minor degree through the passage between Spitzbergen and Greenland over the Nansen Ridge, and the Bering Strait. It is now known that a channel, the "Lena trough" with depths of 3000 metres or greater, exists through the Nansen Ridge, thus it can no longer be assumed that circulation through this passage is restricted above a limiting sill depth of 3000 metres (Volkov, 1961).

Water flows out of the Arctic Ocean through the passage between Greenland and Spitzbergen in the east Greenland Current which moves southward through the Denmark Strait carrying with it the greatest proportion of sea ice annually removed from the Arctic Ocean. The other outlets which carry Arctic water into the north Atlantic are Smith Sound and the passages of the Canadian Archipelago.

Although considerable work has been carried out in the Norwegian and Greenland Seas there still exists a most obvious discrepancy in the solution of the transport balance. Russian investigators have established that the principal exchange of water between the Arctic and the Atlantic Oceans takes place between Songnefjord, Norway and Iceland via the Faeroe-Shetland Strait, and also through the Denmark Strait. Kiilerich (1945) proposed that the Atlantic influx through the Barents Sea and to the west of Spitzbergen may be roughly estimated at 63,000 km^3/year. Timofeyev (1956, 1960) has calculated that the annual influx of water into the Arctic Ocean through the Faeroe-Shetland Strait is 152,074 km^3/year and Treshnikov (1960) has suggested 128,500 km^3/year as the net northward transfer of water through this passage.

The determination of the southern flow through the Denmark Strait is even less reliable. Kiilerich (1945) was unable to calculate the transfer of water through this passage on account of the many eddies which would make the course of the reference level too irregular; his estimate of 46,400 km^3/year is based on current speeds determined from the drift of ships in the east Greenland current. More recent estimates for the discharge of Arctic water southward through the Denmark Strait are published by Timoveyev (1960) 160,658 km^3/year, and Treshnikov (1960) 159,500 km^3/year. To the latter figure is added 200 km^3 representing the water which is annually carried southward in the form of ice. The final figure of 159,700 km^3/year is remarkably similar to Timofeyev's estimate and is accepted as most reliable.

The combined total outflow from the Arctic Ocean through the passages of the Canadian Archipelago including Smith Sound is calculated to be 53,927 km^3/year. Coachman and Barnes (1961) show that the average annual influx of Pacific water into the Arctic Basin through Bering Strait is 31,536 km^3/year and Antonov (1958) states that each year 4,380 km^3 of water enter the Arctic Ocean as a result of continental drainage. Based on these figures a tentative transport account of the Arctic Ocean is presented in Table XVII.

TABLE XVII

Volume transport budget, Arctic Ocean.

Inflow into Arctic Ocean	km^3/year
Faeroe - Shetland Strait	152,074
Bering Strait	31,536
Continental drainage	4,380
	187,990
Outflow into Baffin Bay, Atlantic Ocean	
Denmark Strait	159,700
North American Arctic	53,927
	213,627

The discrepancy in the balance does not preclude the general validity of these figures since the possible deviation in the transport balance in the Greenland-Norwegian Sea is itself at least as large as the difference between the inflow and outflow totals in Table XVII. Zaicev (1961) has pointed out that the Russian figures for the exchange balance in the Greenland-Norwegian Sea produce a total flow through a profile along the 80th parallel that is much too great for the section.

It appears that the flow determinations for the Bering Strait and Davis Strait are the best established factors in this equation. Thus, the transport calculations for the Canadian Archipelago must be of the correct order of magnitude. It is possible that the exchange through the Norwegian and Greenland Seas is much too high. Nevertheless, the influx of Atlantic water from the south into the Norwegian Sea must be equal in volume to that discharged in the opposite direction and the circulation of Arctic water within the Norwegian Sea will have little effect on the volume transport budget of the Arctic Basin.

Such determinations are of course first approximations for which it must be assumed that atmospheric precipitation and evaporation are equal and that the export of ice from the Arctic Basin takes place mainly through the straits between Spitzbergen and Greenland (Gordienko and Laktionov, 1960; Timofeyev, 1960).

In summary, attention should be drawn to the fact that there is evidence of rapid, large scale variations in the volume of flow through Lancaster Sound. A comparison of the volume transport through each of the 1957 Lancaster Sound sections makes it apparent that considerable differences existed between each of these sections even though the intervening time lag was relatively short. In 1956 the net transport through the eastern end of the passage was of the same order of magnitude but in the opposite direction (Collin, 1958). Kiilerich (1939) comments on the improbability of arriving at a theoretical estimate for the volume exchange through a channel in which strong eddy movements are common and Bailey (1957), commenting on this discrepancy, suggests that perhaps the flow through the channels leading into northern Baffin Bay is influenced by the atmospheric pressure gradient between Baffin Bay and the Arctic Ocean.

The 1957 observations in Lancaster Sound show the effect of the apparent tidal fluctuations that take place through this passage. The evidence contained in the longitudinal profile and in the horizontal distribution of temperature and salinity (Figs. 21, 14, 15) suggests that it is the tide in conjunction with the predominant wind that causes the remarkable variation in current and volume transport that has been recorded in Lancaster Sound.

CHAPTER X

DISTRIBUTION OF DISSOLVED OXYGEN AND INORGANIC PHOSPHATE

Determinations of dissolved oxygen and inorganic phosphate were carried out at 33 stations during the 1956 cruise and at 57 stations in 1957. The standard Winkler method was used for the oxygen analysis and the inorganic phosphate determinations were carried out in a custom built spectrophotometer (Barnes, 1959; Strickland and Parsons, 1960). A number of the phosphate observations are doubtful owing to electrical failure in the instrument, nevertheless, accurate data are available for the entire region. The average dissolved oxygen content and the per cent saturation for selected depths in Lancaster Sound and the adjoining channels for September 1956 are presented in Table XVIII.

TABLE XVIII

Average Oxygen Concentration in ml./l. and Per Cent Saturation for the Lancaster Sound System September 1956.

1956

Depth m	ml./l.	Per Cent Saturation
surface	8.4	101
20	8.4	101
100	7.1	85

The oxygen values recorded in 1957 present an interesting comparison with those of 1956. At the time of the earlier cruise average oxygen content varied from 7.1 to 8.3 ml./l. in Lancaster Sound and from 7.2 to 8.6 ml./l. im Prince Regent Inlet and the Gulf of Boothia. These data represent saturation values of 85 per cent to 101 per cent. The mean meridional distribution of dissolved oxygen in the Atlantic leads one to the assumption that the 1956 oxygen observations represent the normal condition in these waters and that any significant deviation of this parameter is the result of large fluctuations in the biological cycle or a change in the character of the water masses (Richards, 1957). Such a condition could be the result of unseasonal weather trends causing a large scale variation in the plankton cycle and unusual ice distributions or an extensive disparity in the circulatory system caused by conditions remote to the region in question. The 1957 oxygen determinations are uniformly lower than those recorded in 1956. The difference in these two sets of data has led to an investigation of the reliability of the original observations and a study of any possible mechanism that would account for this deviation.

Average content of dissolved oxygen in the Lancaster Sound system in September 1957 varied from a mean of 5.0 ml./l. at the surface to slightly over 4.0 ml./l. at the bottom. These figures produce saturation values much lower than those reported in 1956 and require an explanation involving more than the biological deoxygenation of the water. Another noteworthy feature of the 1957 oxygen profiles is the lack of a well defined maximum within the upper 20 metres. Normally, profiles of dissolved oxygen content show a distinct maximum within the top 20 metres and a secondary maximum between 20 and 50 metres. This condition is a result of continued aeriation at the surface and the photosynthetic production of oxygen within the photic zone. Below the compensation depth the respiratory consumption of oxygen exceeds the production of oxygen and the net change is a loss, even though the photosynthetic production continues. The penetration of light is accepted as the most important factor determining the depth of the compensation zone but temperature, differences in the species of plankton, and the nutrient supply are also important (Harvey, 1955, pp. 32-36).

Oxygen is consumed by the respiration of plants and animals, including bacteria, at all depths in the ocean. The consumption is controlled by the quantity of organic matter which can be produced in the water and, under normal circumstances at sea, is balanced by the ventilating processes so that the oxygen content is never exhausted. However, under certain hydrographic conditions the subsurface circulation is restricted and the oxygen balance is disturbed. This situation obtains in the Black Sea and in certain well-known threshold fiords where the circulation of the deep water is limited by the configuration of the bottom (Sverdrup, 1942, p. 651). In such regions the oxygen content is low and in extreme cases the anearobic metabolism of bacteria produces hydrogen sulphide.

There is little recent information available on the consumption of dissolved oxygen at sea under natural conditions. Riley (1951) has prepared a table which gives the oxygen consumption in ml./l. per year for various sigma-t surfaces in the Atlantic Ocean. The value given for the natural loss of oxygen on the 26.5 sigma-t surface is 0.21 ml./l. per year. This fugure can be taken as a rough approximation of the annual oxygen consumption which would take place at a depth of about 100 metres in the Lancaster Sound region. If no oxygenation took place at this level through replenishment by water of higher oxygen content or photosynthetic production by plants within the photic zone, a decrease of 0.21 ml./l. per year would be expected. It is apparent that within this depth range the circulation pattern in Lancaster Sound would make this an extremely unlikely situation.

Consequently, it is improbable that biological activity can account for the marked difference in the oxygen content which apparently took place between September 1956 and September 1957. To accept these values, therefore, it is necessary to assume a recent large scale volume exchange in this system which would result in the influx of water of low oxygen content and temperature and salinity characteristics similar to those observed in Lancaster Sound.

Water of similar oxygen characteristics has been defined in the deeper levels of Baffin Bay to the east of Lancaster Sound. Riis-Carstensen (1936) has described these conditions at "Godthaab" station 145 and Smith, Soule, and Mosby (1947) have shown that oxygen values in this area decrease from 6.0 ml./l. at a depth of 400 metres to a minimum of 3.6 ml./l. at 2000 metres; the per cent saturation at this depth range is between 52 per cent and 60 per cent, similar to that observed in the study region. Richards (1957) has suggested that the formation of oxygen-poor water in the deeper sections of northern Baffin Bay is the result of weak circulation and states that on occasion water containing about 5 ml./l. dissolved oxygen can flow across the Davis Strait ridge into the Labrador Sea where it has been observed as an oxygen - minimum layer. The limiting depth through Davis Strait is approximately 500 metres, less than the mean depth in the eastern end of Lancaster Sound.

The temperature and salinity characteristics of the low oxygen water of Baffin Bay are similar to those of the deep water of Lancaster Sound, thus, the density gradient does not preclude the lateral transfer of this water from Baffin Bay westward into Lancaster Sound. This has already been shown to be a characteristic feature of the circulation pattern; however, the possible influx of deep Baffin Bay water into Lancaster Sound cannot possibly account for the existence of abnormally low oxygen values throughout the entire water column, since density considerations exclude the possibility of intermediate and surface water of Lancaster Sound originating at depth in Baffin Bay. For this reason it must be accepted that the 1956 oxygen data are correct and that the observations reported in 1957 do not depict the normal distribution of dissolved oxygen in these waters.

Representative Dissolved Oxygen Content

Dissolved oxygen figures representative of Lancaster Sound in summer and of the Arctic Ocean in late winter, expressed in cubic centimetres per litre are given in Fig. 29. The oxygen content for Lancaster Sound is consistently higher in the 0-40 metre layer and shows a much steeper increase directly at the surface. The maximum at 20 metres is well formed in Lancaster Sound and the Arctic Ocean station shows a similar secondary maximum at 50 metres. The obvious comparison is at the 150 metre level where the T-3 curve shows a distinct minimum of 5.56 ml./l. and the Lancaster Sound graph reaches a high of 7.26 ml./l.

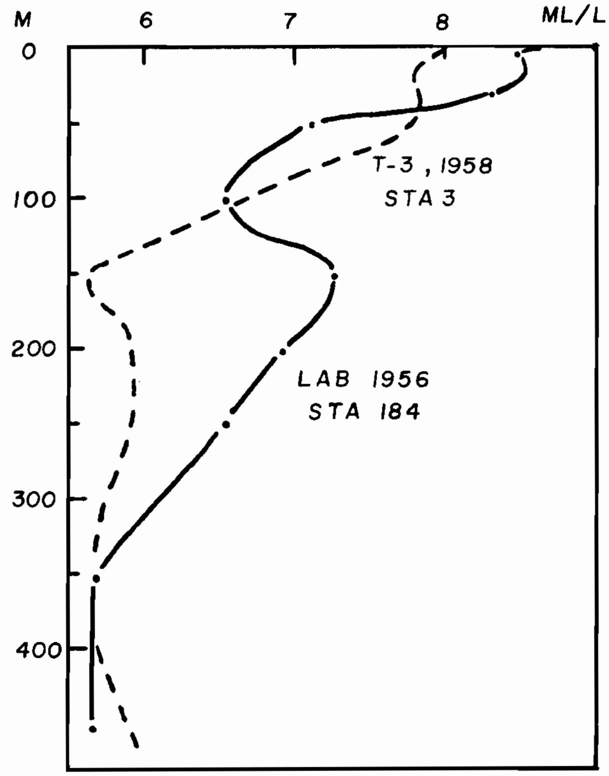

Fig. 29 Content of dissolved oxygen, Lancaster Sound, Station 184, Arctic Ocean, Station 3.

The Arctic Ocean oxygen minimum at 150 metres is coincident with the persistent temperature minimum at this depth discussed on page 140 and its origin can probably be traced to the mixing of Bering Sea water and shelf water which forms on the adjacent, shallow continental platform. The dissolved oxygen minimum in Lancaster Sound at 100 metres is typical of eastern Arctic waters and is apparently the result of winter decrease in oxygen content within the upper 100 metres.

Distribution of Inorganic Phosphate

A limited investigation of the inorganic phosphate content was undertaken in 1956 and 1957 to gain an indication of the nutrient concentration in these waters.*

The 1957 values are somewhat lower than those recorded in 1956 but the gradation with depth is similar (Table XIX).

In 1956, variations from 1.00 to 1.88 mg.- at./l** were found at the surface where the average concentration was 1.37 mg.-at./l. Generally, a minimum concentration of 0.83 to 1.42 mg.-at./l. was found at 10 metres, but in several localities the lowest content occurred at 20metres. Below the depth of the phosphate minimum, concentrations increased to a maximum at 75 to 100 metres where values from 1.47 to 2.22 mg.-at./l. were common. Below 100 metres values generally decreased with depth to 1.50 mg.-at./l. at 200 metres.

The 1957 data show a spread of surface values from a trace to 1.61mg.-at/l. with an average of 0.70. A distinct minimum, with average values at 0.28 mg.-at./l., was a constant feature at a depth of 10 metres and a maximum of approximately 1.13 mg.-at./l. normally occurred at 100 metres. The depth of the minimum layer was quite constant, whereas the depth of the phosphate maximum varied from 75 to 150 metres.

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* Strickland and Parsons (1960) define the expression "inorganic phosphate", as used in the literature, as the total content of inorganic and organic reactive phosphorus in addition to the inorganic or organic phosphorus that is adsorbed onto particles or is otherwise out of solution in sea water, but which becomes soluble and takes part in the chemical determination.

** Milligram-atom per litre = weight of the element in milligrams divided by its atomic weight per litre, (mg.-at./l.), Harvey, 1957, p. 228).

TABLE XIX

Average Inorganic Phosphate Content in Milligram-atoms per litre,

Lancaster Sound, September 1956, 1957.

	1956	1957
surface	1.37	0.70
10 m, minimum	1.10	0.28
100 m, maximum	1.85	1.13

SUMMARY

Within recent years Canada has undertaken oceanographic research in the channels of the Arctic Archipelago and in the waters bordering these islands. This thesis is a description of the oceanographic parameters identified in the eastern Arctic and a partial analysis of the marine conditions. The work is based upon field investigations conducted in the eastern Arctic from H.M.C.S. "Labrador" during the summers of 1956 and 1957 and the discussion is complemented by observations recorded in the Arctic Ocean from the ice-island T-3 during the period May to October, 1958. In September 1959, further observations were taken in northern Foxe Basin and Hudson Strait from C.G.S. "Labrador" and in 1960 and 1961 additional oceanographic information was obtained at 11 stations in the passages of the western archipelago. These data have contributed the first description of subsurface conditions in these waters and are considered in the thesis.

Geographic and scientific exploration in the area is at present progressing with renewed vigour, the result of pressing national demands for information of economic and strategic importance. Hydrographic surveying, work largely the responsibility of the seasonal supply vessels prior to 1955, is now of immediate significance and oceanographic research is urgently required in all phases of the Arctic marine environment.

Depth of water through Parry Channel is now known to vary from 600 fathoms in Pond Inlet to a limiting depth of about 100 fathoms through Barrow Strait; within the main channel the greatest

depth of over 500 fathoms occurs in the eastern end of Lancaster Sound. Depths of over 200 fathoms are consistent in Prince Regent Inlet, and in Wellington Channel the depth of water increases from 75 fathoms in the southern end to 180 fathoms in the north.

All the eastern Arctic passages exhibit a typical "U" shaped cross-section and most show bathymetric features indicative of glacial activity; however, the bottom topography of Prince Regent Inlet appears to differ from the typical form thus leading to the assumption that a recent ice margin was situated across Prince Regent Inlet in the vicinity of Bellot Strait.

Ice conditions in the Canadian Arctic Archipelago limit the navigation season for surface vessels, although it is usually possible for an ice-strengthened ship to navigate these waterways during the latter part of August and most of September each year. Recent ice reconnaissance information indicates that restricted areas of open water form in Lancaster Sound in May and reinforced ships may proceed as far west as Resolute Bay by late July. Periodic influx of ice from Barrow Strait and Wellington Channel causes occasional increases in the ice concentration during the summer but generally Lancaster Sound remains open until late September, at which time young ice forms rapidly along the protected shore.

Regional averages of temperature and salinity have been computed for all standard depths for 1956 and 1957. Little variation of temperature between the north and south sides of Lancaster Sound was apparent in 1956, at which time normal temperatures at the surface were from -0.9° to -1.4°C with an increase with depth to 0.5°C at the bottom. Salinity values ranged from 32.37‰ at the surface to a constant value of 34.40‰ at 500 metres.

Extremely low temperatures of -1.7°C were recorded in Barrow Strait in September 1956, but this appears to be an exceptional case. Average temperatures in Prince Regent Inlet and Wellington Channel were in the range -1.5° to -0.8°C.

Averages of temperature and salinity computed from the 1957 data show significant deviations from the 1956 readings. The 1957 temperatures are considerably higher than the 1956 observations within the upper layers while below 30 metres the 1957 temperatures in the south section of Lancaster Sound are similar to, if not lower than the 1956 figures. Salinity averages in the eastern end of Lancaster Sound for 1956 and 1957 show that in 1956 lower salinity values were found in the northern side of the passage, whereas, in 1957, the lower salinity averages occurred at the southern stations. Initial observations of physical conditions in Peel Sound and Franklin Strait indicate that in this region subsurface temperatures lie in the range of -0.2° to -1.3°C and that salinity content increases from a minimum of 23.50‰ at the surface to 33.00‰ at 300 metres. In Wellington Channel seasonal conditions are characterized by temperatures of -0.3° to -1.6°C and salinity values from 31.79‰ to 32.88‰. Average conditions in Penny Strait, at the most northerly station of the 1957 cruise, were similar to those recorded in Wellington Channel. At this station the range of temperature and salinity throughout the water column was -0.7° to -1.5°C and 31.60‰ to 33.41‰.

Charts and graphs of the horizontal distribution and the vertical stratification of temperature and salinity are presented for Lancaster Sound and the various connecting waterways. The diagrams of horizontal distribution show a linear pattern which follows the current configuration at these levels, and the vertical sections illustrate the pronounced surface stratification in the passages and the similarity of the water characteristics through the system.

Temperature-salinity diagrams have been used in an analysis of the water masses. The outstanding features of the T-S relationship are the uniformity of the properties of the water within the upper layers and the marked similarity of the Lancaster Sound and Baffin Bay waters below a marginal depth of 200 metres. A comparison of the T-S curves for each section of Parry Channel shows that, within the zone 0-200 metres, T-S characteristics are identical, whereas, on opposite sides of Barrow Strait contrasting T-S components indicate dissimilar water masses at depths greater than 200 metres.

A schematic representation of the influx of water of Baffin Bay origin into Lancaster Sound shows that in 1957 this water intruded into the channel as far west as Prince Regent Inlet and in the eastern end of the passage was detected at all depths below 250 metres. An analysis of the equivalent thickness of the Baffin Bay intrusion from all information available for the region, reveals that at the time of the 1957 cruise the Baffin Bay influx was almost 22 per cent greater than that indicated in any of the previous data.

Within the limitations imposed by shallow water, currents have been calculated by means of an investigation of the topography and the salinity distribution along the 26.5 sigma-t surface and by routine dynamic computations. It is shown that the dominant flow through Lancaster Sound is to the eastward but that significant movement to the westward into Lancaster Sound from Baffin Bay is common and on occasion predominates.

The calculated surface velocities in Lancaster Sound indicate a maximum of 50 cm./sec. in the eastern end of the channel, while at depth, velocities decrease rapidly to about 15 cm./sec. at 100 metres.

The total net volume transport through the Lancaster Sound system has been determined at $1.0(10^6)m^3$/sec. of which 0.49 $(10^6)m^3$/sec. pass to the eastward through Lancaster Sound into Baffin Bay. This figure is in accordance with observations reported by earlier investigators and, when combined with the exchange determined for Jones Sound ($0.29(10^6)m^3$/sec.), and an average figure of $0.44(10^6)m^3$/sec. recorded previously for the southward transport through Smith Sound, results in a total of 39,000 km^3/year for the combined net southward transfer across the Davis Strait ridge. The final figure arrived at for the total southward flux from the Arctic Ocean through the Canadian Arctic Archipelago is 40,051 km^3/year. It appears that a significant north-south volume flow of $0.50(10^6)m^3$/sec. takes place through Wellington Channel and Prince Regent Inlet.

The combined total outflow from the Arctic Ocean through the passages of the Canadian Archipelago including Smith Sound is calculated at 53,927 km^3/year. When this figure is considered in the light of recent information on the total volume exchange between the Arctic Ocean and the Atlantic and Pacific Oceans the discrepancy in the balance is small, indicating that this figure is a close approximation of the true value.

Dissolved oxygen figures are presented for summer conditions in Lancaster Sound and the Arctic Ocean. The surface maxima of 7.90 and 8.60 ml./l. are identifiable in both curves and a second maximum between 20 and 50 metres is also apparent. The conspicuous difference in the dissolved oxygen content at the two localities is at the 150 metre level, where a typical minimum of 5.60 ml./l. is recorded at the Arctic Ocean station and a secondary maximum of 7.26 ml./l. appears in the Lancaster Sound graph. The minimum at 150 metres at the T-3 station is coincident with a temperature minimum at this depth and is possibly the result of mixing between Bering Sea water and the colder shelf water.

Determinations of inorganic phosphate recorded in Lancaster Sound in the summers of 1956 and 1957 show a variation of from 1.37 to 1.85 mg.-at./l. with depth in 1956 and a range of 0.70 to 1.13mg.-at/l. in 1957. In both instances the higher values were recorded at the 100 metre level.

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RECORD OF OBSERVATIONS

The measurements and observations discussed in this thesis were recorded during the summer months of the years 1956-1961. The detailed sampling in the Lancaster Sound region was conducted from the Canadian icebreaker "Labrador" in 1956 and 1957 and in September and October of 1959 further investigations were completed from this vessel in northern Foxe Basin and Hudson Strait.

In 1956 extensive scientific and survey commitments were carried out aboard H.M.C.S. "Labrador" in the eastern Arctic in the period July 3 to October 13. The scientific investigations included physical oceanography, marine biology, sea ice physics, hydrography, and sea ice navigability. In the course of the summer, hydrographic surveys were conducted at several locations on the coast of Baffin Island and Foxe Basin in addition to extensive reconnaissance surveys in the Gulf of Boothia, Prince Regent Inlet and Lancaster Sound.

The oceanographic programme was concentrated in Foxe Basin and Foxe Channel but passage through Fury and Hecla Strait and Prince Regent Inlet made it possible for additional, preliminary oceanographic observations to be recorded in these hitherto unsampled waters.

The 1956 oceanographic observations carried out in the waters north of Fury and Hecla Strait included:

42 oceanographic stations
336 salinity determinations
169 oxygen determinations
169 phosphate determinations
42 bathythermograph lowerings
25 bottom samples
25 plankton collections

The 1957 "Labrador" cruise had a major hydrographic survey as a primary commitment, nevertheless, favourable weather and ice conditions enabled the oceanographic programme in the Lancaster Sound area to be completed and expanded to include Prince Regent Inlet, the Gulf of Boothia, Peel Sound, Franklin Strait, and Wellington Channel. The most northerly oceanographic observations were taken at 76°40' north, in Penny Strait. During the summer of 1957 H.M.C.S. "Labrador" was at sea from June 25 to October 11, a total of 109 days. The oceanographic survey was highly successful in that, in addition to the proposed project, reconnaissance investigations were completed in Peel Sound, Franklin Strait and Wellington Channel. The programme was divided into sections each consisting of an individual unit of the Lancaster Sound system and each unit was completed as a separate segment. In this way the time lag was reduced to a minimum thereby increasing the reliability of the synoptic data.

The 1957 Arctic oceanographic programme resulted in the following observations:

120	oceanographic stations
218	bathythermograph lowerings
1440	salinity determinations
682	oxygen determinations
682	phosphate determinations
104	bottom samples
25	bottom cores
50	plankton collections

Current measurements and tidal observations were conducted in Bellot Strait when weather and ice permitted and a continuous record of ice concentration and weather conditions was maintained by the ship's meteorological office.

During the summer of 1958 an extensive oceanographic programme was conducted on the I.G.Y. drifting station T-3, at that time in the vicinity of 78° north, 124° west, in the Arctic Ocean. This project was under the administration of the United States I.G.Y. Committee and was directed by the Air Force Cambridge Research Centre. Data collected on T-3 between May and September 1958 have been taken as representative of the western Arctic for the purpose of comparison and are embodied in the thesis.

In May 1959 several oceanographic stations were successfully occupied in the southern Beaufort Sea. This work was undertaken at the invitation of the Arctic Research Laboratory of the United States Office of Naval Research. In September of the same year further oceanographic observations were recorded in northern Foxe Basin and Hudson Strait from C.G.S. "Labrador".

Seventeen oceanographic stations were occupied in the passages of the western Arctic Archipelago and across the Arctic continental shelf in April and May 1960. This survey was continued in April and May 1961 at which time a series of stations was completed across the western end of M'Clure Strait and current measurements and subsurface conditions recorded in Eureka Sound. At the same time additional observations of dissolved oxygen were carried out in the coastal waters in the vicinity of Isachsen, N.W.T.