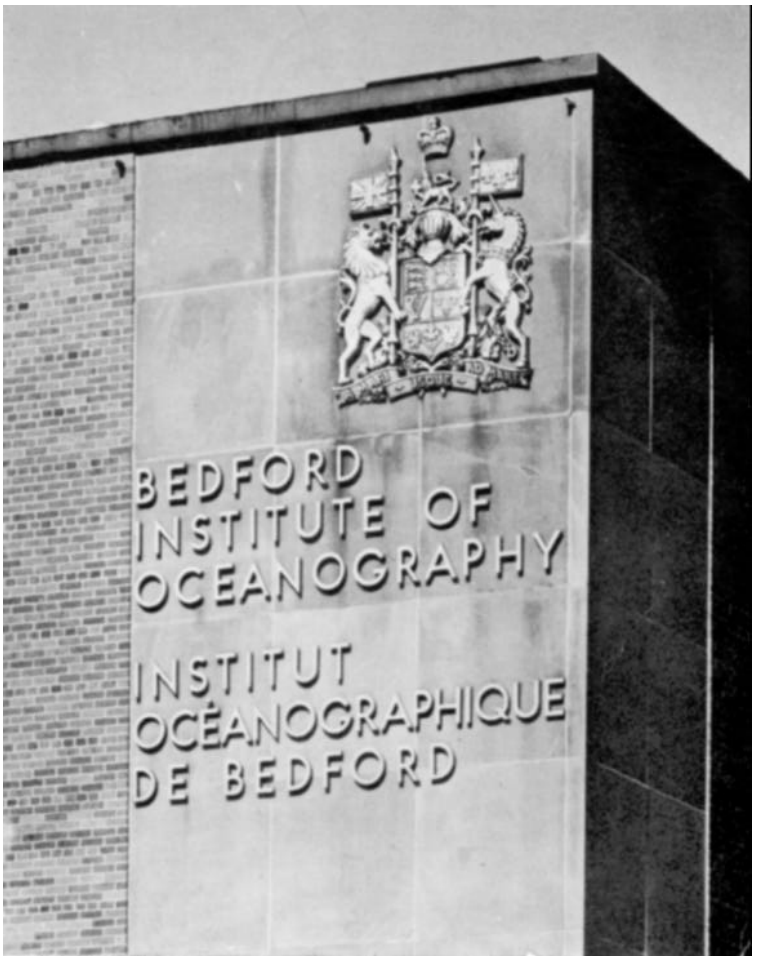
ToC



FIFTH ANNUAL REPORT

1966

Report BIO 66 - 10

BEDFORD INSTITUTE OF OCEANOGRAPHY

FIFTH ANNUAL REPORT

1966

Part A The Annual Report For 1966 of the Atlantic Region, Marine Sciences Branch, Department of Energy, Mines and Resources. *

Part B The Annual Report for 1966 of the Dartmouth Laboratory of The Fisheries Research Board of Canada.

Report BIO 66-10

* Formerly Department of Mines and Technical Surveys. The new title came into use October 1, 1966.

(This page Blank in the original)

Foreword

It has been a matter of national policy for some years to increase substantially the scale and scope of Canadian oceanographic research and survey. A major step in the implementation of this policy was the creation of the Bedford Institute of Oceanography (BIO). It was conceived as and has become an organization which brings together in one place a broad spectrum of the scientific, engineering, and technical disciplines, as well as support facilities, notably ships, essential to the effective realization of its purpose. BIO was opened in mid-1962 and by the end of 1966 had a combined complement of over 600 persons.

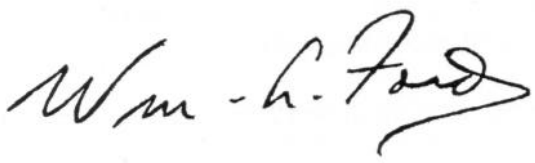
The research activities of BIO, as part of the national oceanographic program, come under the aegis of the Canadian Committee on Oceanography. This committee, on which eight agencies of the Federal Government and four universities are represented, is the central coordinating and policy recommending body for Canadian oceanography.

Of the several units comprising BIO, the largest is the Atlantic Region, Marine Sciences Branch (MSB), Department of Energy, Mines and Resources (DEMR). The Branch was established in 1961 to combine the operations of the Canadian Hydrographic Service and marine research in the physical and geosciences. This wide spectrum of activities is reflected in the program of the Atlantic Region which embraces physical and chemical oceanography, air/sea and air/ice/sea interactions, marine geology, tides and currents, hydrographic charting, and, in support of all of these, instrument research and development. The buildings of the Institute, five ships, *CSS Hudson, Baffin, Kapuskasing, Acadia,* and *Maxwell,* and some 35 survey launches, are operated by the Atlantic Region, MSB.

The second largest unit in BIO is the Dartmouth laboratory of the Fisheries Research Board of Canada's (FRB). It is an independent entity within BIO with its own Director, research programs, and administration responsible to the Chairman of FRB in Ottawa. Up to 1965, its main area of research was in the field of environmental oceanography in coastal and shelf waters of interest to fisheries. It employed a staff in the fields of physical and chemical oceanography, geology, and geochemistry, as well as a small group in biological oceanography. The biological field of research is in the process of considerable expansion into new investigations concerned with the measurement of the production, abundance, and distribution of fish and their foods in close conjunction with the environmental studies. CNAV *Sackville* is allocated by the Royal Canadian Navy to FRB, Dartmouth, and is included in BIO's ship pool. In addition, the biological research vessels MV A T *Cameron* and MV E E *Prince* are programmed jointly by FRB, Dartmouth Laboratory and the other biological stations on the east coast in St. Andrew's, New Brunswick and St. John's, Newfoundland.

BIO houses the Secretariat of the International Commission for the Northwest Atlantic Fisheries (ICNAF). While Mr L. R. Day, Executive Secretary, and his staff of five, participate in and contribute to the general scientific life in BIO, they are not directly concerned with its program. Also accommodated in BIO are several small groups from other branches of DEMR engaged in activities unrelated to oceanography. Accordingly, the work of ICNAF and of these other groups is not included in this report.

In keeping with the underlying objective of building a strong marine research community through effective collaboration, based upon the mutual interests of the many disciplines here represented, this Annual Report of BIO is presented as a joint undertaking.



Wm. L. Ford,
Director, BIO, for
Marine Sciences Branch,
Department of Energy, Mines
and Resources.

L. M. Dickie,
Director,
Fisheries Research Board,
Dartmouth, in BIO.

HOME

Table of Contents

Part A - Atlantic Region, Marine Sciences Branch, Department of Energy, Mines and Resources

Part B - Dartmouth Laboratory, Fisheries Research Board of Canada

Part A

The Annual Report for 1966 of the Atlantic Region, Marine Sciences Branch, Department of Energy, Mines and Resources

(This page Blank in the original)

Part A

The Annual Report for 1966 of the Atlantic Region, Marine Sciences Branch, Department of Energy, Mines and Resources

Director's Remarks

Nineteen sixty-six, the fourth full year of operation of the Bedford Institute of Oceanography (BIO), was a time of coming of age for several of our programs. The build-up of staff, equipment, and technique, which absorbed so much of the effort in previous years, began to yield increased dividends in the productivity of field work, in services to the economy, and in scientific publications. This growth emphasized problems of organization peculiar to research and survey activity, covering a wide range of interdependent scientific, engineering, and support disciplines. In 1966, the designed capacity of the existing establishment was reached, and there is every indication of continued growth. Accordingly, plans have been made for additions, extending over the next 4 years, to accommodate the anticipated increase in staff.

After several years of investigation of the physical oceanography of the Gulf Stream system, in the region between the Grand Banks and the Azores, an atlas of the data and a paper presenting a new concept of the major mass transports in this area have been produced. A 2-month cruise in CSS *Baffin* in 1966 enabled us to gain further information about the system. In addition, a good start was made on tackling the challenging problems of the mechanism of formation and the rate of production of the deep waters of the North Atlantic. In late winter, 143 oceanographic stations, each extending to the bottom, and covering virtually all of the Labrador Sea, were occupied by CSS *Hudson*. Planning and preparations were completed for a more extensive and comprehensive cruise by *Hudson* to the Irminger Sea and Denmark Strait in the first 3 months of 1967. This cruise is a joint undertaking of physical oceanographers from the National Institute of Oceanography, Woods Hole Oceanographic Institution, and BIO.

In the broad program of marine geophysics, the investigation of the Mid-Atlantic Ridge continued to play a prominent part. The 1966 program was built upon the experience and success of the 1965 cruise of *Hudson* which examined in detail the bathymetry and the gravity and magnetic anomalies of a 60 X 20 mile area centred at 45°30' N lat and 28° W long over the rift valley of the Ridge. In 1966, again by *Hudson*, comprehensive exploration was extended westward in a 60-mile wide section, with the object of answering questions concerning the structure of the flanks of the Ridge. Perhaps the greatest accomplishment of this cruise was the full utilization of a technique for producing on-the-spot bathymetric, magnetic and gravitational maps of the area, and then using the knowledge gained to determine the most interesting and promising places at which to sample the bottom by coring, photography, and dredge hauls. This technique was made possible by the now reliable data logging and processing system, Geodal, developed by the scientists of the electronic instrument research and design group in BIO. While the full scientific results of the cruise must await completion of detailed study of the great mass of data obtained, some significant findings have already emerged and are reported in the section on Marine Geophysics (p. 25).

An intensive study, begun 3 years ago, on the growth of polar sea ice and on related processes in the sea water beneath is now yielding results. The temperature field as a function of time in a developing ice sheet at Cambridge Bay, Victoria Island, in the Northwest Territories, has been precisely observed and an analysis of the results reported in a recent paper. The process of salt ejection from the ice as it grows and the resultant effects in the sea water below have been studied both in the field and in a laboratory model. The latter work is leading to quantitative information about the dynamics of the streamers of salt-rich water which flow downwards from the ice/sea water interface.

The hydrographers of the Canadian Hydrographic Service in BIO were engaged in charting and tidal projects extending from the Arctic Archipelago to the southern extremity of Nova Scotia. The major undertaking was the Grand Banks survey, the result of which will be the first modern detailed charts of this great shelf. In 1966 ,35,825 sq. miles of the southern part were charted by

CSS *Baffin*. For about half the area, continuous recordings were obtained from a towed magnetometer and a shipborne gravimeter; next year, it is intended to have full magnetic and gravity coverage; completion of the entire survey is expected to take another 2 years. The key to the survey was the successful deployment of a long-range system of position-fixing which permitted the coverage with a position accuracy of approximately 700 ft to reach the outer limits of the Bank, about 500 miles from the base line. The line ran from Sable Island to Lance Point, Newfoundland, the location of our slave stations. Modifications to the Decca Lambda position-fixing system, made by the Engineering Services Section of BIO, resulted in the 25% gain in range, i.e., from about 400 to 500 nautical miles, needed to cover the region of the survey.

The continuing program of marine geological investigation of the continental shelf encompasses a wide variety of projects. Field work extends from the Arctic to the Bay of Fundy and includes such major embayments as Hudson Bay and the Gulf of St. Lawrence. Of more than usual interest is the progress made in delineating the sedimentary structures underlying the Scotian Shelf by the study of exposed strata along the continental slope, culminating in the recovery of rock samples bearing significant amounts of hydrocarbons. The samples were in the form of fresh blocks of siltstone torn from outcropping strata of the wall of the canyon known as "The Gully", mostly in the depth range 750-1,500 m a few miles to the east of Sable Island.

Because significant advances in the exploration of the sea are dependent upon the creation of ingenious, reliable, and soundly-designed instruments, research on and development of specialized instrumentation continued to play an important part in support of our scientific investigations and survey operations. Mention has been made already of the Geodal; another example is a device for retrieving sample cores of a few inches in length from bedrock in oceanic depths, an objective of great interest to the marine geologist and geophysicist. The rock core drill, which uses the hydrostatic pressure of the sea to provide the energy for drilling, has been successfully demonstrated at sea. Realization of its full potential, however, requires the development of more precise means than are presently available for placing the drill on bedrock outcrops.

Computer services at BIO have experienced tremendous growth since the installation of a CD3100 machine in late 1965 and the acquisition of two PDP-8 units in 1966. Growing demands being made on these facilities, by virtually every segment of BIO, point to the need for an immediate expansion of the capacity of the main computer, and the purchase of additional units for on-line data handling systems, which would be used chiefly at sea.

The temporary employment during each summer of selected students from universities and institutes of technology continues to receive considerable emphasis, because of the importance of interesting them in the work of BIO and of obtaining a preliminary appraisal of them as potential permanent staff members. A secondary consideration is their significant value as assistants to the regular staff in both field and laboratory projects during the busy summer season. This year, 30 university and 17 institute of technology students were employed by the Marine Sciences Branch (MSB) in BIO under this program, see Appendix A-4, (p. 77).

Continued growth in staff and experience has generated the need for certain changes in organizational structure; two of these were of a major nature. What had been for several years the Engineering Service Section was divided into two : one part became a new Section called Metrology responsible for research, design and development in the field of specialized oceanographic instrumentation directly related to the overall program of the laboratory; the other part retained the name Engineering Services Section and the responsibility for general engineering support functions including the care and maintenance of most of the electronic equipment in the laboratory and the ships. The division was motivated by recognition of the functional differences between the two activities and the need for a more rational grouping of personnel and functions. It has already resulted in improved response to the growing demands for services.

The other major organizational move, the formation early in the year of a new Section, Applied Oceanography, brought under single leadership scientists from both the Dartmouth Laboratory of the Fisheries Research Board (FRB) and the Atlantic Region, MSB, in BIO, together with a pooling of physical resources as required by individual projects. As the name implies, the Section is concerned with projects in which the use of the research results is clearly defined, as, for example, in the development of techniques for forecasting oceanographic conditions of interest to fisheries; or the study of the

heat budget of such area as the Gulf of St. Lawrence, from the point of view of the potential for ice formation. Although not yet a year old, the experiment has proved itself administratively viable, and the Section has developed a fine spirit of cooperation which augurs well for the future.

As explained in the Foreword, BIO houses not only the Atlantic Region of MSB, but also the Atlantic Oceanographic Group of FRB, the International Commission for the Northwest Atlantic Fisheries and certain other groups. It is, therefore, appropriate to comment here on the pattern of growth for the entire organization, relevant statistics for which are given in Table 1. The overall growth in 1966 was about 60% of a projection made a year ago and nearly all of the deficiency occurred in the MSB sector (see column one, Table 1). A part of the lag is attributed to the difficulty in recruiting suitably qualified persons in today's tight employment market. The main cause of the lag arose from a delay in the release of positions against which to hire technical and clerical support personnel--a consequence of the major reorganization of personnel management currently underway in the Civil Service of Canada coincident with preparations for the introduction of collective bargaining. However, later in the year the positions became available and an active recruitment campaign for technicians and other support staff was undertaken which promises to overcome most of the deficiency by early in the new year. Therefore, although somewhat delayed, the central objective of the MSB personnel recruitment plans in 1966, the provision of a more adequate support to the professional staff, will, for the most part, have been met.

TABLE 1. Growth of staff in BIO.

	MSB	FRB	ICNAF	Others[a]	Lab Total	MSB Ships	Grand Total	Remarks
Dec. '62	94	15	-	3	112	237	349	Lab occupied in July '62
" '63	134	15	6	5	160	300	460	*Hudson* commissioned
" '64	158	15	6	8	187	300	487	
" '65	212	25	6	12	255	307	562	
" '66	239	-	-	14	296	314	610	
" '67	(280)	(47)	(6)	(9)	(342)	(350)	(692)	Projected including *Dawson* commissioning

[a] Comprised of staff of purchasing agent and other departmental personnel not engaged in oceanography.

The projections for 1967 shown in Table 1 are based upon financial and personnel estimates approved in principle, and envisage an overall growth in BIO laboratory staff only slightly greater than was realized this year. There is in addition a substantial increase projected for ships' personnel required for manning the new MSB research ship CSS *Dawson* scheduled for commissioning late in 1967. If the 1967 figures prove to be valid, the overall pattern of growth in the 5 years from December 1962, the year BIO was opened, will have been a tripling of the laboratory complement to about 340 and a doubling of the grand total, which includes ships' complement, to a figure approaching 700.

The need for major additions to BIO was the subject of a detailed joint study with FRB. This resulted in the submission to the federal authorities of a 4-year building program estimated to cost about $2,310,000. It was based upon lower and upper estimates of growth in overall complement to totals of 433 and 540 respectively by 1970. The present building has a designed capacity of 283. The plan envisages a 50% extension of both the laboratory and office wings of the main building, a second depot building, and the provision of small boat berthing facilities. It also proposes a building specifically designed to house a regional library for the marine sciences. The plan, if implemented as scheduled,

should meet the accommodation needs of both MSB and FRB staff, as well as the relatively minor requirements of other agencies, pending the construction of an FRB laboratory anticipated early in the 1970's.

At the beginning of the year, Dr W. E. van Steenburgh moved from the post of Deputy Minister of the Department to undertake a special assignment connected with the work of the Sciences Secretariat of the Privy Council Office. It is a pleasure to express our indebtedness to Dr van Steenburgh for the vital leadership he gave in the conception and creation of BIO and for his unfailing encouragement and support in the critical first years of its operation. He is, in large measure, responsible for establishing the essential character of BIO as a centre for marine research characterized by a spirit of a cooperative venture among the many disciplines.

The continued healthy growth of BIO has been assured by the support and guidance of the Ottawa Headquarters of MSB and in particular by the Branch Director, Dr William M. Cameron, despite the fact that he, for most of the year, was much involved with the reorganization of the Department. This task arose from the substantial new responsibilities which came to the Department as a result of the re-alignment of resource management in the Federal Government announced by the Prime Minister in December 1965. The new organization came into effect October 1, 1966, under the title, Department of Energy, Mines and Resources, replacing the old title, Department of Mines and Technical Surveys. Dr Cameron undertook, for the balance of the year, the duties of Assistant Deputy Minister for Water, one of the four sectors into which the activities of the reorganized and enlarged Department have been grouped, while continuing to hold the position of Director of MSB. We welcome Mr Arthur T. Davidson as Assistant Deputy Minister for Water as of the beginning of 1967.

Wm. L. Ford,
Director.

ToC

Oceanographic Research

The Oceanographic Research Section is engaged in fundamental research studying the physical properties of the ocean and its boundaries. The basic objective is to obtain an understanding of those physical laws which produce the phenomena which are observed in the ocean. Because of the variety of disciplines involved in the studies, which cover a range from the geophysics of the structures in the earth beneath the sea floor, through the ocean layer, to the air-sea interaction at the air-water boundary, the Section is divided into seven groups which are basically self-contained. Federation of the groups into a single section materially assists the cooperative aspects of the several programs. The work of the individual groups is described by project reports on subsequent pages, including equipment development, data collection and analysis.

There have been a number of changes in the organization of the Section during the year. In February, the Current Measurement Studies Group, a number of technical staff in Physical Oceanography, and the personnel attached to Oceanographic Services for Defence, were transferred to the newly formed Applied Oceanography Section. At the same time an Ocean Circulation Group under C. R. Mann was formed including the physical oceanographers working on problems in the Atlantic, Labrador Sea, Arctic, and most of the Theoretical Studies Group. L. A. E. Doe returned to full time research as leader of the Air-Sea Interaction Group in October, being replaced as Senior Oceanographer by C. D. Maunsell.

Two members of the Section who were on educational leave completed the requirements for their Ph.D. degrees and returned to BIO: S. D. Smith of the Air-Sea Interaction Group from the University of British Columbia, and H. Sandstrom of the Ocean Circulation Group from the University of California, San Diego.

C. D. Maunsell

Air-Sea Interaction

L. A. E. Doe

G. E. Awalt[1]
J. A. Dimmers
R. H. Loucks
S. D. Smith
R. G. Stevens[1]
R. G. Tippett
B. Trudel

In 1955 the distinguished oceanographer Henry Stommel wrote, "In spite of the intensive effort that has been made to measure the stress of the wind on the sea, there is so much scatter in the various determinations that the stress is still not well known. It is hard to imagine an object of study more important to the oceanography of ocean currents. . . . " (The Gulf Stream, p. 17). During the decade since then, a number of investigators have succeeded in making measurements over relatively shallow water in conditions of moderate wind and waves. The question of what happens on the open sea during strong winds, however, remains unanswered and essentially uninvestigated.

The main immediate objective of the Air-Sea Interaction Group at BIO, therefore, continues to be the development of equipment and techniques for the measurement of wind stress under conditions of strong wind and unrestricted fetch. Progress towards this goal during 1966 has been sporadic, but as the year ends the program appears to be developing well.

Early in the year a new stable platform was designed, and was constructed by the Department of Transport's Marine Agency at Prescott, Ontario. The installation of this platform outside the mouth of Halifax Harbour was, however, deferred until 1967, when it became clear that the other instrumentation would not be ready before the weather had deteriorated in the fall. The design is based on that of the original BIO platform which was described in the Redfield Anniversary Volume of Limnology and Oceanography, November 1965. The new platform will be installed in 35 fathoms of water.

A prototype of the new thrust anemometer was tested extensively in the wind tunnel and found to perform adequately for stress measurements. Some non-linearities in its response have not yet been satisfactorily explained, but they do not invalidate it for use in the intended manner. A field model is now being prepared for installation on the platform.

Since it will not be possible to board the stable platform except in very calm weather, it has been decided to telemeter the data ashore and to operate the sensors and telemetry system by remote control. Telemetry was successfully used during 1964 to transmit data from the original BIO stable platform to a receiving station on Prince Edward Island, and no difficulty is expected with this part of the system. The command system is being assembled and tested at the present time and will be subjected to extensive field trials before installation. This system is designed to be expanded as required to control additional sensors and functions as these are installed on the platform (p. 57).

A small laboratory trailer was acquired and is being equipped as a receiving station. The intention is to park it near a lighthouse on a headland within line-of-sight range of the platform. It will house the receiver, command transmitter, recording system, and monitoring equipment. Data will be transmitted and recorded in multiplexed f.m. form using IRIG frequency bands. Data processing will continue to be done in the laboratory at BIO, primarily by digital techniques.

Work on the various parts of this system was held back during most of 1966 by a shortage of technical and scientific personnel. This shortage was most acute at the end of the summer when R. H. Loucks, the only scientist working full time on the project, returned to university on educational leave. (He has gone to the University of Michigan to study for a Ph.D.). At the same time, B. Trudel left for several months to man a Decca station for a hydrographic survey, and our one summer student returned to university, leaving J. A. Dimmers and R. G. Tippett to carry on essentially alone.

In October, however, the manpower tide ceased to ebb, and the strength of the Group was rapidly restored. R. G. Stevens, who had been studying waves at Woods Hole Oceanographic Institution for a number of years, joined our staff, and S. D. Smith returned from the University of British Columbia where he had just completed his Ph.D. work on the measurement of wind

[1] Joined BIO in 1966.

stress. At the same time, L. A. E. Doe relinquished his duties as Senior Oceanographer and returned to work full time on the project. G. E. Awalt joined the Group as an electronic technician in November, and B. Trudel returned from his field assignment to strengthen this part of the team still further.

While most of our effort continues to be on technical development, some work on the analysis of past records was done by R. H. Loucks during the earlier part of the year. He presented a paper at the Second International Oceanographic Congress in Moscow on "Some measurements of wind stress over water". This dealt with a sampling of measurements previously made in three different field locations. The results raised a number of questions that have not yet been adequately answered concerning both the wind stresses and the techniques which we had used to measure them. Answering some of these questions will occupy a major portion of our attention for some time to come.

L. A. E. Doe also gave a paper at the International Oceanographic Congress on "A new model of spherical thrust anemometer for wind stress measurements". Prior to rejoining the Group, S. D. Smith submitted a manuscript to the Journal of Marine Research on "Thrust anemometer measurements of wind-velocity spectra and of Reynolds stress over the sea". This was based on his Ph.D. research at the Institute of Oceanography, University of British Columbia. He also was one of the authors of Pond, Smith, Hamblin and Burling: "Spectra of velocity and temperature fluctuations in the atmospheric boundary layer over the sea", Journal of Atmospheric Sciences, vol. 23, No. 4, July 1966, p. 376-386. His Ph.D. thesis appeared as BIO Report 66-8 (Appendix A-l).

L. A. E. Doe

Frozen Sea Research

E. L. Lewis

J. D. Bradbury
P.H. Bridge[2]
J.A. Elliot
R. W. MacKay[2]
S. W. Moorhouse
H. G. Wells[1]
K. O. Westphal[2]

The Frozen Sea Research Group is engaged in studies of the processes involved in the growth and decay of the ice cover over the ocean. This includes studies of the heat flow through the ice, energy exchange at the boundaries between atmosphere, ice, and ocean, and the changes in the ocean caused by the rejection of salt as sea water freezes. Field investigations are carried out in the Arctic during the winter, most operations having been at Cambridge Bay, North West Territories, although work at other locations is planned. Laboratory experiments, and preparations for field work, are made in Victoria, B.C.

Experimental

In March and April, a series of oceanographic stations were taken through the ice at Cambridge Bay. Observations were made at various phases of the tidal cycle to see how tidal changes compared with the seasonal ones. Shadowgraph photographs were taken of the water immediately under the ice. It was hoped to observe streamers of salt-rich water falling from the ice .water interface, but none were photographed.

In the laboratory cold rooms, shadowgraph and Schlieren equipment has been used to study convective streamers falling down from the interface. Sufficient data has been collected at various rates of ice growth to give statistically significant values for streamer configuration and velocity.

Analysis of the experimental data on heat flow through an ice sheet has continued throughout the year. A paper on "Heat flow through winter ice" was presented to the Internatlonal Conference on Low Temperature Science at Sapporo, Japan, in August. A further paper is in preparation. It is hoped to present a fairly complete picture of the influence of ice growth on Arctic surface waters. Further measurements will be made this winter before finally assessing the seasonal variation in the water structure under a growing ice sheet.

The engineering program in support of field operations has suffered greatly from the absence of professional engineering assistance after the departure of P. H. Bridge in April 1966. However, at least one Arctic mobile research unit should have field trials this coming winter. This unit consists of a tracked prime mover, a towed sledge, and accessory gear including automatic data logging equipment. Many lesser projects have also been undertaken. Instruments enabling the measurement of temperature differences to an

---

[1] Joined BIO in 1966.
[2] Left BIO in 1966.

accuracy of ± .001° C at frequencies up to 5 cycles per sec have been constructed and should be in use next spring.

Work on the microwave properties of sea ice has been undertaken in conjunction with the Electrical Engineering Department of the University of Alberta. Present plans are to design and test an instrument for the remote measurement of the thickness of sea ice.

E. L. Lewis

Theoretical

As a part of BIO's program of investigation into the physical processes governing the growth and decay of sea ice and related oceanographic phenomena in the Arctic environment, the theoretical study of heat transfer in sea ice was continued by the author until his departure in December.

Stipulating Stefan-Boltzmann's radiation law to hold at the surface of a freezing water body, the position of the progressing phase change front has been obtained using an approximate method. A paper on the work has been written and submitted to the International Journal of Heat and Mass Transfer.

Using the data collected by E. L. Lewis, an attempt was made to calculate the thermal diffusivity of sea ice. It turned out, however, that because the temperature profile in the ice is relatively insensitive to the value of the thermal diffusivity, significantly accurate values are difficult to extract from the data and were not obtained.

K. O. Westphal

ToC

Ocean Circulation

C. R. Mann

B. D. Carson
A. B. Grant
J. R. N. Lazier
G. T. Needler
B. D. Price[2]
C. Quon
R. F. Reiniger
C. K. Ross
H. Sandstrom[1]

The Ocean Circulation Group was formed early in 1966 of scientists at BIO engaged in experimental and theoretical studies of the North Atlantic. The aim of the Group is to study the fundamental physical processes occurring in the oceans and to increase knowledge of the major current systems.

Two major cruises have been carried out in the North Atlantic, programs have been written for the numerical analyses of oceanographic data, and models for ocean circulation have been studied. In the latter part of the year, considerable effort was put into the organization of a major 3-month cruise of CSS *Hudson* into the North Atlantic early in 1967. This cruise has been undertaken in cooperation with scientists from the National Institute of Oceanography, UK, under J. Swallow, and from Woods Hole Oceanographic Institution, USA, under V. Worthington. It is designed to examine, under winter conditions, the flow of water through Denmark Strait, and the water masses in the Irminger Sea.

Up to now, most of the oceanographic data collected by this Group has been obtained by hydrographic bottle casts which at times have been supplemented by bathythermograph, parachute drogue, Swallow float and GEK measurements. Recently, however, a continuous recording salinity-temperature-depth meter has been obtained and consideration has been given to the collection of data from moored buoys. The future availability of such equipment makes the investigation of the time-dependent processes in the ocean more feasible, and it is expected that the Group as a whole will become more involved with such investigations.

The Group was augmented in September by the arrival of H. Sandstrom who has been on educational leave. Dr Sandstrom has obtained his Ph.D. degree from the University of California at San Diego. His thesis is entitled "The importance of topography on the generation and propagation of internal waves", and at BIO he is continuing his work on internal oscillations and their relationship with other oceanic processes.

The details of other investigations are given below.

The Gulf Stream

The analysis of the data collected over the past 3 years on the Gulf Stream between the Grand Banks and the Azores was completed in 1966. The data have been published in the form

[1] Joined BIO in 1966.
[2] Left BIO in 1966.

of an atlas of sections of temperature, salinity, and oxygen. A paper has been prepared on the current system in the area and has been submitted for publication.

This study has been particularly rewarding since it has been possible to clarify the basic current system in the area around the Grand Banks as well as to define the path of the Gulf Stream after it passed the Tail of the Banks (Fig. 1). The work has revealed several interesting and important oceanographic features associated with the current system. In 1964, a cyclonic eddy was observed to break off to the south, from the Gulf Stream. It is desirable to determine whether or not this is a frequent occurrence since such an eddy is a mechanism for returning water to the Sargasso Sea. A large anti-cyclonic eddy seems to be permanent over the Newfoundland Basin, to the north of the Gulf Stream. In the area immediately south of the Gulf Stream considerable quantities of the 18° C water of the Sargasso Sea are formed by cooling in the winter. To the north, masses of water with characteristic temperatures of 14° to 15° C are formed. These features are worthy of further study with emphasis on the physical processes occurring. Some thought needs to be given to the type of experiment to be performed if the physical processes are to be understood, and until this is done, further studies in this area of the ocean will not be undertaken.

C. R. Mann

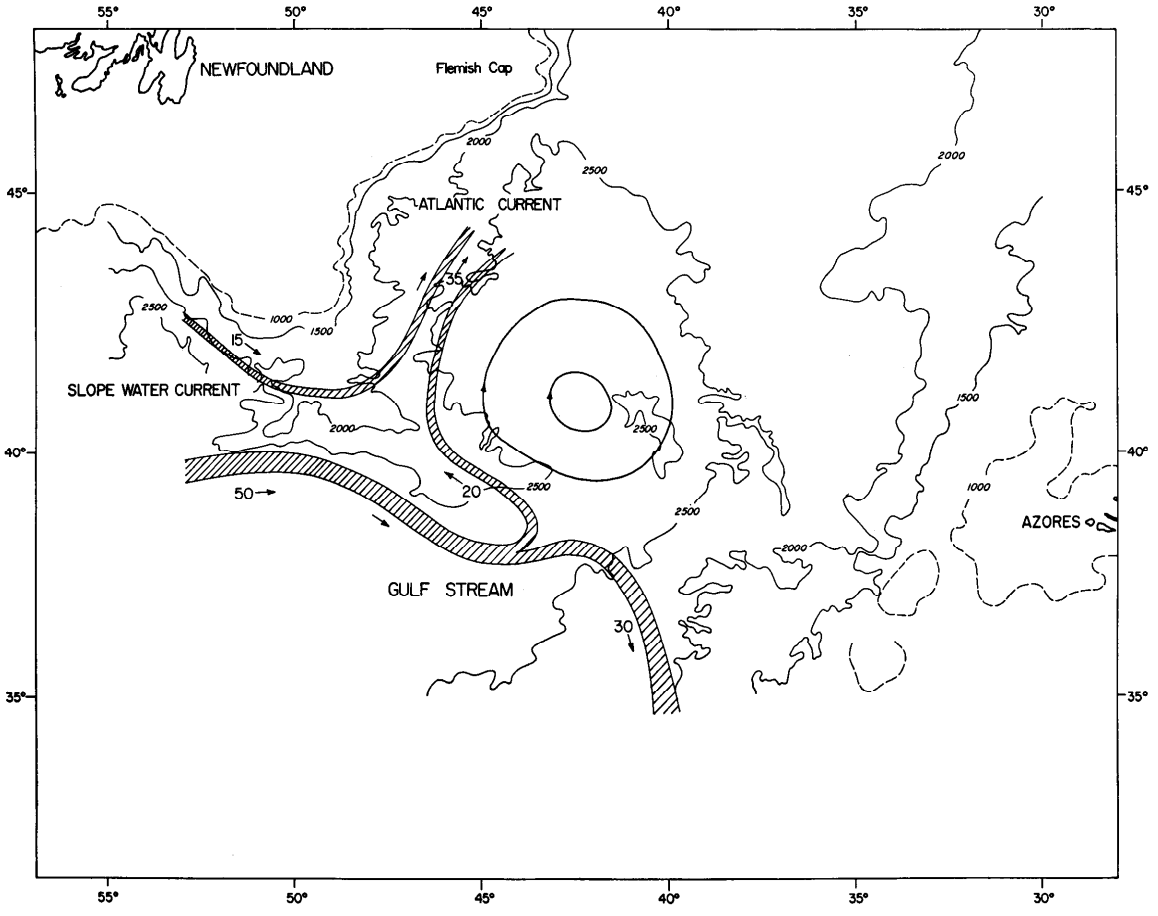


Fig. 1. Map showing basic current system in the region of the Newfoundland Basin.

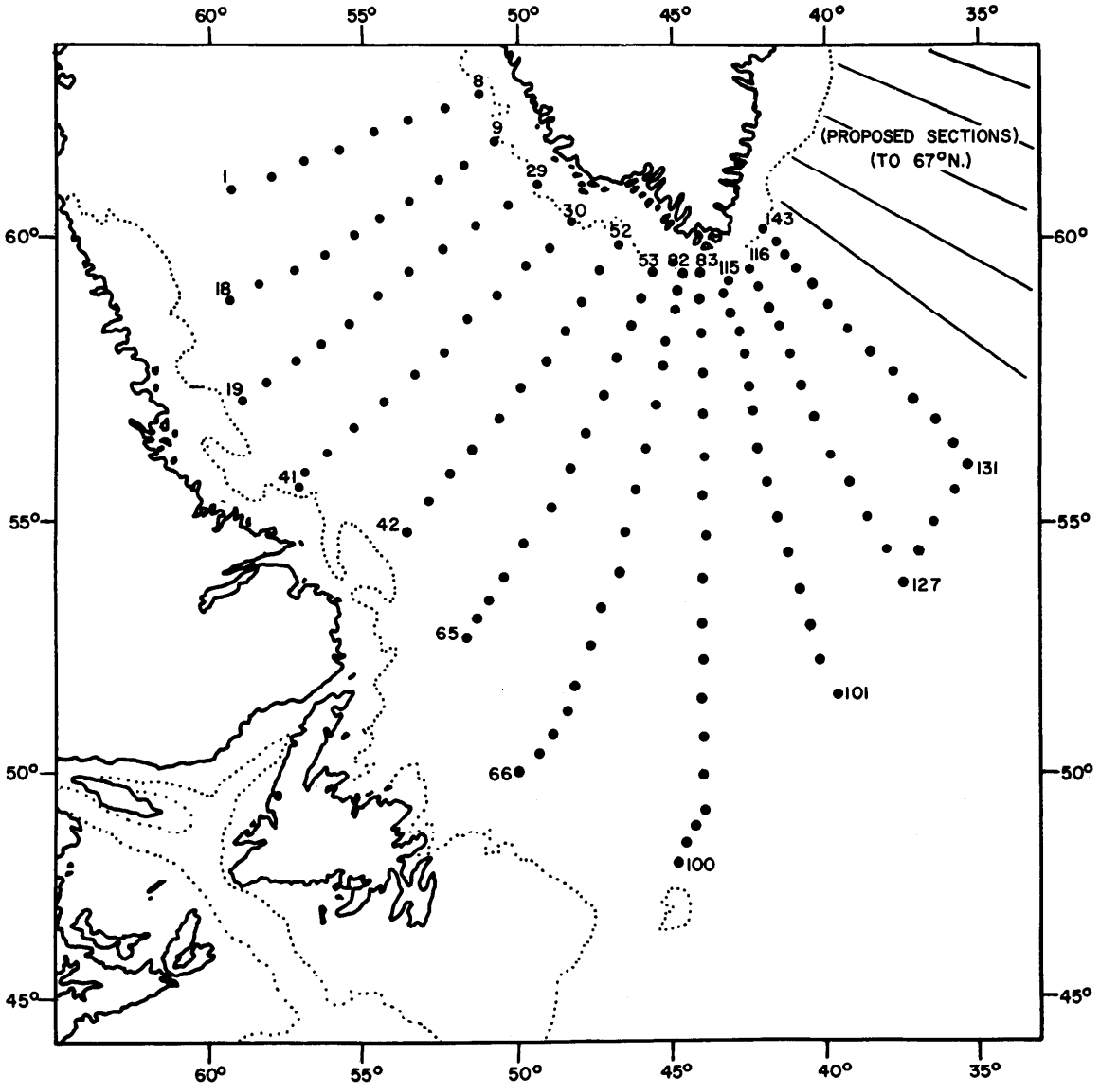


Fig. 2. Oceanographic stations occupied during 1966 in the Irminger Sea.

Labrador Sea

Between March 12 and May 12, 1966, a physical oceanographic cruise was undertaken aboard CSS *Hudson* in the Labrador and Irminger Seas (Fig. 2). The primary purpose of this cruise was to measure the temperature, salinity and dissolved oxygen in order to gain knowledge of the characteristics, formation and movement of the water mass. In addition, investigations on bacteria, dissolved and particulate organic matter, and sea bird populations were conducted by investigators from Dalhousie University. The cruise was undertaken at the end of the cooling season so that the deep convective overturn of surface water masses at that time might be studied. The main water masses being investigated are the Labrador Sea water, the North Atlantic deep water and the bottom water.

The analysis of the data from this cruise, and from another cruise to Davis Strait in September-October 1965, has not progressed far enough to enable the results to be reported definitively. However, it seems apparent, already, that convective overturn did not penetrate as far as the depth of 2,000 m sometimes quoted in the literature. It is hoped that the data will be published early in 1967 by the Canadian Oceanographic Data Centre with an atlas of cross-sections following by the fall of 1967. As mentioned above, the observational program is being

extended into the Irminger Sea on the proposed cruise to Denmark Strait between January 9 and April 7, 1967. The proposed sections are shown in Fig. 2.

The oceanographic stations used by the U.S. Naval Oceanographic Office (USNOO) in their ice forecasting program were again occupied in 1966 from the Department of Transport icebreaker CCGS *Labrador*. B. D. Carson of BIO assisted three members of the USNOO in I his work.

J. R. N. Lazier

Models of ocean circulation

Work has continued in the past year on several aspects of both steady and time-dependent ocean circulation. A particular exact solution to the problem of thermohaline circulation has been obtained. A report (BIO 66-1) on the subject has been issued and a paper outlining further work has been submitted for publication. Some work has been done on the approximate methods used to solve the long wave equations. In addition, a short paper has been prepared with C. R. Mann on the problem of aliasing in studies of long-term oceanic variability off Canada's coasts. The theory of sampling indicates that, if a parameter is measured at discrete times rather than continuously, errors can arise; one such error is known as "aliasing". It has only recently been realized that aliasing is likely to pose a problem in oceanographic observations.

G. T. Needler

Numerical analysis of oceanographic data

Early in 1966, a report was published on the interpolation scheme developed in 1965 (BIO Report 66-3).

In the past year, the programs making up the oceanographic data processing system for the CDC 3100 computer have been completed and are now operational. The programs will accept and process raw temperature and chemical data. Pressure has been adopted as the independent variable for oceanographic parameters as opposed to the traditional use of depth. The programs have been written to point out probable errors in the data and have already been used to process the data from three recent cruises. Data compatible with the Canadian Oceanographic Data Centre is produced by the program, and can be forwarded to the agency on magnetic tape.

Work has begun in the latter part of the year on writing a series of programs for the PDP-8 computer to process data at sea. It is expected to be able to determine corrected temperatures and pressures as well as plot oceanographic parameters in time for the CSS *Hudson* cruise early in 1967. An effort has been made to make the data format as compatible as possible with the data format for the CDC 3100 computer program.

R. F. Reiniger
C. K. Ross

Coastal Oceanography-St. Lawrence Estuary

W. D. Forrester M. E. MacLean[2]

The Group is engaged in a project with the dual purpose of assessing the usefulness of the application of the geostrophic approximation to circulation in coastal channels and of contributing to knowledge of the physical oceanography of the Gulf of St. Lawrence as a whole. During 1966 the Group was occupied with the interpretation of data obtained during an oceanographic and current survey across a section of the St. Lawrence Estuary in the Father Point region. The preparation of the current meter data required the most time; poor developing of the film records necessitated much re-reading and editing in order to obtain acceptable data from them. The BIO Computing Centre was of great assistance in providing editing programs to check the consistency of the current data and in carrying out harmonic analyses and certain averaging operations on the mass of numbers obtained from the current meters.

After much plotting and intercomparison of the oceanographic parameters and current velocities, a reasonable picture of the manner in which the density field responds to the velocity field has begun to emerge. It is now felt that some of the features observed in this survey can be fitted reasonably well to a simple tidal model of the estuary, in a manner consistent with that employed in other recent surveys. Unfortunately, the currents are very small and the current shears

2 Left BIO in 1966.

even smaller, so that it is usually difficult to test hypotheses conclusively. The report on the survey and its results is now being prepared, and should be completed early in 1967.

During 1966 lectures on the above survey and related matters were given by W. D. Forrester at The John Hopkins University, The Royal Society of Canada, and Memorial University of Newfoundland. M. E. MacLean left the Group in September to return to college.

W. D. Forrester

ToC

Chemistry and Marine Radioactivity

I. M. H. Pagden

V. N. Beck
A. R. Coote
R. S. Hiltz
T. Kuwamoto[3]
J. C. Sutherland [1,2]
R. R. Weiler[1]
W. Young

From the beginning this work has had two objectives: firstly, the use of chemical species as indicators of water mass types and secondly, the use of the fission products from atmospheric fallout for the study of transport phenomena in the oceans. The advent of high resolution, moderately efficient gamma ray spectrometers, offered, it was thought, the prospect of performing interference-free radio isotope analyses due to the extremely high resolving power of a pair of spectrometers operating in coincidence. In addition, the use of present digital data handling techniques would enable a number of radio isotopes to be identified simultaneously. An investigation of the utility of these spectrometers in problems of sea water analysis seemed desirable Accordingly, the emphasis in this work has changed the past year. Apart from sampling, very little has been done towards obtaining information on the fission product distribution in the oceans. Most attention has been given to the problems associated with the measurement of trace elements using activation analysis.

Chemistry

Work on the oceanic silicate distribution has continued and a decrease in silicate concentration near the bottom in water to the north of the Gulf Stream was again observed. Further improvements have been made to the method for dissolved oxygen measurement in the laboratory but their worth has yet to be confirmed on cruises.

Experiments have continued on the measurement of neutron induced activities in geochemical samples. Specimens of ocean salt, quartz, manganese nodule, a standard rock sample G-l, and chelex resin have been irradiated and their gamma ray spectra observed with a Lithium drifted germanium (Ge(Li)) gamma ray detector. Bombarding an element with neutrons generally creates a radioactive material, which may be identified by the energy of the gamma rays it emits; in many cases, two gamma rays of different energy are emitted simultaneously. The spectra of such coincidences from irradiated G-1 and ocean salt have been observed using two Ge (Li) detectors. Pure radio isotopes provided energy calibrations and allowed the measurement of relative and absolute efficiencies of the detectors at known energies.

It has been possible to assign components in the single gamma ray spectra to various radio isotopes, although not always unambiguously, owing to the multiplicity of gamma rays. It has proved possible to make quantitative measurements of some elements in G-l, from the “pure” lines in its spectrum, within the predictable limits of experimental accuracy.

Information concerning the production and decay of radio isotopes has been put on punched cards and transferred to magnetic tape. A number of computer programs have been written to correlate our experimental data with this library information. It has been possible to determine to what extent interference between different isotopes occurs in the coincidence spectrum and the resolution required to remove such interferences. On this basis, it has been possible to make confident assignments to events observed in the coincidence spectra. So far no events have been observed due to radio isotopes whose presence has not been deduced from the single gamma ray spectra and fewer radio isotopes have been apparent in the coincidence spectra than in the single spectra. The coincidence spectra are of interest since they offer greater capacity for identifying radio isotopes if the detectors are sufficiently sensitive.

The experiments so far indicate that quantitative results are obtainable using a simple approach, and this is now being incorporated in a computer program. It appears also that chemical separations before or after irradiation will be

[1] Joined BIO in 1966.
[2] Left BIO in 1966.
[3] NRC Fellow.

necessary for the measurement of at least some of the trace elements sought.

T. Kuwamoto, NRC postdoctoral fellow from Kyoto University, Japan, has undertaken the development of a number of chemical group separations which might be suitable for pre-irradiation chemistry. Some samples which have been processed by these schemes have been irradiated and the resulting gamma ray spectra are under investigation.

During the summer we benefitted from co-operation with Dr F. C. Flack of the University of Exeter, England, and we acknowledge the valued collaboration of Dr I. K. MacKenzie of the Physics Department, Dalhousie University, on several aspects of the work throughout the year.

Marine radioactivity

Thirty-eight samples for fission product analysis were taken at stations in the Labrador Sea and North Atlantic. Some stations were selected in close proximity to locations used 5 years ago to give additional information on processes thought to have a comparable time constant.

Services

The Group has supplied technical assistance to other groups and external agencies. Approximately 8,000 salinity samples were processed in the past year and routine chemical analyses performed for cruises. A number of 10-litre sea water samples have been sent to the Central Institute for Industrial Research, Oslo, Norway, to assist their researches on the stable rare earth distribution.

I. M. H. Pagden

Marine Geophysics

B. D. Loncarevic

D. L. Barrett
R. V. Cooper
G. N. Ewing
L. J. Fitzgerald[2]
M. D. Hughes[1]
D. R. Locke
R. Sparks[1]
S. P. Srivastava
H. R. Steeves[2]
K. S. Manchester
D. I. Ross[1]

The study of the solid boundary of the oceans is conducted by the Group using three approaches: (i) systematic system of specific areas (e.g., the Orpheus anomaly and Mid-Atlantic Ridge investigations); (ii) reconnaissance surveys through participation with other groups and agencies (e.g., with the Hydrographic survey on the Grand Banks and with DOT in Baffin Bay); (iii) development of new geophysical methods and techniques (e.g., measurement of telluric currents, VLF navigation, digital data acquisition and shipboard computers).

The statistics for major 1966 field projects are compared with previous years in the following table.

	1963	1964	1965	1966
Man-days at sea	210	273	573	653
Ship gravimeter (nautical miles)	2,500	7,500	22,585	11,372
Ship magnetometer (nautical miles)	5,990	9,500	40,325	28,612
Gravimeter miles / man-day at sea	12	28	40	18
Magnetometer miles / man-day at sea	28	35	70	44

[1] Joined BIO in 1966.
[2] Left BIO in 1966.

The 14% increase in man-days at sea over 1965 is a reflection of the 22%$_0$ increase in staff. The decrease in gravimeter and magnetometer miles/man-day at sea is due to the diversification of the Group. In addition to underway recording, the following experiments were undertaken on geophysical cruises: underwater photography, experimental rock core drilling, marine seismics, sediment coring, rock dredging, biological sampling and hydrographic casts.

An air-conditioned geophysical laboratory was designed and built on CCGS *Labrador,* which will enable a sea gravimeter to be used on the future Arctic cruises of this ship. A non-magnetic hut was built near BIO for sensitive magnetic model measurements. The Group became custodian of two general-purpose digital computers, acquired by BIO for shipboard use. Each installation consists of a PDP-8 central processor, a fast paper tape punch, a photo-electric paper tape reader and a 30-inch Calcomp plotter. One computer was used extensively during the Mid-Atlantic Ridge cruise and operated for a total of 407 hr (7.2 hr/day) without a failure. Production work included five geophysical data reduction program.

During 1966, the Group was visited by P. S. Naidu and A. Becker, both of the Geological Survey of Canada, R. Chase from Woods Hole Oceanographic Institution, R. Stoneley from Cambridge University, T. J. G. Francis and J. Mudie, both from Scripps Institution of Oceanography, G. F. West from the University of Toronto, and M. Caputo from the University of British Columbia.

B. D. Loncarevic continued a series of lectures on Physics of the Earth at Dalhousie University and S. P. Srivastava gave part of the seminar course in Advanced Geophysics to graduate students at Dalhousie University.

Instrumentation

A complete new Anschutz gyro-stabilized platform was delivered in October and it is hoped that the new Askania sea-gravimeter purchased for use with it will arrive soon. The new platform is equipped with an electrically-erected gyro instead of the older oil-erected type. The electrically-erected gyro gives superior stabilization performance under almost any sea conditions.

Two new Edgerton, Germeshausen and Grier underwater camera systems were purchased and an older EG&G underwater stereo camera system renovated. The EG&G stereo system and the new EG&G model 200/210 research systems were used for a general survey of a section of the Mid-Atlantic Ridge. Over 5,000 usable pictures were taken.

A 4-ft long Braincon Corporation V-fin towed transducer was used successfully for two months on the CSS *Hudson* at speeds up to 12 knots in all sea conditions encountered.

The Tracor VLF navigational equipment (Fig. 3) was improved with the purchase and use of an Omega commutator which enabled the reception of Omega navigational signals to be recorded. The system performed satisfactorily but it is still in an experimental stage and cannot be considered as a routine navigational aid such as the Decca or Loran navigational aid systems.

K. S. Manchester

Orpheus anomaly

The geological interpretation of the Orpheus gravity anomaly which was mapped 2 years ago has been completed. The results are shown in Fig. 4. The large negative magnitude and horizontal gradient of the anomaly is due to the density contrast between high density basement rocks and the low density Windsor evaporites. The latter are postulated to lie immediately over the basement rocks. The effect of the density contrast is enhanced by the geometric shape of the causative bodies. The steepness and linearity of the basement structure suggests that the structure is fault controlled.

The interpretation of the gravity anomaly is an excellent example of how seisimic, magnetic, and gravity information can be integrated to yield an interpretation that is in agreement with the known local geology. The study also emphasizes the importance of using a shipborne gravimeter in routine surveys of the continental shelf.

G. N. Ewing

Continental Shelf

Routine magnetometer and shipborne gravimeter surveys were carried out in conjunction with a hydrographic survey on the Tail of the Grand Banks. The magnetometer survey area was contained in roughly two rectangular blocks; the first block lies between long 53°2' W and

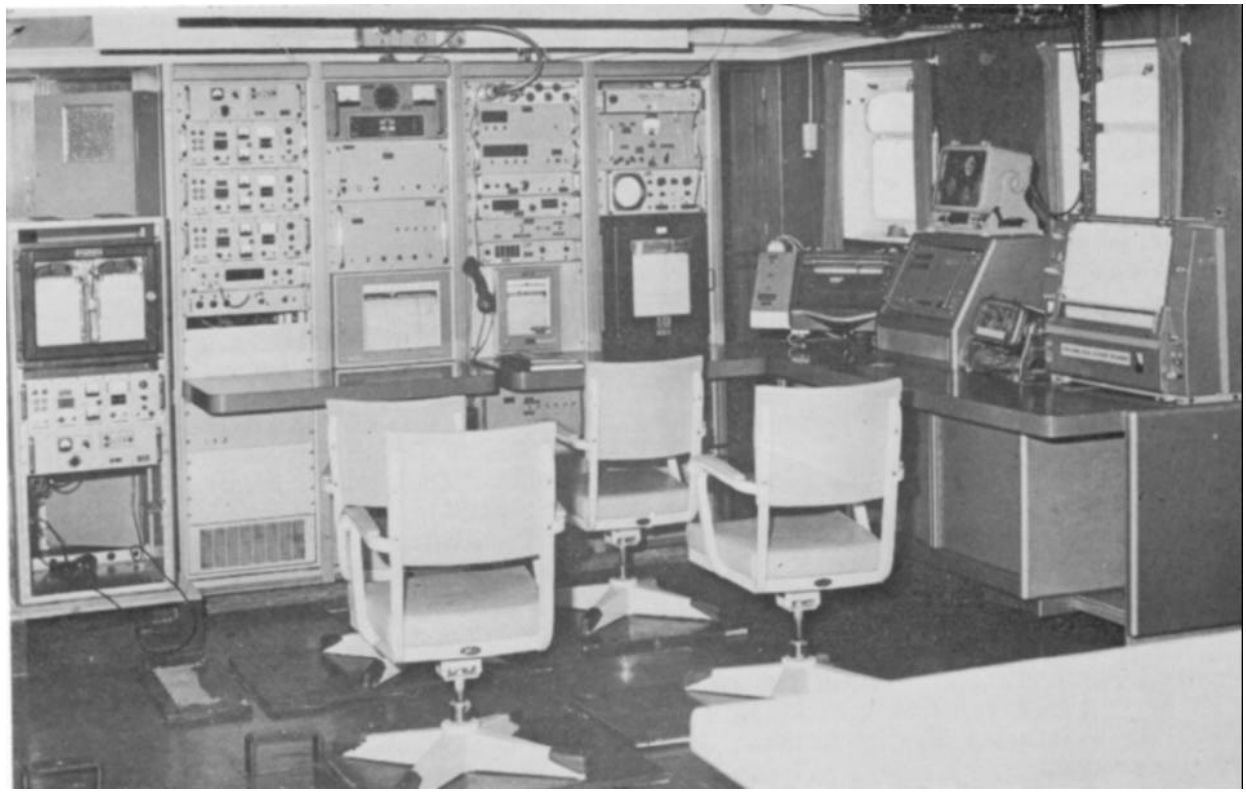


Fig. 3. General view of the electronic data handling equipment on CSS *Hudson*. This set-up is typical of equipment used during a standard geophysical survey.

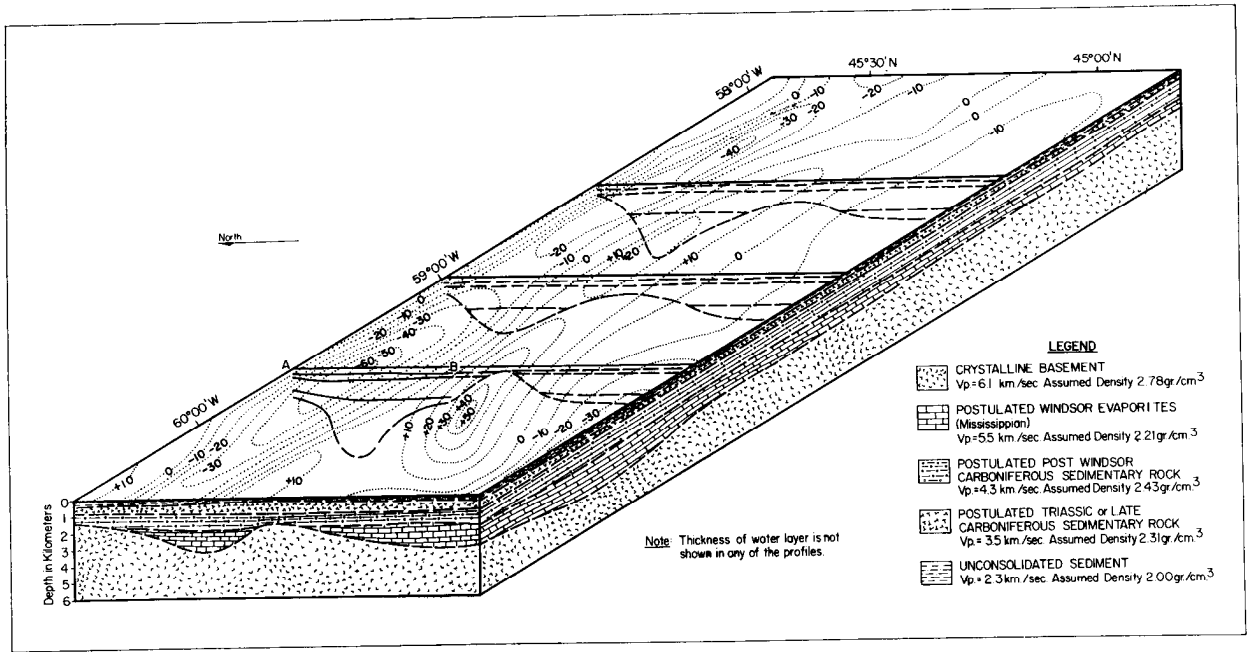


Fig. 4. Three dimensional model of the “Orpheus” Gravity anomaly.

48°20' W and lat 42°32' N and 43°46' N, the second adjoins the first and lies between long 50°46' W and 48°20' W and between lat 43°46' N and 45°00' N. Shipborne gravimeter measurements were made in the first block only.

Intense magnetic anomalies were observed near the continental shelf break. A few low amplitude magnetic anomalies occur on the Banks but, in general, the magnetic field is flat or gently undulating.

The free air gravity anomaly reflects the major trends of the bathymetry. On the Banks (within the 40-fathom contour) a pronounced gravity low trends in an east-west direction. The low exhibits a definite 15-milligal closure and a low of 25 milligals is suggested. The bathymetry within the 40-fathom contour shows exceptionally little relief which suggests that the gravity low is most probably caused by the density distribution of the sub-surface rocks.

G. N. Ewing

Mid-Atlantic Ridge

The investigations reported in 1965 have been continued in 1966. The total area surveyed to date is in excess of 3,000 sq miles. The survey is located between 45° and 46° N and has as its eastern boundary the eastern flank of the Median Valley. The survey coverage is illustrated in Fig. 5. Radar transponder buoys were again used for navigational control. Approximately 85% of the survey lines were referenced to two or more buoys. Ranges of up to 12 miles were achieved with 90% reliability. The average moored time per buoy was 3 days and 18 hr. Rl served as the master control for Phase I and the mooring stayed in place for 16 days and 19 hr. During Phase II, Rll was used as the master control and its mooring stayed in place for 17 days and 10 hr and survived a close passage of Hurricane Faith. In addition to bathymetric, gravity, and magnetic surveys, the 1966 expedition occupied 55 stations. The work included 32 camera lowerings, 8 successful sediment cores (total core length 8,422 cm), 7 successful rock dredges (145 hand specimens and boulders), 26 lowerings of the rock core drill and 26 biological stations

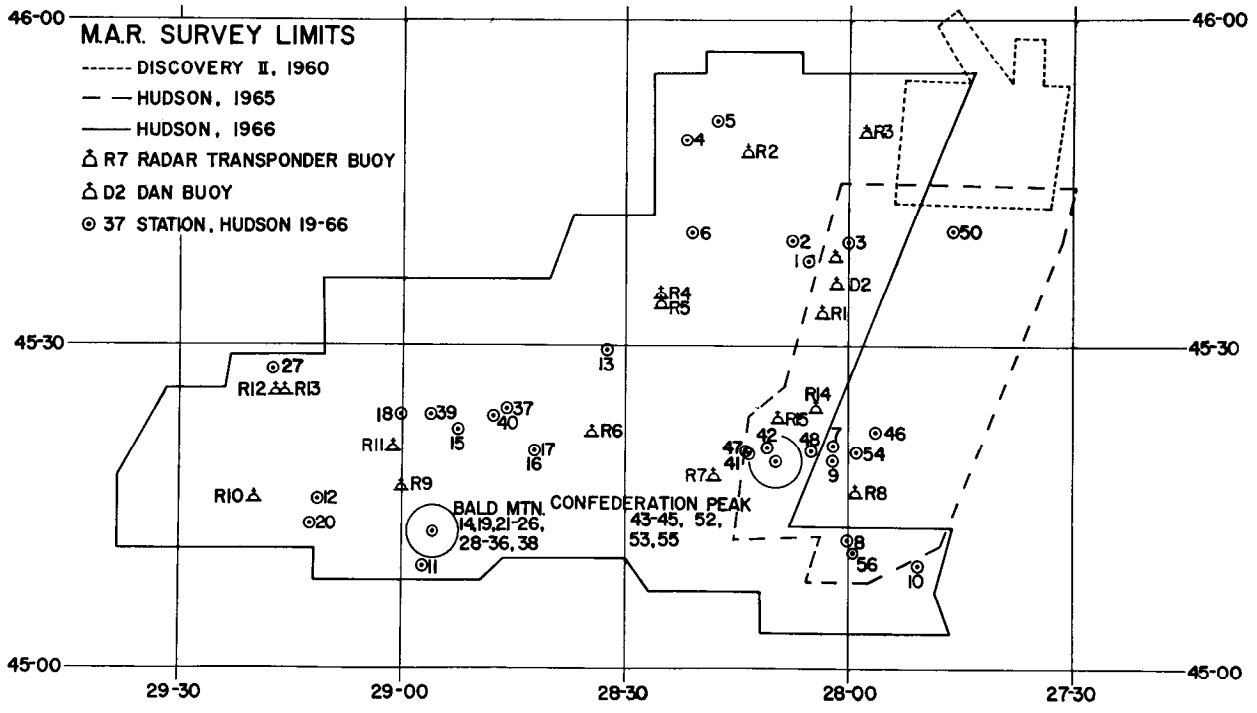


Fig. 5. General area of recent Mid-Atlantic Ridge survey.

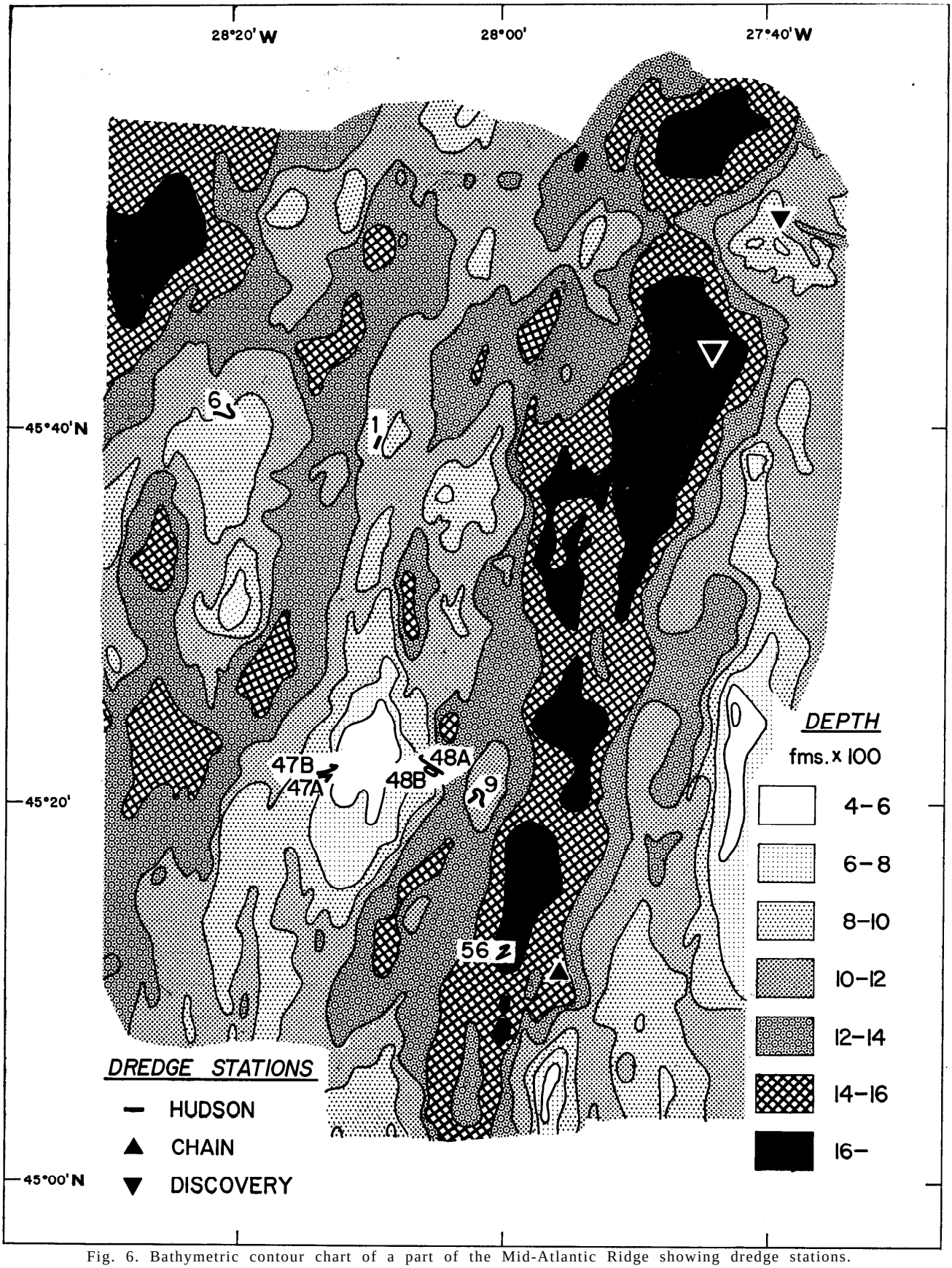


Fig. 6. Bathymetric contour chart of a part of the Mid-Atlantic Ridge showing dredge stations.

Bathymetry of the surveyed area east of 28°30' N is shown in Fig. 6. The deep area near the eastern margin is the Median Valley. The photographs taken on station 8 (near dredge station 56) show extensive fields of pillow lavas. These pillows appear to be uniform in size (approximately 2 ft across: and show chilled margins. Two samples were recovered by dredging. When brought on board, they were covered with highly stressed glass selvages without any manganese coating. The photographs showed only superficial sediment cover which could not be sampled by coring. The sediments are more abundant in the northern part of the Median Valley and a 150-cm core was recovered from a depth of 3,560 m at station 50.

On the western flank of the Valley, in lat 45°20' N is a prominent volcanic peak named "Confederation Peak". Extensive dredging around this peak provided a complete suite of submarine volcanic rocks. F. Aumento of the Geological Survey of Canada, Ottawa, is studying the petrology of these rocks.

The topography of the area shown in Fig. 6 is very rough. The total field magnetic anomalies showed a linear pattern parallel to the Median Valley anomaly. To the west of 28°30' W this pattern became less well defined. The change in the character of magnetic anomalies corresponds to the change in the character of the bottom topography. This change in topography might indicate that the forces responsible for the emergence of the Mid-Atlantic Ridge were variable in space and time.

B. D. Loncarevic

Arctic geophysics

Reduction of the 1965 magnetometer data has been completed. The investigations around Devon Island tend to confirm the interpretation of the 1964 Lancaster Sound survey (BIO Contribution No. 46) that Devon Island has been subjected to major tectonic forces resulting in a relative northward movement of the Island of about 8 km.

A program of reconnaissance magnetometer surveying in Baffin Bay and Davis Strait, which began in 1963, was completed this year. As shown in Fig. 7 approximately 15,000 nautical miles of magnetic field profiles were obtained. The 1966 data is now in the process of reduction and the following results are, therefore, of a preliminary nature: large magnetic anomalies were observed in Baffin Bay over the Greenland and Baffin Island shelves and also when crossing the edge of the continental slope (200 - 500 fathoms). In general, magnetic anomalies were not observed over the abyssal depths of Baffin Bay but, on a few crossings, small amplitude and long wavelength anomalies were noted. These anomalies are of the same period and magnitude as the temporal variations in that area and probably do not reflect basement structure.

A detailed magnetometer survey over the area of concentrated earthquake activity, northeast of Baffin Island in Baffin Bay, revealed a number of short wave-length anomalies characteristic of near surface features. Susceptibility calculations should determine whether or not these anomalies are caused by the presence of volcanic rocks in this area of seismic activity.

A number of short wave-length, high amplitude magnetic anomalies (up to 1,000 gamma) were observed along the north-south profiles in Davis Strait. Although susceptibility calculations have not been carried out, it would appear that the Tertiary volcanics exposed on Disko Island, Greenland, and around Cape Dyer, Baffin Island, are continuous across Davis Strait.

A detailed magnetic survey in Ungava Bay indicates a considerable thickness of Paleozoic sediments in central and northern Ungava Bay and possibly in Hudson Strait. There are two prominent (arcuate) anomalies in the eastern half of Ungava Bay. Their extent and alignment is similar to that of the Belcher Islands in Hudson Bay.

Two unreversed seismic refraction profiles were shot in Baffin Bay to study the nature of the crust on the Baffin Island shelf and under Baffin Basin. The seismograms have not been examined in detail but, from a brief preliminary study, the first arrivals on both profiles are somewhat later than expected, indicating a considerable thickness of low velocity unconsolidated or semi-consolidated sediments.

D. L. Barrett

Electromagnetic studies

Magnetotelluric measurements were made during the summer at three locations in eastern Canada in cooperation with the University of Cambridge. The main purpose of the experiment

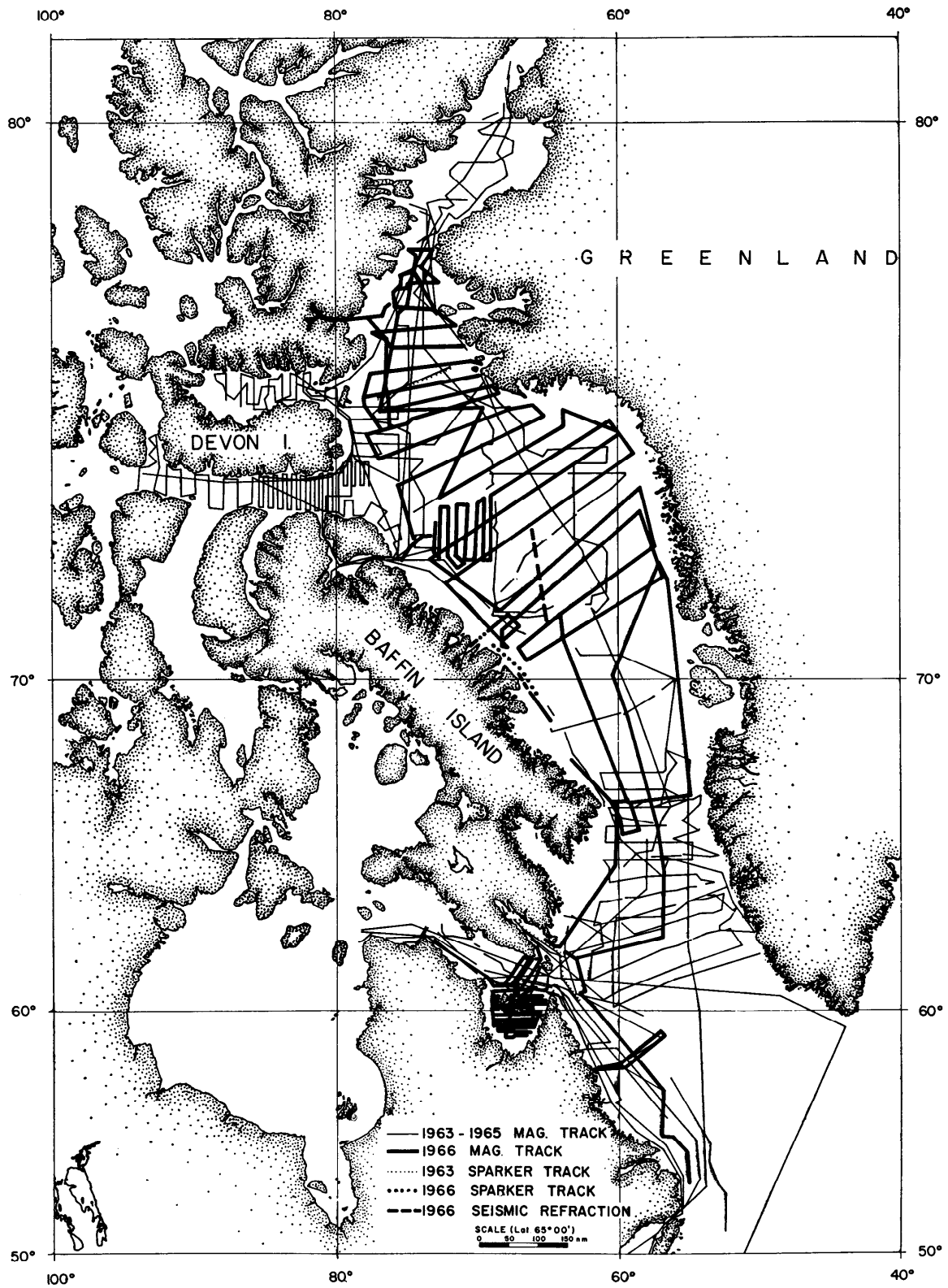


Fig. 7. Geophysical track chart in Davis Strait.

was to study the effect of the coast on magneto-telluric variations. Three component proton precession magnetometers built by Cambridge University and a fluxgate magnetometer borrowed from the University of Toronto were used to record magnetic variations at Sable Island, Halifax, N.S. and Fredericton, N.B. Portable total field proton precession magnetometers were also used at each of the stations to record the total magnetic field. In addition, telluric currents were recorded at each of the stations using lead plates and copper-coated steel rods as electrodes. The telluric current data is now being digitized for a detailed analysis. During the preliminary examination of the data the following features were observed :

1) The intensity of the variations in the vertical component of the magnetic field seems to decrease gradually from Fredericton to Sable Island, indicating the probable absence of a marked coastal effect;

2) The intensity of the variations in the horizontal component (H) of the magnetic field seems to be lower at Halifax than at Sable Island and Fredericton:

3) The intensity of the variations in the electric field was largest at Fredericton and smallest at Halifax.

In addition to recording the telluric currents on Sable Island, an attempt was made to record them at the bottom of the ocean about 3,000 ft distant from the Island. Two AgAgCl electrodes were placed in a north-south direction about 2,000 ft apart in water 50 ft deep and with cables leading to a recorder on the Island. This was our first attempt to study the conductivity distribution below the ocean. The experiment was very successful and an attempt will be made in future to design self-contained equipment to record telluric currents in deep water.

S. P. Srivastava

Other investigations

R. T. Haworth arrived from Cambridge early in July to continue his investigations on the cross-coupling errors in gravity measurements at sea. He operated the two analog computers developed at Cambridge University and the Dominion Observatory, Ottawa, throughout the Mid-Atlantic Ridge cruise, digitizing all his results using the FM digitizing system developed by the Electronics Design Group at BIO. Since the end of the cruise he has been involved in the reduction and analysis of these results which he will continue on his return to Cambridge at Christmas.

B. D. Loncarevic

Computing Services

ToC

R. C. Richards

V. N. Beck A. V. LeBlanc P. S. Trites

The year 1966 marks the first complete year of operation of the CDC 3100 computer at BIO. During this year the computing centre has operated on a completely open shop arrangement. This method of operation has proven very beneficial to both scientists and programmers with most small jobs being completed within 10 min of presentation. With this method of operation the average central processor time for 1966 was about 30 hr per week. This represents a very full one-shift operation. It is anticipated that by this time next year a second shift will be operating at near capacity.

The Group is, at present, operating with only about one-third of its planned staff. It is hoped that vigorous recruitment effort will yield the badly needed but difficult to find programmers in sufficient numbers to meet the growing demand for computing services.

The CDC 3100 basic software package has been fairly exhaustively tested over the last year and many modifications have been made. These modifications have made the system easier to operate and have also made it faster, more flexible and more powerful.

Approximately 100 operational programs were written for the CDC 3100 in 1966, but their documentation is very limited. However, this is not unreasonable with the present shortage of staff.

The computer configuration now on hand is daily becoming more inadequate. A study has been initiated to determine our projected needs over the next 5 years.

Two PDP-8 computers were delivered this year, primarily for shipboard use. Programs have been written for the CDC 3100 which will produce both paper tape for the PDP-8's and

list paper from the PDP-8's on the CDC 3100 printer. Even with this saving of time to the PDP-8 user, one machine is kept fairly busy at BIO developing and testing programs. As time goes on it appears that a third PDP-8 will be necessary for permanent installation in the computer room. This machine will be used for the development and testing of programs along with other related duties.

Down time on the CDC 3100 computer has proven to be nearly negligible. With a resident maintenance man it has been possible to repair or replace defective parts either immediately on detection or at a time convenient to the user if the defect is not serious. This is a most convenient arrangement and has aided greatly in the smooth operation of the computing centre.

R. C. Richards

ToC

Applied Oceanography

In accordance with the growing emphasis on cooperation and the coordination of programs between MSB and FRB groups within the BIO, a new Section of Applied Oceanography was established early in the year. The Section is supported and manned by both DEMR and FRB. It takes responsibility for carrying out surveys, studies, and analyses to meet physical oceanographic requirements in fisheries, defence, coastal engineering, navigation, hydrography, pollution, and basic research.

The purpose of this new organizational unit is to pool the resources of a number of small groups which have been working on related problems, mostly of a practical nature, or which seek answers to specific problems. For example, it is generally agreed that much of the information required for defence purposes is similar to that required for fisheries purposes. It was also evident that the division of current measuring responsibilities among several groups at the Institute has not led to maximum efficiency. The new Section is, in effect, an experiment to see whether the research and survey activities of a number of administrative units can be integrated under a single operational control.

For convenience, the Section is loosely divided into three primary units: Synopsis, Monitoring and Forecasting; Nearshore Studies; and Coastal and Deep Ocean Surveys. Common support groups are gradually being established to deal with the evaluation, calibration and maintenance of current meters, tide gauges, and allied equipment used by the Section; numerical analysis and data processing; moorings and buoys; and technical records.

At the time of formation, the Section was supported by 10 MSB staff members, four from FRB, and one NRC Post Doctorate fellow. In October, F. K. Keyte, who had been on educational leave at MIT and WHOI, joined the Section. W. I. Farquharson, who had been in charge of tidal current studies, retired from service in October. Under his leadership, Canada moved quickly from the laborious anchored-ship method of current measuring to the automatic self-recording meters. The wealth of tidal information he possessed and imparted, and the strength and enthusiasm with which he pursued tidal current studies, will be greatly missed by his associates. Dr M. P. M. Reddy, an NRC Post Doctorate fellow from India, completed 2 years at BIO. During the latter half of the year, however, serious illness largely prevented him from actively pursuing his research studies.

At the year's end, the Section was comprised of 11 MSB and six FRB staff members. The Section is particularly understaffed in the professional ranks and at the junior technical level. A number of new positions that became available for recruitment late in the year, are expected to give some relief on the technical side. Some improvement in the professional strength is anticipated during 1967.

R. W. Trites

Coastal Studies and Deep Ocean Surveys

W. I. Farquharson[2]
D. Dobson
F. D. Ewing
T. R. Foote
F. K. Keyte[1]
D. J. Lawrence
E. A. Lewis
W. J. MacNeil

The primary objective of the Group is to undertake surveys and studies in support of fisheries, defence, navigation, and basic research. Special emphasis is given to the development, evaluation and application of the direct measurement of water movements. Assistance is also provided to other projects in the use of current

[1] Joined BIO in 1966.
[2] Left BIO in 1966.

meters and the analysis of current data. Increasing emphasis is being given to measuring other parameters such as temperature, pressure, and salinity, with the view to developing moored self-recording packages, to sense a wider range of physical oceanographic parameters.

St. Lawrence Estuary and Belle Isle Strait

Analyses of the surveys undertaken in these areas in 1963 have been completed (BIO Report 66-6 and Report 66-9). In the Estuary, it was evident that additional data with regard to the tides and tidal streams are required to depict more accurately the cotidal lines in the Estuary between the River entrance and Anticosti. It was also evident that 1 month's observations are insufficient to separate the residual flow from the tidal stream constituents. In order to isolate the responses to the semi-monthly tidal stream constituents MS_f, and M_f, the observations should cover a period of 6 months. This is probably also the minimum period for the reliable analysis of the smaller constituents associated with the monthly changes in the moon's distance from the earth, such as M_m, Q_l, and J_l, and M_l.

The survey in Belle Isle Strait was undertaken in order to obtain a better understanding of the interchange of water masses between the ocean and the Gulf of St. Lawrence. The residual current pattern fluctuates markedly from time to time. The 50-day mean current, as well as typical patterns when either an incoming or an outgoing flow is predominant, are shown in Fig. 8. The direction of predominant flow through the Strait can be correlated with the north-south barometric pressure gradient. When a low pressure system travels eastward over northern Quebec, the pressure at Hopedale may be as much as 20 mb below that at St. John's. Under these conditions there is a movement of water from the Gulf into the ocean. On the other hand, when a low pressure system travels eastward along the Atlantic seaboard, the north-south pressure gradient between Hopedale and St. John's is reversed and there is a movement of water from the ocean into the Gulf.

During the period of the survey, the mean residual outflow from the Gulf was about 0.25 X 10^6 c.f.s., usually confined to the southern side of the Strait and in the upper layer. This was approximately balanced by an outflow which occurred near the northern shore and in the lower depths across the Strait. With very disturbed meteorological conditions the flow in one direction or the other will predominate, and may persist for several days. These predominant flows can result in a one-way mass transport of about 10^6 c.f.s., mainly of water in the upper depths.

W. I. Farquharson

Cabot Strait

A part of the study of the tidal currents, circulation, dynamics and distribution of properties in the Gulf of St. Lawrence involves detailed examination of the boundary conditions. In 1966, field studies utilizing two ships were concentrated in the Cabot Strait area. The purpose of the survey was to determine the flow pattern and mass-field distribution in the Strait.

The MV *Theta* moored 19 Braincon current meters at seven equally spaced stations along a line from Cape North to Cape Ray and after a 29-day period recovered 15 of them (Fig. 9). An examination of the film from these instruments indicates that there are 12 full length perfect records, which, while not as representative of Cabot Strait as planned, are expected to provide sufficient data to meet most of the objectives of the project.

As part of an evaluation program, three of the new Bergen/Nato type current meters as manufactured by the Plessey Company were moored near one of the current meter sites. These meters were down for 27 days and all three functioned well. The results are now being processed and will be compared with those from the Braincon meters, located nearby.

When all the current meters were laid, the *Theta* was used to collect temperature and salinity data on six consecutive runs across the Strait in order to provide information on the mass-field distribution. A total of 43 stations were occupied at eight-equally spaced positions across the Strait.

While the *Theta* was occupying oceanographic stations on the Cape North-Cape Ray line, CNAV *Sackville* occupied 52 oceanographic stations on two parallel lines 30 miles to the east and west in order to provide three-dimensional information on temperature, salinity and density distributions. The *Sackville* also made observations of the drift patterns through the Strait using

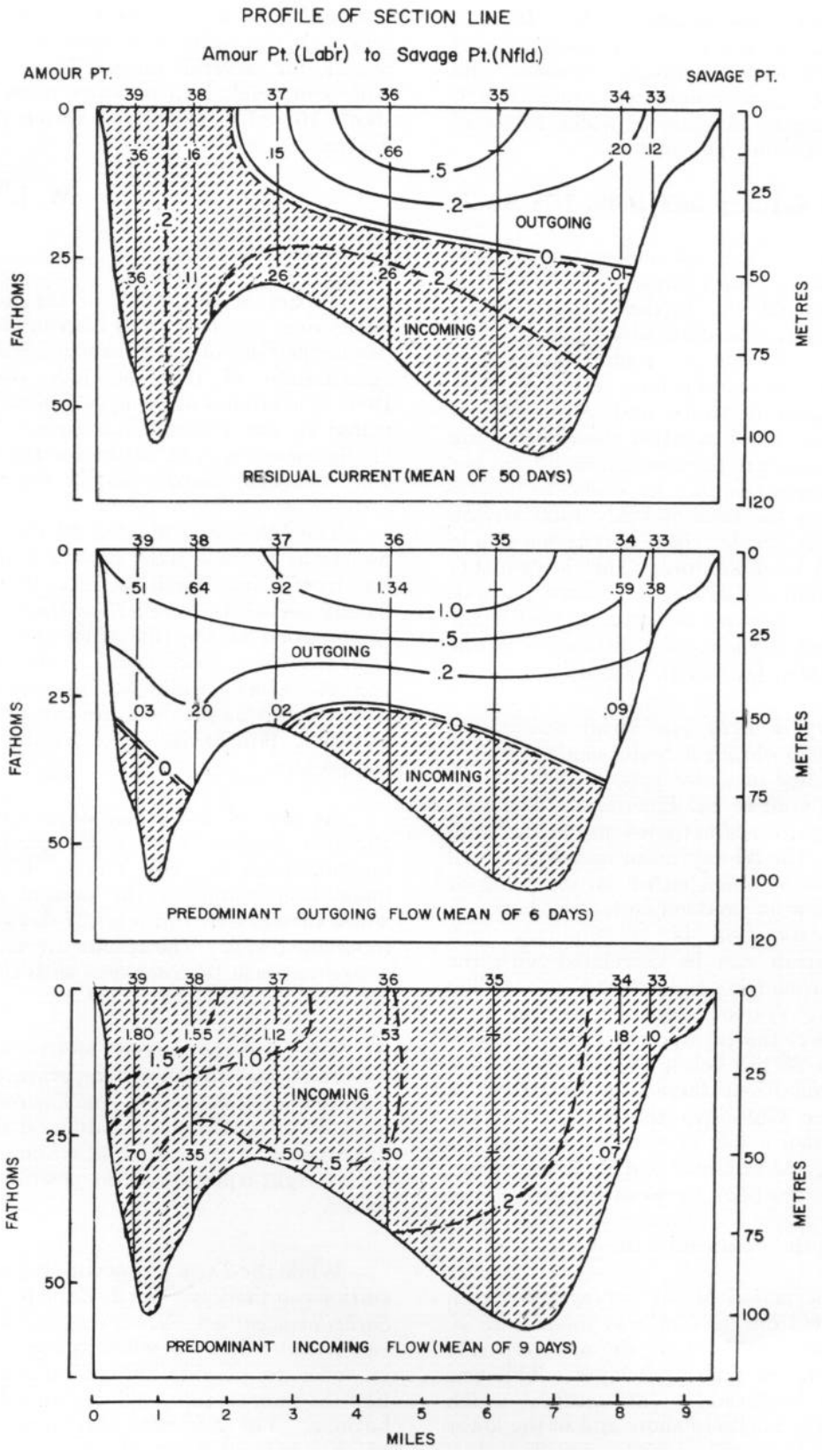


Fig. 8. Current sections in the Strait of Belle Isle area.

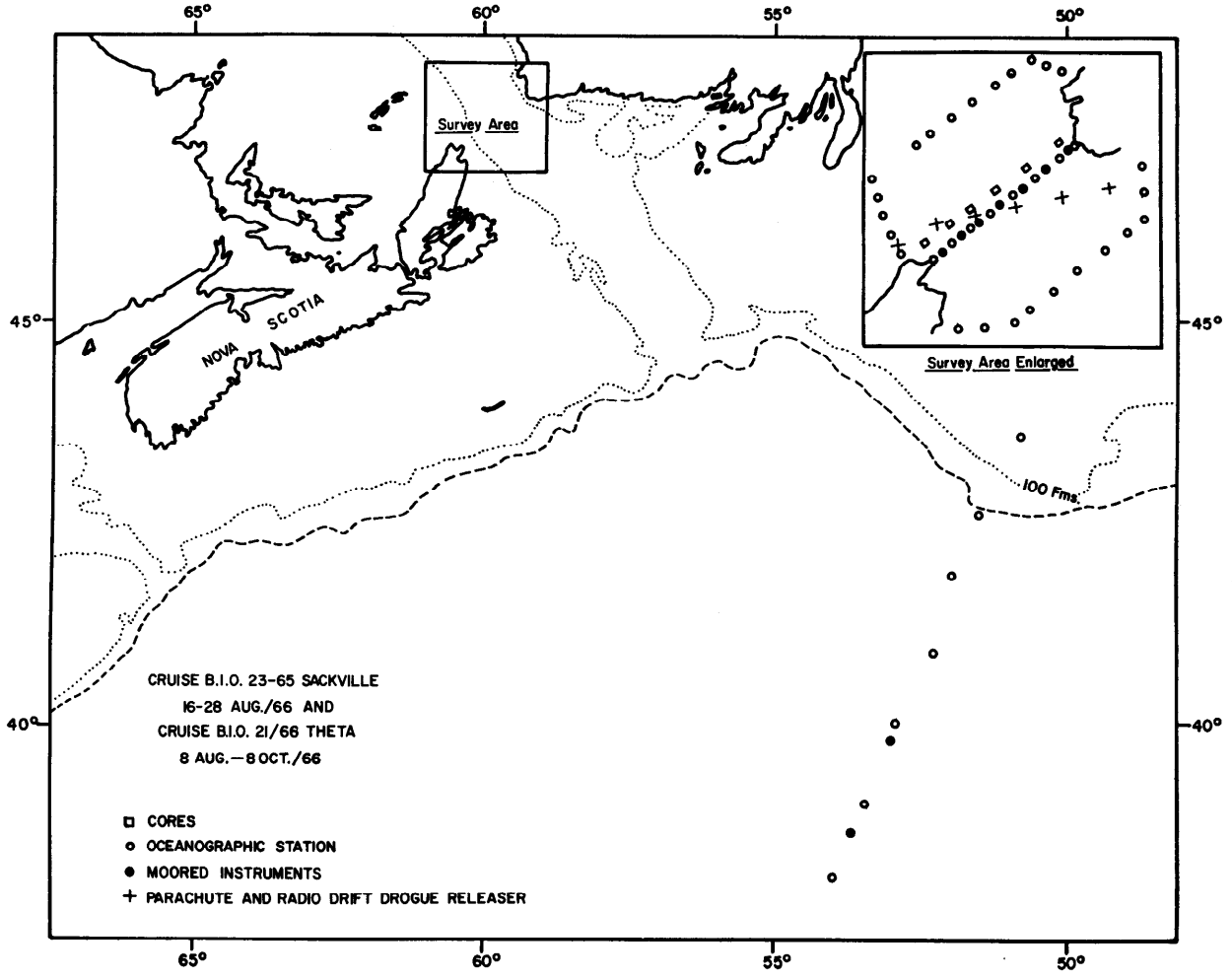


Fig. 9. Chart showing areas of activity in the Cabot Strait and deep ocean programs.

parachute drogues set at 6, 75, and 325 m, and using radio drift buoys with parachutes set just below the surface. These were all set out on arrival in the area, and tracked intermittently. The movements tended to be very irregular, indicating the need for much frequent position-fixing.

D. J. Lawrence
T. R. Foote

Deep ocean surveys

In support of the Ocean Circulation Group, the charter ship *Theta* carried out studies in the deep water off the southwest side of the Grand Banks (Fig 9). Earlier surveys of this area indicated a slow intermittent northwesterly flow of Labrador water in the upper layers near the shelf, and a stronger, well-defined east-southeasterly flow of Slope water between the Labrador water and the Gulf Stream.

From the earlier surveys, it was not possible to establish just how steady or persistent these flows may be. The object of the 1966 survey was to place current meters at three sites along a section running south-southwest from the Banks: one in Labrador water, a second in Slope water where the current was strongest, and a third in Slope water 50 miles southwestward of the second location.

The sites for the current meters were established from a preliminary temperature section of the upper 1,000 m. Owing to mooring difficulties, only two moorings were laid. Each of these consisted of four Braincon current meters, a recording depth gauge, a radio beacon on the sub-surface float, and two timed-release devices in parallel on the main anchor. The release devices were placed so that firing of either one would permit the sub-surface float to rise to the surface

but still remain tethered loosely by the instrument wire and a groundline to a second anchor. After the two moorings were laid, a detailed temperature and salinity section was run along the original line.

Upon return to the current meter sites at the expected time of release, nothing was apparent at the surface. Extensive dragging and visual searches in the area gave no positive results. Unreliable fixes aggravated the recovery attempts. In view of the losses of equipment on this cruise several improvements are under immediate consideration. They are: some form of search sonar, acoustic command release devises, acoustic pingers for sub-surface buoys and for the anchors, more powerful and longer lasting radio beacons, and better radar reflectors for the buoys.

D. J. Lawrence
D. Dobson

Nearshore Studies

R. W. Trites[3]

D. P. Krauel[1,3]
C. J. Langford
S. B. McHughen[3]
J. W. Pritchard
M. P. M. Reddy[4]
G. B. Taylor[3]

The primary function of this Group is to survey and study physical oceanographic parameters and processes in the nearshore environment. The rapid increase in urbanization and industrialization of coastal regions, as well as increases in fishing activity, recreation, and developing marine production studies has placed increased emphasis on the need for oceanographic information to answer problems arising in fisheries, pollution, and coastal engineering. Despite an increase in the level of effort at BIO in this part of the environment, the demands outpace our capacity to undertake studies at the desired level.

The data gathered in surveys undertaken at Belledune Point, Chaleur Bay, 1964, and in the inner reaches of the Bay of Fundy in 1965, have been processed and published as data records (BIO Data Report 65-1 and BIO Data Report 66-2-D respectively).

Petit Passage

In response to a request from the Department of Public Works, (DPW) a 2½ month combined tides and current study in Petit Passage was carried out between May and July (Fig. 10). Although the primary purpose of this project is to provide current information to support feasibility studies being carried out by DPW on a proposed causeway, the program was designed to obtain considerable fundamental information about the behaviour of flow through such passages.

The field program involved current meters at 13 sites, tide gauges at eight locations, wind speed and direction together with air temperature and water temperature measurements at one location, driftpole observations, photography, and an EMF installation. A great deal of difficulty was experienced in recovering the current meters. Strong tidal currents, a relatively short period of slack water, and poor visibility, delayed considerably the eventually successful recovery of all instruments. The need for timed or other types of release devices for use in such installations was clearly demonstrated. Eighteen current meters were installed for 29 days with a 78% successful performance. Difficulty was experienced in getting the EMF installation operational. As a result, a good calibration of the voltage records with the current meters was not possible. Apart from temporary recorder failure from an electrical storm and reference cell malfunction, the installation functioned successfully for several months. The recorder was removed when electrode polarization gradually built up beyond tolerable levels.

Data processing and analysis has progressed slowly to date owing to staff shortages and illness.

J. W. F. Pritchard
M. P. M. Reddy
R. W. Trites

Other projects

Physical oceanographic studies initiated in 1965 at Margaree Harbour and the harbour approaches, and off the Cheticamp River, in Cape Breton, were continued in 1966. The aim of the

[1] Joined BIO in 1966.
[2] Left BIO in 1966.
[3] FRB Staff.
[4] NRC Post Doctorate Fellow.

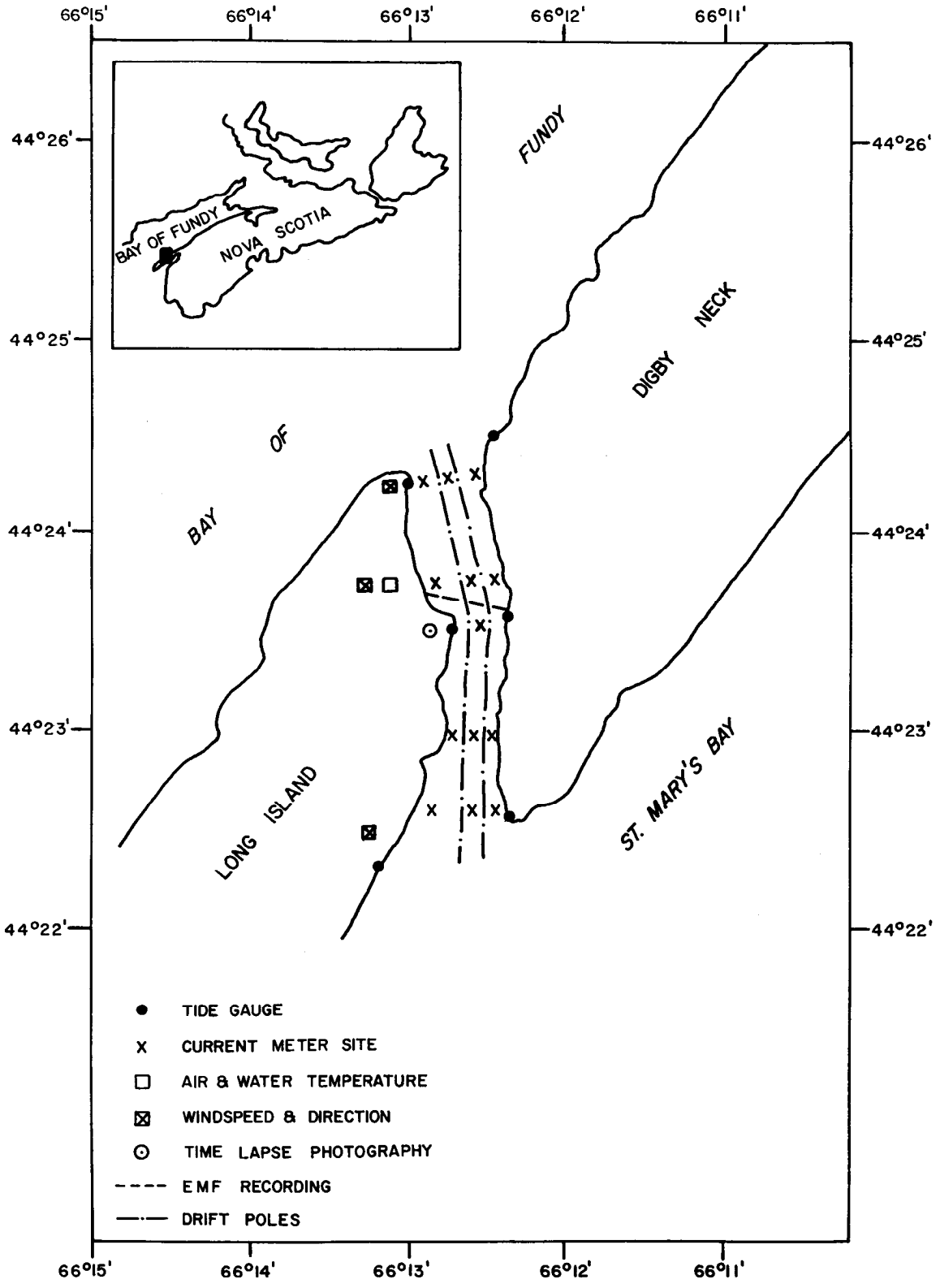


Fig. 10. Petit Passage installations.

study is to gain knowledge and understanding of the way in which the fresh and salt water mix and move seaward. This study was carried out to complement biological studies of Atlantic salmon stocks, and is reported more fully in the FRB section of the Annual Report (p. 100, Part B).

Preliminary studies were initiated in St. Margaret's Bay in June, as a background to an anticipated large scale multi-discipline study of marine production processes. The physical oceanographic program, which consisted primarily of current measurements near the mouth of the Bay, is reported more fully in the FRB part of this Annual Report (p. 100, part B).

A Geodyne current meter, mounted on a stand, was placed on an artificial lobster reef near Richibucto. The meter was in place for 2 months (July-August) but only a record of current direction was obtained, owing to a malfunction in the current speed sensing system.

R. W. Trites

Synopsis, Monitoring, Forecasting

W. B. Bailey
J. Butters
T. A. Grant[3]
W. G. Warshick

The primary purpose of this Group is to provide synoptic physical oceanographic information. In many respects it is analogous to a meteorological service. In addition to providing a picture of present conditions, there is a requirement for oceanographic information of a climatological nature, and for forecasts of anticipated conditions. In order to provide the best possible service, however, it is clear that rather extensive research programs are necessary in order to validate existing procedures and to improve these to account more fully for changes that take place.

In addition to Oceanographic Services for Defence, a major effort of the Group, the Halifax Section was monitored twice for fisheries purposes, and the Gulf of St. Lawrence ice forecast survey was undertaken for the Department of Transport.

Sambro light vessel, located off the approaches to Halifax Harbour, has taken twice daily bathythermographs (BT's) for the past 17 years. In September it was replaced by a moored navigational buoy. This represents a significant loss of a source of oceanographic data. It is hoped that the loss can be partially recovered with moored temperature recorders.

Oceanographic Services for Defence

Oceanographic Services for Defence, (OSD) located in HMC Dockyard, Halifax, is manned by three staff members from BIO and two technical assistants from the military meteorological service. In addition, professional and technical assistance is provided on a part-time basis by the Command Weather Officer. Basically, OSD performs a dual role, in that it provides a much needed service in supplying current oceanographic information to various military and civil organizations, and that it undertakes researches aimed at improving the products of the Service.

The Service aspects of the organization have been divided for convenience into four categories: executive, forecast, training, and operational research.

The officer-in-charge acts as Staff Officer Oceanography, and as such forms part of the operational services of the Operations Department of Maritime Command Headquarters. He is also chief adviser to the Maritime Commander on all matters of an oceanographic nature pertaining to the Command.

The forecast function deals with all aspects of the dissemination of oceanographic information. During 1966, in addition to the regular production of oceanographic charts of conditions in the Western North Atlantic Ocean, regular forecasts were made for the Nova Scotia and Bermuda areas, and special forecasts for such widely separated places as the Caribbean Sea, Arctic Ocean, and the Mediterranean Sea. The largest single operation carried out by OSD is the production of oceanographic charts for broadcasting on radio facsimile and for mailing.

The dissemination of oceanographic charts to various offices and organizations has continued to expand and efforts have been made to supply them only to places where they are needed. While the great bulk of the charts go to addresses in the Atlantic Provinces, they are also sent to Scotland, California, Virginia, Washington, D.C.,

[3] FRB Staff.

and Ottawa. In all, a total in excess of 18,000 charts were distributed to some 31 regular and several part-time recipients. A breakdown of the chart distribution is given below:

Military offices.. . . . . .5,670 charts

Meteorological offices.. . . . . .6,192 charts

Oceanographic laboratories. . . . . .2,582 charts

Fisheries laboratories. . . . . .2,736 charts

Fishing companies. . . . . 432 charts

With the establishment of the new Maritime Command early in 1966, the training role carried on in previous years was passed to the new Training Command. This eliminated the necessity of presenting several brief series of lectures. A considerable amount of time was spent preparing the scenario of a training film on Oceanography for Training Command. The coordination of oceanographic training was retained, and activities during the year became more advisory in nature.

Operational research in oceanography during 1966 was confined to the assessment of the requirement for atlases and charts and an investigation into the validity of charts prepared from merchant ship observations as compared with the detailed pattern of airborne radiation thermometer data.

W. B. Bailey

Environmental forecasting research

The daily oceanographic charts (OSD) depicting various parameters are drawn on the basis of past investigations into the nature of the oceans and the daily data available from weather and BATHY reports. It is obvious that a significant complexity exists in the oceans for which existing models are unable to account. Therefore, a program of detailed oceanic investigation must accompany the daily production of charts in order to validate existing procedures and to expand and improve these to account more fully for the apparent changes that take place.

During 1966, it was planned to continue the detailed investigations into the distributions of various parameters in an area 200 miles wide and 800 miles long, south of Nova Scotia. Unfortunately, a fire in CSS Hudson caused the cancellation of this survey Two oceanographic cruises were carried out aboard CNAV *Sackville* in direct support of the OCEAN IV program. The analysis of data is continuing.

W. B. Bailey

Instrument shop

An instrument maintenance, calibration and evaluation shop is operated as a combined service to meet, in part, the needs of the Applied Oceanography and Hydrography Sections. The major responsibility of the shop is for current meters and tide gauges, but the acquisition of temperature and pressure recorders, release devices and allied equipment is placing an increased load on the shop. At present, it is manned by two full-time technicians. However, to keep abreast of the present instruments, and new ones expected shortly, the complement of the shop will be doubled.

In the past year over 70 current meters were overhauled and modifications were carried out to many of them with the cooperation and assistance of company personnel. Much time was spent in the routine but necessary task of doing compass swings on these instruments. Meters were prepared and loaned to several groups within BIO and to several outside organizations. About 45 tide gauges were serviced and calibrated for installation in various places along the East Coast and in the Arctic. In addition, temperature recorders, depth gauges, timed release devices, and strain gauges, both old and new, came in for evaluation and maintenance. At present, most of the current meters record on 16 mm photographic film which is developed in the shop. From the 1966 field season a total of about 4,000 ft were developed, representing about 1,600 instrument days of data.

D. J. Lawrence

Numerical analysis and data processing

Harmonic analyses of the Petit Passage current meter data have been started by the Computing Group at BIO but there are difficulties due to the high velocities encountered in the area. P. S. Trites of the Computing Group has developed programs to analyze the data from the new Plessey current meters, and improvements will be made as more data become available. D. J. Lawrence has used Fourier analysis and power spectrum programs on the current meter

data from the 1964 deep ocean cruise and these are now being used on the 1965 data, both from the deep ocean and from the current meter comparison station in the St. Lawrence River. To assist in the presentation of the results, a program has been written for the PDP-8 computer in order to make use of the very accurate plotter attached to it. At present, progressive vector diagrams can be quickly plotted, and it is planned to adapt the program to plot resolved components against time.

D. J. Lawrence

ToC

Marine Geology

B. R. Pelletier

G. A. Bartlett
L. C. Brown[1]
D. E. Buckley
R. Cormier[2]
G. A. Duncan
C. A. Gooden[1]
A. C. Grant
T. A. Holler
L. H. King
K. M. Kranck
B. MacLean[1]
J. I. Marlowe
R. M. McMullen
S. S. M. Pitcher[2]
M. A. Rashid[1]
K. R. Robertson[1]
D. W. Sarty[1]
B. K. Sen Gupta[3]
G. Vilks
F. J. E. Wagner

Marine Geology at BIO involves physical geology, geochemistry, and micropaleontology. In the field of physical geology, studies are made of submarine physiography to relate the various physical features to their configuration, composition, and origin. General features of the bedrock such as mineralogy, petrology, stratigraphy, and structure are studied and related to the physiographic development of an area, as well as to the distribution of unconsolidated sediments. Certain factors of physical oceanography are considered, particularly in sedimentological studies, and these may also include observations on chemical parameters in order to present a total environmental picture

Geochemical investigations involve both wet and spectrochemical techniques, and include studies in organic and inorganic chemistry. The organic geochemistry is studied in order that the various sedimentological environments in which hydrocarbons are formed may be understood and that the relationship of the organic constituents and the associated sediments may be discovered. Inorganic geochemistry is studied as an aid in interpreting various sedimentary processes such as sedimentary transport; the weathering of minerals is also studied, since such investigations may lead to interpretations of ancient environments and diagenetic processes which may be operating at the depositional site.

Micropaleontology is studied at BIO to assist in the interpretation of ancient oceanic environments. However, the modern environment and its effect on living specimens is also studied with a view to illuminating problems of speciation, morphology, evolutionary trends, migration, zoning, taxonomy and the dating of geological and oceanographic events.

These researches were carried out in part, or in total, over the Arctic Ocean and adjacent channels of the Arctic Archipelago, the approaches to Hudson Bay, the Atlantic Ocean over the Grand Banks of Newfoundland, the inshore waters of the Atlantic Provinces, the Bay of Fundy, and the Scotian Shelf and adjacent continental slope (Fig. 11). In addition, a laboratory project was commenced on cores collected from the Mid-Atlantic Ridge in the vicinity of lat 45° N, together with new faunal studies on sediments from the Grand Banks.

In the laboratory, plans were made to fabricate a submersible rock core drill that will operate on the sea bottom from remote controls on deck by means of the ship's electrical power. This drill is designed for very shallow penetration in depths of water not exceeding 1,000 ft. Plans have also been completed for the installation of a living foraminiferal laboratory in order to carry out experiments on the feeding habits of these organisms and the relationship of these habits to growth and shell morphology.

Other activities included the preparation of several displays for use by BIO at the Fishermen's Exhibition at Lunenburg, Nova Scotia, and at the national convention of the Geological Association of Canada held in Halifax in 1966. At the Halifax convention, most of our scientific staff served on committees, or presented papers at the technical sessions. The scientific staff also visited various research organizations and educational institutions where they delivered

[1] Joined BIO in 1966.
[2] Left BIO in 1966.
[3] NRC Port Doctoral Fellow.

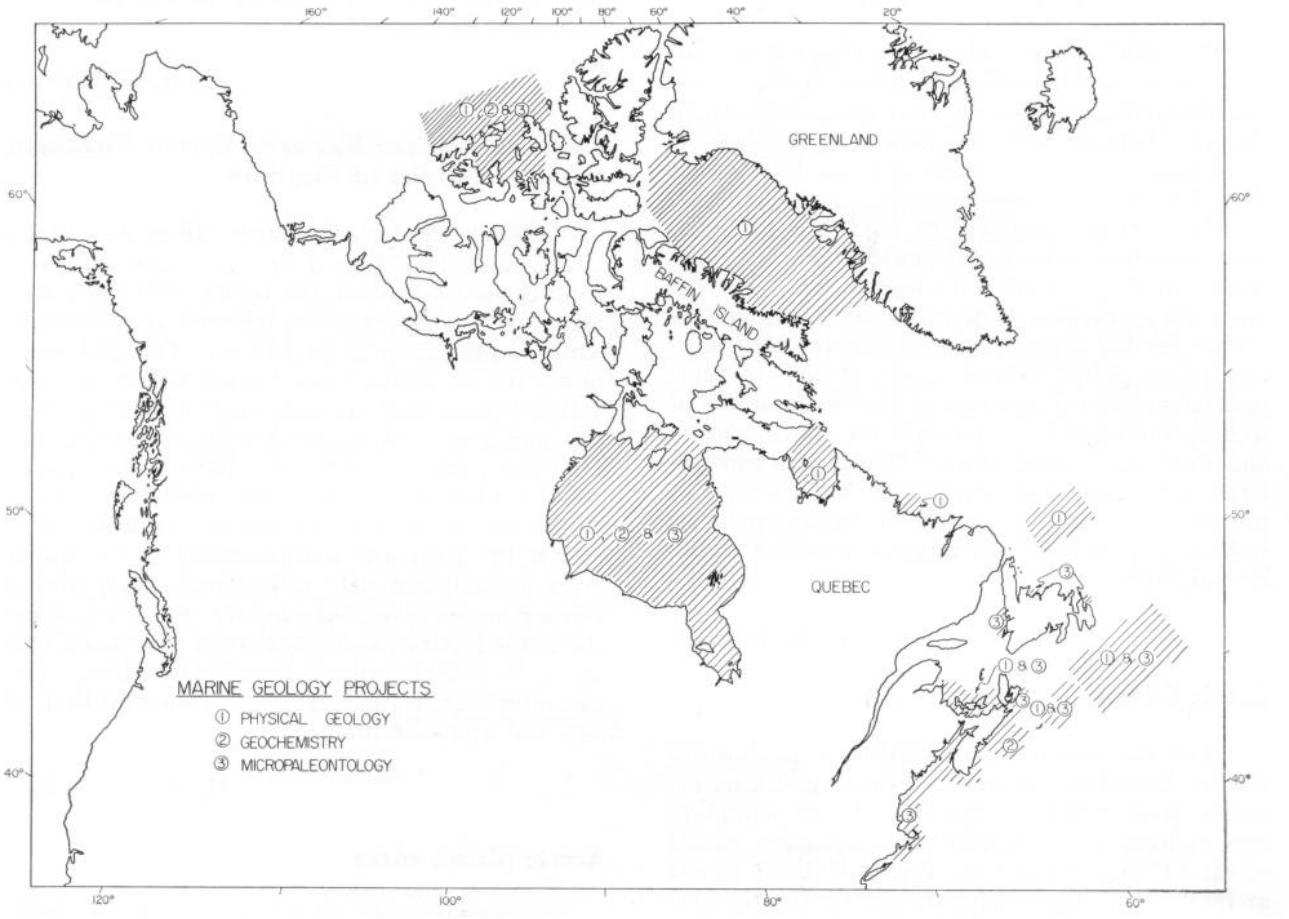


Fig. 11. Marine Geology projects and areas of investigation.

several lectures and papers, and led seminars on their own fields of interest.

The turnover in staff, in 1966, amounted to a net addition of five members. K. R. Robertson arrived from a government pathological laboratory, L. C. Brown from an industrial laboratory, D. W. Sarty from Dalhousie University and C. A. Godden from a defence laboratory. All are technicians assigned to the various laboratory groups. M. A. Rashid an organic chemist and B. MacLean, a geologist, also joined the staff and are assisting L. H. King in the Organic Geochemistry Group. Dr Barun Sen Gupta, an NRC postdoctoral fellow, is also undertaking research with this Group.

On educational leave, G. Vilks received his M.Sc. from Dalhousie University's Institute of Oceanography. D. E. Buckley transferred from the University of Southern California to the University of Alaska where he is completing his Ph.D. requirements.

Members of this Section continue to work actively with the universities. R. Herzer of Queen's University has been supported with research material for his B.Sc. J. M. Shearer was supported on his own field program in Port-au-Port Bay, from which research he is preparing for his M.Sc. degree at Memorial University of Newfoundland, and C. Yorath, of Queen's University, who was supported on our field program last year, continues to receive the advice of our staff on his Ph.D. program. Prof. K. Hooper of Carleton University is receiving material aid and technical services from us in connection with his micropaleontological research on the Atlantic Continental Shelf and Slope east of Nova Scotia. Mrs John Henderson (formerly Penny Wise) is completing her research on the petrography of Arctic marine sediments at The John Hopkins University.

B. R. Pelletier

Physical Geology

Physical geology refers to geological investigations in Sedimentology, geomorphology and bedrock geology and to the inter-relations between the sea bottom and the overlying waters. A wide range of field equipment is used to gather data for these studies including corers, bottom grabbers, trawl dredges, SCUBA diving gear, echo sounders, seismic sub-bottom profilers, and underwater photographic equipment. In the laboratory, various techniques are employed to obtain further data and these involve interpretation of graphical records made at sea, textural and mineralogical analyses of the sediments, and wet spectrochemical analyses on both organic and inorganic constituents. These data are collated with field observations in an attempt to present a concept of the total environment as well as a history of the physical features under investigation.

J. I. Marlowe

Arctic Ocean

For the seventh consecutive year, bottom studies have been made over the Arctic Continental Shelf, which complete a broad sampling and hydrographic program from Meighen Island at lat 81° N, to southern Prince Patrick Island at lat 75° N. Generally, the Arctic Continental Shelf is submerged to a depth of 400 m. When the land stood higher in relation to sea level, the inner part of the shelf underwent fluvial erosion, followed by glaciation. The effects of these events are still evident 40-50 miles offshore, where the ancient coastal plain merges with the outer continental shelf. Sediments in the topographic depressions are extremely fine and consist of silt and clay. Over the topographic highs, the sediments are more arenaceous. Rates of sedimentation are compared with those estimated for the channels of the adjacent Archipelago. In the channels near fluvial sources, sedimentation since the last glacial epoch amounted to approximately 5 ft. These sediments are yellowish-brown in colour and can be traced seaward to the edge of the continental shelf where the same layer is only 5-6 inches thick. Thus, sedimentation is considerably less in the outer areas of the continental shelf. Iceborne material is ubiquitous, but is not considerable, and amounts to only a few percent of the total sedimentary content. Carbon content varies between 0.6-1.0%, and carbonate content is generally less than 6%. These low contents may reflect the presence of a sparse fauna living in mainly ice-covered waters, which are relatively poor in phytoplankton. This work is discussed in BIO Report 64-16 and BIO Contrib. Nos. 26 and 29.

B. R. Pelletier

Hecla and Griper Bay area Queen Elizabeth Islands, District of Franklin

During the early summer, 48 grab samples and 2 short (less than 1 m) cores were obtained from the sea bottom in the Hecla and Griper Bay area. The samples were collected at random in water depths from 17 to 458 m. The grab samples vary in colour from brownish-grey to pale yellow-brown, and are composed mainly of clay-size particles. They also contain some silt- and sand-size particles, and a few have some angular pebbles that could have been ice-rafted. Each of the two cores is composed of two layers separated by a distinct disconformity. The upper layer in each is a pale yellow-brown clay and is thicker in the core taken nearer the shore, while the lower layer in each consists of a medium reddish-grey stiff clay that is occasionally silty. The disconformity is marked by a concentration of silt- and sand-size material.

R. M. McMullen

Arctic piston corer

In an effort to meet the need for a short-radius piston corer that can be operated through small auger holes in sea ice, a prototype release and corer head were designed and built in time for trials at sea on the *Kapuskasing* in April. Modifications were subsequently made and working models of the equipment were taken to the Arctic and used in the field by G. Vilks. Further modifications were made according to the suggestions of G. Vilks, and the equipment has been adapted for regular use in the Arctic.

J. I. Marlowe

Hudson Bay-I

The second phase of a major geological-geophysical-oceanographic project which commenced in 1961, was completed in 1965. Contributions from this project have been submitted to the centennial volume on Hudson Bay edited by Dr C. S. Beals, formerly the Dominion Astronomer of Ottawa. A discussion on the bathymetry and sediments is given here; the accounts of the fauna and bedrock geology are given elsewhere by F. J. E. Wagner and A. C. Grant respectively (p. 45, 41)

Generally, the bathymetric contours in Hudson Bay are concentric with the periphery of the Bay and range from zero to an average of 250 m in the low central featureless area. However. there are two major troughs which are greater than 300 m, and a shoal that extends from the south shore nearly to the centre of the Bay, thus disrupting the general saucer-shaped configuration of the bottom. Evidence of an earlier (perhaps pre-Pleistocene) drainage system is indicated by the occurrence of several valleys traceable for 100 miles from existing estuaries around most areas of the Bay. The deep trough west of the Ottawa Islands appears to be the result of subaerial erosion along a geological contact, particularly as Paleozoic rocks occur on its west wall and Precambrian rocks on the east wall. The other major trough is in the northeast, where it extends easterly into Hudson Strait at depths exceeding 500 m. This is thought to have a similar origin to the above trough, involving subaerial erosion along a geological contact. in view of the fact that a known fault occurs in the immediate area and extends easterly from the trough to the south side of Hudson Strait.

Sediments around the periphery of the Bay are coarse-grained and contain considerable ice-rafted debris. Toward the centre, the sediments are finer and the increments of ice-rafting are less. Carbon content is low, about 0.75, and is associated with the finer sediments. Carbonate content is high, particularly in areas underlain or bordered by Paleozoic carbonate rocks. Broken bedrock occurs in certain shoals as indicated by the high percentage of blocky, angular fragments recovered in the dredge hauls.

B. R. Pelletier

Hudson Bay-II

During the summer of 1965, over 1,100 nautical miles of continuous seismic profiling was carried out as part of the Hudson Bay project. The results of this survey as they pertain to bedrock structures are being reported in the Hudson Bay centennial volume for 1967 under “Marine Geological Investigations in Hudson Bay” (in press).

Nearly continuous profile coverage was obtained from east to west across central Hudson Bay, and a number of profiles were recorded along lines radiating to the northeast, north, and northwest from the approximate geographical centre of the Bay. Apparent dips observed in the sub-bottom bedrock along these lines are practically all at a low angle (less than one-half degree) toward the centre of the Bay, indicating that the Paleozoic sediments in Hudson Bay comprise a basinal structure. Regional strike on the basis of observed dips indicate a north-south elongation of this basin, and the major topographic trends in this direction are considered to be a reflection of the bedrock structure. Based on the figure for average regional dip indicated by these shallow seismic data, the estimated maximum thickness of Paleozoic strata attainable in central Hudson Bay is about 3,900 ft. An eastward convergence of sub-bottom reflectors in the order of 10 ft per mile was observed on profiles to the east and north of the Bay centre. Structure imposed subsequent to the deposition of the Paleozoic sediments in Hudson Bay may have influenced the development of drainage features. The latter were the centre of considerable drift accumulation (100 ft plus) during Pleistocene time.

A. C. Grant

Ungava Bay

From August 10 to 29, 1966, 3,000 nautical miles of magnetic and bathymetric profiling and 600 nautical miles of continuous seismic profiling were completed in Ungava Bay and Hudson Strait from CCGS *Labrador*. The continuous seismic profiles are currently being analyzed in conjunction with the bathymetric information obtained, and these data will be incorporated into a joint geophysical-geological report.

Akpatok Island in Northwest Ungava Bay is composed of flatlying Ordovician limestone and is bounded on all coasts by an escarpment ranging in height from 100 to over 600 ft. Bathymetric information shows that the Island rises from the northwest quarter of a submerged plateau, roughly 70 miles in diameter, that occupies the central portion of the Bay. Laterally from Akpatok Island, the plateau surface drops across two major escarpments and terminates at a third, and the continuous seismic data indicate that this submerged area is also composed of flatlying strata. A semi-circular trough bounding this plateau complex attains depths in excess of 200 fathoms. The eastern and western ends of this trough terminate as hanging valleys to the easterly trending deep in Hudson Strait. To the south and west, the axis of this trough can be taken as the approximate boundary between the Akpatok Island Paleozoic mass and the Precambrian

rocks on the Ungava Bay shore. To the east, the Paleozoic strata may extend across the trough, or there may be excessive accumulation of unconsolidated sediments in that region. To the north, a similar speculation may apply for similar features extending into Hudson Strait.

A. C. Grant

Shelf and slope off Northeast Newfoundland

Approximately 875 miles of continuous seismic profiling was completed as an auxiliary program to the Institute of Oceanography, Dalhousie University geophysical cruise over the slope and shelf off northeast Newfoundland in June and July, 1966. The continuous seismic equipment was operated from the MV *Theta*, which was serving as shot-ship to the CSS *Hudson* in a refraction seismic study.

Over the continental shelf, the continuous seismic profiles generally show flat-lying sub-bottom reflectors extending to an apparent depth of 20-60 fathoms, which truncate reflecting surfaces with low-angle dip toward the continental slope. Sub-bottom reflections on profiles traversing the slope are approximately parallel to the slope surface. Toward the foot of the slope, some records show underlying horizontal layers. Topographic irregularities at the foot of the slope have the appearance of erosional features in predominantly east-dipping, discontinuous reflectors.

A. C. Grant

Grand Banks off Newfoundland

A study was begun early in 1966 of 129 bottom samples collected in the summer of 1964 from the Grand Banks area. This study has been augmented by several hundred underway samples collected by CSS *Baffin* during her hydrographic survey this summer and autumn. The 1964 samples have been investigated as to size distribution, heavy and light mineral contents and pebble composition. Almost all of these samples are composed of more than 90% sand-size or larger material. There is no obvious relationship with the bathymetry except that there are apparent concentrations of sand at approximately 34 and 64 fathoms. The heavy mineral studies showed that the area can be divided into four "provinces", each dominated by a different heavy mineral, indicating that the provenance of the sediments is complex. This is more fully discussed in BIO Contrib. No. 64. The recently obtained samples are now being studied.

R. M. McMullen

Continental Slope off Nova Scotia

Further investigations were carried out along the continental slope near Sable Island, in order to define sub-bottom structure and identify bedrock formations. Sparker surveys conducted on board the *Kapuskasing* indicate that several hundred feet of unconsolidated sand and mud cover the bottoms of three large canyons between "The Gully" and the Cabot Strait Trough. In "The Gully", however, this cover is not present to the same extent, and sparker records show reflecting layers occurring over distances as great as 20 miles along the sides of this canyon. The structure of this series of reflecting layers suggests that the outer edge of the continental shelf is underlain by a sequence of gently seaward-dipping, sedimentary rock formations.

Dredge samples taken from the *Hudson* of outcropping formations from water depths as great as 2,200 m in The Gully contained microfossils which allow precise correlation of these rocks. Samples from trawls made across the l,000-1,800 m range contained Oligocene-lower Miocene faunas and correlated very closely with beds of the same age in Venezuela and the Caribbean region. (G. A. Bartlett, p. 46). Miocene beds in The Gully, therefore, have a minimum thickness of 800 m, which is greater than any other known locality in North America. Such a sizable thickness, as deduced from this single measured section, implies that a basin of deposition existed on the Scotian shelf during Miocene time. This implication could be of considerable economic importance.

Faunal correlations between The Gully and other localities in the Caribbean-Atlantic Coastal Plain region show that warm, sub-tropical conditions existed in lower Miocene time from the Antilles to Nova Scotia, and that water depths over the outer continental shelf were much the same as they are today. Conclusions from this study allow the extension of the known northerly limits of the Atlantic Coastal Plain physiographic province from Georges Bank to Sable Island; furthermore, the thickness and lithology of the formations in The Gully suggest that they may extend considerably farther north.

J. I. Marlowe

George Bay

During July and August, a total of approximately 6 weeks was spent in conducting a seismic survey and in bottom sampling in George Bay. This work was carried out as part of a multiphase geological study in collaboration with the Geological Survey of Canada. One hundred and five bottom samples were collected and 185 miles of "Sparker" seismic profiles run.

Seismic records show that the Bay is underlain by gently folded Carboniferous sedimentary formations similar to those outcropping along the shores. The surficial sediments of the Bay consist of sand and gravel near the shores, overlain in the central part of the Bay by a blanket of recent sediments.

K. M. Kranck

Strait of Belle Isle

Bottom samples and piston cores were collected from the Strait of Belle Isle during a cruise of the MV *Theta*. The cruise was under the direction of Dr M. Dunbar of McGill University, and the purpose of the geological phase of the program was to collect information upon which to base future work in the area. Field observations indicate that the bottom in the southern part of the Strait consists of mud, and the narrow central part is underlain mostly by gravel and minor sand.

K. M. Kranck

Northumberland Strait

A sedimentological survey of Northumberland Strait was continued in 1966. At the request of biologists of FRB, a sediment distribution map of Abegweit Channel was provided for use in biological investigations connected with the proposed Northumberland Strait causeway. A preliminary map of the bottom sediments of the western and central part of Northumberland Strait, based on sounding lines and field descriptions, has been completed. Three major sedimentary facies : recent mud, sand, and sandy gravel, have been differentiated. A bottom topography map of the Strait compiled from Canadian Hydrographic Survey field sheets shows the recent mud to occur as an even, featureless deposit; the sandy and gravelly bottom is characterized by ridges and depressions. Comparison of the sediment distribution in Northumberland Strait with the detailed current information available from the report of W. I. Farquharson, of the Canadian Hydrographic Service, on the 1958 Tidal Survey for the NorthtImberland Strait Causeway, shows present-day conditions in the Strait to be controlled by the tidal currents. In the parts of the Strait characterized by less than half-knot currents, mud deposition is taking place; the portions of the Strait with stronger current velocities have a bottom composed of sand and sandy gravel. The sandy gravel is relic glacial material associated with a relic glacial topography, and is prevented by currents from being covered with recent sediments. Sand waves and other features show much of the sand to be transitional and to move intermittently with the currents.

During the summer of 1966, the unsampled eastern portion of Northumberland Strait was sampled from the CSS Kapuskasing. The bottom sediments in this area, from Cape Bear eastward, appear to be similar to those of the rest of the Strait with the same dependence on tidal currents. Some piston cores from the recent mud have been obtained. These show most of the soft sediment to be underlain by glacial till, but in a few places, mainly in the western part, a stiff red clay forms the sub-bottom layer. Further information on the sub-bottom of Northumberland Strait was obtained through a program of sparker profiling conducted on CSS *Maxwell* and CSS *Kapuskasing*. These records are presently being examined, but preliminary results indicate that the portion of the Strait east of Pictou Island possesses a structure and history essentially different from that of the rest of the Strait.

K. M. Kranck

Minas Basin, Bay of Fundy

A long-term project to study intertidal and shallow water sedimentation under the extreme tidal conditions of the Minas Basin was begun in the late summer. This study is being made partially in conjunction with Dr D. Swift, formerly of Dalhousie University and now with the Puerto Rico Nuclear Centre. The main aspects of the study will be sediment transport, tidal current measurements, bed forms, internal sedimentary structures, sediment size distribution, gross morphology of the sand bodies within the Basin, and the application of hydraulics to sedimentation. Some field work was done and some of the results are presented in joint papers with D. J. Swift, BIO Contrib. Nos. 71 and 72.

R. M. McMullen

Geochemistry

Geochemical studies are being conducted on material from the Scotian Shelf. Since the geological setting is basic to such studies, considerable effort is devoted to the sedimentological and stratigraphic problems of the shelf. One of the major long-term objectives of the project is to determine the relationship of the depositional environment to the chemical constitution of the organic matter associated with the sediment. Considerable progress has been made in all aspects of the project during the past year.

Field and mapping activities

From April 2 to 14 and April 25 to May 13, geological sampling was continued on Fisheries Chart 4040, and 680 sampling stations were occupied. This essentially completes the sampling for this sheet, and a chart showing the surficial geology of the entire sheet is now in preparation. Approximately 600 miles of coverage with a continuous seismic reflection profiler were also completed.

Work which will lead to complete geological coverage of the Scotian Shelf is now in progress on the sheets east and west of Chart 4040. Geological information from the hydrographic echograms is being compiled by B. MacLean for Fisheries Chart 4041; G. Drapeau, a Ph.D. candidate from Dalhousie University, is using the facilities at BIO to complete Chart 4012 (Yarmouth to Halifax).

Sediments and stratigraphy

Sediments on the Scotian Shelf can be grouped into five facies units, and all appear to be products of a relict environment. During the Pleistocene age, the shelf was covered with glacial debris, and subsequently, during a low stand of sea level, much of the glacial debris was reworked and deposited in littoral and sub-littoral environments. The stratigraphic interpretations are based on echograms, continuous seismic reflection profiles, radiogenic ages, and the interpretation of the surficial geology. The studies indicate that the unconsolidated sediments rest on an erosional unconformity developed across beds of possible Tertiary age.

Inorganic geochemistry

The normative mineralogical composition has been calculated from the chemical analyses of a suite of sediments from the shelf, and enables a quantitative mineralogical comparison of both fine and coarse samples. The study illustrates the importance of grain-size distribution to an understanding of the composition of sediments and the compositional changes that can be brought about by mechanical fractionation. The fine facies are poor in quartz and rich in chlorite, mica, kaolinite, and plagioclase; the converse is true for the coarse facies.

The chemical and mineralogical data do not appear to contradict the hypothesis of glacial origin for the sediments.

Organic geochemistry

The isolation of organic matter from marine sediment constitutes one of the major problems in its chemical investigation. In this investigation an alternate acid-base extraction is employed and 50% yields are obtained which have ash contents of from 2 to 5%. A comparison with soil material on the basis of humic/fluvic acid ratios indicates that the marine material is in some respects similar to chernozem soils.

A knowledge of the functional groups present on the periphery of the molecules of organic matter is one of the most important means of characterizing and determining the constitution of organic substances. The major oxygen-containing functional groups in the organic matter of marine sediment are similar to those found in soils and coal, and include: carboxyl, phenolic hydroxyl, alcoholic hydroxyl, and carbonyl groups. However, the quantity and distribution of the functional groups of marine material differs from the material of terrestrial origin. For example, carbonyl groups are enriched in marine material, and phenolic hydroxyl groups are prominent in soils. Differences in functional group distribution are also being noted between the organic fractions from marine sediments on the Scotian Shelf which differ in age and origin. This work is carried out in collaboration with M. A. Rashid and with the technical support of G. A. Duncan.

L. H. King

Micropaleontology

Micropaleontological investigations involve various aspects of the relationship of microorganisms (Foraminifera in particular) to their environment. Foraminifera afford an excellent

source of modern and paleoenvironmental data because of their wide geographic range, large numbers in small samples, and long geological history. These organisms occur in nearly all marine and brackish water environments. Detailed conventional and statistical studies of life cycles, distribution, abundance, and test morphology are being conducted both in the field and in the laboratory. In addition, detailed X-ray diffraction and electron probe micro-analysis of modern benthic and planktonic Foraminifera have been initiated. Furthermore, the stratigraphy of Tertiary through Pleistocene sediments is being determined on the basis of the constituent Foraminifera. Various projects in the Western Arctic, Hudson Bay, Grand Banks, Gulf of St. Lawrence and Scotian Shelf are listed below.

G. A. Bartlett

Arctic Ocean

This laboratory project is undertaken in collaboration with the field work by B. R. Pelletier. Much of the early work is summarized in BIO Report 64-1 and Geological Survey of Canada Paper 61-27. Although no significant variation in species as related to substrata occurs, a zonation according to bathymetry is apparent. The zonation is a broad feature and the faunal change is noted only in areas where the bathymetry has varied by an amount of several hundred metres. These faunal zones have been correlated with other zones established by other workers in the Arctic Ocean, and now comparisons are being made with fauna recovered in sediments from the eastern channels of the Arctic Archipelago and the waters between Greenland and Canada.

F. J. E. Wagner

Arctic Archipelago

Continuous foraminiferal studies are in progress of the bottom sediments of the inshore and offshore waters of the Queen Elizabeth Islands, NWT. In the 1966 field season, 48 grab samples and two cores were collected in Hazen Strait and Hecla and Griper Bay (lat 70°30' - 77°30' N, long 109° - 116° W). In addition, temperature and salinity measurements at 50-m intervals were taken in the water column at one locality (lat 77° W, long 112° W). The sampling was carried out from a Bell 204B helicopter provided by the Polar Continental Shelf Project.

Preliminary results of the analyses of sediments and field data are, to a large extent, similar to previous findings in Prince Gustaf Adolf Sea, and its inshore waters. On the basis of temperature, the bathymetric range of the present study (17-458 m) can be divided in two ecological zones : the surface low-salinity and low-temperature zone, (0-200 m) and the deep-water zone with relatively higher salinities and temperatures. Associated with these zones are two distinct foraminiferal faunas: at localities shallower than 200 m, bottom sediments contain arenaceous Foraminifera dominated by *Trochammina lobata Trochamminella atlantica, Cribrostomoides crassimargo, C. jeffreysi* and *Textularia torguata.* At localities deeper than 200 rn, the foraminiferal fauna is usually richer, containing for the most part calcareous faunas, including *Globigerina pachyderma.* The benthic forms are dominated by *Islandiella teretis,* and *I. islandica;* and in coarser sediments by *Cibicides lobatulus.* The commonest deep-water arenaceous foraminifer is *Saccammina spaerica.*

G. Vilks

Arctic Archipelago II

The applicability of association analysis to the study of foraminiferal ecology was tested utilizing previously published data. (G. Vilks, 1964, Foraminiferal Study of East Bay, MacKenzie King Island, District of Franklin, GSC Paper 64-53). The analysis was carried out using a statistical model and a computer program written by W. T. Williams, CSIRO Computing Research Station. Australia.

Although the model was designed for the study of plant ecology, present results indicate that benthic environments can be classified using the association of Foraminifera. In making comparisons of the present findings with those of 1964, it was found that the association analysis not only supports some of the previous conclusions, but also shows differences in environment that were suspected but could not be demonstrated with simple statistics.

G. Vilks

Hudson Bay

A short paper was written for the Hudson Bay centennial volume. Emphasis in this paper is primarily on fossil molluscs and foraminifers from the Tyrrell Sea (ancestral Hudson Bay) deposits, with the fossil assemblages being compared with the present faunas of Hudson Bay.

The fossil record shows a definite change from colder, less saline conditions (in very shallow depths) early in the history of Tyrrell Sea to slightly warmer, more saline conditions at present.

F. J. E. Wagner

Nova Scotia

Six fossil reports have been written on Pleistocene collections submitted for identification. Of particular interest was a collection of shells from Nova Scotia, presumably the first Pleistocene collection from this province. The shells came from hills along the coastal area of Digby County bordering St. Mary's Bay.

F. J. E. Wagner

Grand Banks

Study of the Grand Banks commenced in November. Bottom grab samples which were taken from a depth range of 50-110 m are being studied for their foraminiferal content. The main objectives of the investigation are delineation of biofacies, assessment of ecological factors, and understanding of intraspecific variations.

B. K. Sen Gupta

Atlantic Provinces

Detailed studies of foraminiferal ecology were initiated in several estuarine, lagoonal, bay, and fiord environments in the Atlantic Provinces. These detailed investigations are a continuation of preliminary field and laboratory studies of Foraminifera in coastal and nearshore environments completed in 1965. Living Foraminifera from these environments are being cultured and grown in modified "Arnold" laboratory systems. A study of these living laboratory cultures, *Elphidium incertum* "complex", *Miliammina fusca* and various *Thecamoebina,* will result in a better interpretation of the distribution of assemblages in the natural environment. The temperature and depth zonation of Foraminifera in shallow waters is not as important as generally claimed. Foraminiferal distribution bears only an indirect relationship to substrata characteristics. Many factors, such as food supply, depth, temperature, salinity, current patterns, and substrata are interrelated in limiting Foraminifera to particular shallow-water habitats. Delineation of single factors as most important in shallow-water foraminiferal distribution is impractical at present.

G. A. Bartlett

Scotian Shelf

A detailed study of planktonic and tenthic Foraminifera in 20 cores and 500 grab samples from the Scotian Shelf is nearing completion. Many of the cores penetrated Pleistocene material, and a reconstruction of the Holocene marine environment is possible.

Foraminifera in marine sediments immediately overlying the glacial debris are sparse. *Elphilidium incertum* "complex", *Elphidium orbiculare* and *Islandiella islandica* are the dominant and commonly the only species present. A prolific benthonic fauna in most cores is evidence of deepening waters and more normal marine conditions. The recent Scotian Shelf fauna is composed of more than 100 foraminiferal species. Thirty species are arenaceous or agglutinated, and 10 species are calcareous imperforate, the remainder being calcareous perforate forms. *Globobulimina auriculata arctica, Nonionellina labradorica, Bulimina marginata Cribrostomoides crassimargo, Elphidium incertum* "complex", and *Cibicides lobatulus* dominate the Recent faunas. *Globigerina pachyderma* and *C. bulloides* are common planktonic forms.

G. A. Bartlett

Continental Slope, Nova Scotia

Bottom sampling in The Gully, a large submarine canyon, has yielded results which indicate the presence along the Continental Slope off Nova Scotia of a stratigraphic section containing beds that range in age from Chattian (Upper Oligocene) to Recent. Abundant foraminiferal assemblages indicate that water depths during the Tertiary period ranged between 120-400 m, and that a warm temperature to sub-tropical climate prevailed. These rocks and the ancient environment of deposition they represent are similar to rocks of the same age in various parts of the world. The sediment and constituent fauna indicate that the area is a promising target for the exploration of natural hydrocarbons (J. I. Marlowe, p. 42).

Pleistocene deep-water deposits on the slope indicate periods of warm water incursion and the establishment of a prolific "warm water" planktonic fauna. Characteristic forms are: *Globigerinoides rubra, Globigerinoides sacculifer, Pullenia tina obliguiloculata, Globorotalia truncatulinoides,* and *Globorotalia scitula.* Also present, but relatively rare, are *Globigerina pachyderma* and *Globigerina bulloides.* These latter species are dominant forms in the present environment.

Benthonic species in the associated sediments are typical of the outer continental shelf and slope.

Pleistocene shallow water deposits on the slope are indicative of a much lower sea level. The sediments and their constituent fauna *Elphidium incertum* "complex" and *EIphidium orhiculare* suggest that the Pleistocene strandline may have approached the 100-fathom line.

G. A. Bartlett

Mid-Atlantic Ridge

Drill cores obtained from the Mid-Atlantic Ridge have been examined and a report is forthcoming. A distinct difference in lithology in one of the cores is indicative of changes in environmental conditions. The lower part of the core is a semi-consolidated Globigerina ooze. The tests are strongly bound with a calcareous cement and the sediment when broken commonly breaks across tests rather than through the cement. The upper portion of the core is much coarser, and darker in colour, and contains a prolific macrofauna. Planktonic Foraminifera dominate the microfaunal assemblage. The most characteristic forms are: *Globigerina inflata, G. builoides, Globiferinoides rubra, Gboborotalia menardii, G. scitula, G. truncatulinoides,* and *Orbulina universa.* The lower, semi-consolidated portion of the core is characterized by the paucity or absence of *Orbulina universa* and the *Globorotalia* suite.

Cores from ponded basins along the Ridge are also being examined.

G. A. Bartlett

ToC

Hydrography

Hydrography

R. C. Melanson

A. L. Adams
R. C. Amero
H. A. Boudreau[1]
C. Boulanger[2]
C. J. Brooks
W. E. F. Burke[1]
T. J. Carew[2]
E. B. Clarke[1]
R. M. Cameron
E. J. Comeau
P. L. Corkum
V. J. Crowley[1]
F. L. DeGrasse
G. R. Douglas[1]
S. S. Dunbrack
R. M. Eaton
V. J. Gaudet
R. P. Haase[1]
M. A. Hemphill
G. W. Henderson[1]
A. D. Kenney
G. H. King
R. B. Lawrence
C. J. Langford[2]
D. D. LeLievre
R. C. Lewis
W. R. MacKay[2]
C. G. Miller[1]
L. P. Murdock
A. R. Newman[1]
D. V. Payn[1,2]
C. J. Pellerin[2]
J. M. R. Pilote
J. W. F. Pritchard[3]
W. J. Probert[2]
L. D. Quick
J. G. Shreenan
T. B. Smith
M. G. Swim
D. W. Vallis[2]
R. G. Wallis
K. T. White
R. K. Williams
G. M. Yeaton

Illustrations, Draughting and Photography Group.
J. R. Belanger[1]
T. M. Calderwood
N. E. Fenerty
J. A. Gasparac

[1] Joined BIO in 1966.
[2] Left BIO in 1966.
[3] Transferred to BIO Applied Oceanography Section in 1966.

The Hydrographic Service in BIO is responsible for chart and tidal surveys within the Atlantic Region, defined as Canada's Atlantic seaboard, the Gulf of St. Lawrence east of Pointe des Monts, Hudson Bay and the Eastern Arctic. Charting was undertaken by four DEMR-MSB vessels and one DOT northern supply icebreaker. Small projects of short duration were carried out by hydrographers on rotation. The Tidal Group installed five new permanent tide gauges and made annual inspection of 23 permanent gauges. This unit, previously known as the Inshore Tides and Currents Group, underwent organizational change, effective April 1, when the BIO Applied Oceanography Section was initiated, and the inshore current facet became its responsibility.

The responsibility for the surveys undertaken from DOT northern supply vessels was transferred here from the Central Region

A task group, headed by R. Douglas, has been organized to review recommendations made in a recent consultant's study on automation in the Hydrographic Service and to propose a plan of implementation.

The Draughting, Illustrations, and Photography Group, consisting of a staff of four, has continued to provide valuable services to all BIO disciplines.

BIO again exhibited a display at the Annual Fisheries Exhibition, Lunenburg, Nova Scotia. This year the display was a combined effort of the Hydrography and Marine Geology Sections, and, as in the past, aroused considerable public interest.

At the beginning of 1966 there were 36 on staff, however, due to resignations and transfers, and despite an active recruiting program, there was a net decrease of one by the end of the year. Nine summer students were employed as assistants to field surveys during part of the survey season in the hope that some would become career hydrographers.

Hydrographic Surveys

R. C. Amero, as Hydrographer-in-Charge of CSS *Acadia,* conducted standard charting surveys in the following areas from May 25 to October 28 (Fig. 12):

1) Amherst Harbour, Magdalen Islands, Quebec ;

2) Baie Verte, Newfoundland;

3) Sir Charles Hamilton Sound and Change Run, Newfoundland.

The purpose of the Amherst Harbour project was to produce an up-to-date chart of this very important small boat harbour on the southern extremity of the Magdalen Islands. In addition, Decca, fixed-error calibrations of chains six and nine were made about the offshore perimeter of the Magdalen Islands and along the southwestern extremity of Newfoundland. The Baie Verte project consisted of a post-dredging survey of the wharf area belonging to Advocate Mines Limited, who have large bulk carriers using its facilities. The survey of Sir Charles Hamilton Sound is a continuing project to provide charts of this sheltered passage. Soundings were taken, three

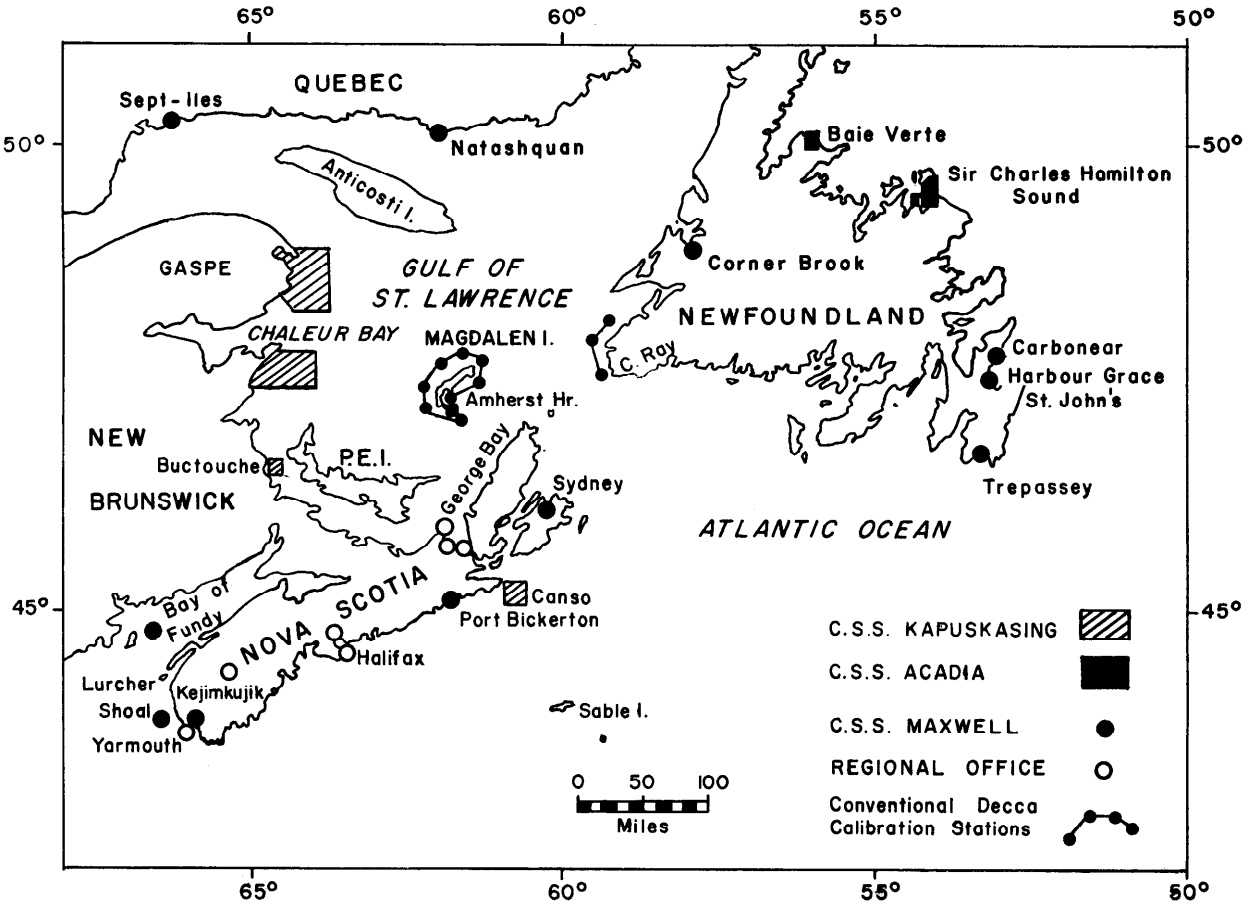


Fig. 12. Hydrographic surveys, nearshore activities 1966.

current meters were moored in the Sound and readings for a full tidal cycle were obtained. All other projects were completed.

D. D. LeLievre, as Hydrographer-in-Charge of CSS *Kapuskasing*, conducted charting surveys in the following areas from June 27 to November 9 (Fig. 12):

1) Buctouche, New Brunswick;

2) Chaleur Bay and Gaspè Bay, New Brunswick and Quebec;

3) Eastern approach to Canso Strait, Nova Scotia.

The project in the Buctouche area consisted of a survey to delineate the configuration of a shoal patch known as North Patch, and to resolve a point of contention between the Canadian Hydrographic Service survey of 1932 and the British Admiralty survey in the nineteenth century concerning the minimum water depth of the area. The Chaleur Bay and Gaspe Bay survey was a continuation of the 1964-65 surveys in this general area. As in the previous year, Hi-Fix in hyperbolic mode was used for positioning, and helicopter support was used for extending geographic control and conducting system calibration. The purpose of this project was general charting. The purpose of the project at the eastern entrance to the Strait of Canso was to fill in an unsounded gap in our present chart of the area. Positioning was done by conventional Decca, and fixed-error calibrations were made by visual observations of prominent shore objects.

All projects assigned were completed.

T. B. Smith, as Hydrographer-in-Charge of *Baffin*, completed the survey of the Tail of the Grand Banks from May 16 to November 9 (Fig. 13). This, in a limited sense, was a combined operation with Marine Geophysics and Marine Geology. A magnetometer and gravimeter were carried out when the instruments could be made available, while bottom samples were obtained from the Banks and delivered to the Marine Geology Section. Again, as in past years, Lambda in Range/Range mode was used for positioning, and the staff to maintain the equipment was supplied by the Marine Electronics Group.

J. M. R. Pilote, as Hydrographer-in-Charge of CSS *Maxwell*, conducted surveys in the following areas from May 2 to November 3 (Fig. 12):

1) Bay of Fundy, Nova Scotia;

2) Lurcher Shoal, Nova Scotia;

3) Sydney Harbour, Nova Scotia;

4) Port Bickerton, Nova Scotia;

5) Trepassey Harbour, Newfoundland;

6) Conception Bay, Newfoundland;

7) Humber Arm, Newfoundland;

8) Natashquan, Quebec;

9) Sept Iles, Quebec;

10) Gulf of St. Lawrence.

A check sounding survey was conducted in a portion of the Bay of Fundy to resolve a discrepancy in bathymetry between the *Kapuskasing* survey of 1957 and the *Baffin* survey of 1964. It was found that the *Baffin* work checked satisfactorily with the *Maxwell* findings. Because the feasibility study of replacing the Lurcher Lightship with a permanent structure on Lurcher Shoal was not completed during the previous fall, we were again requested to cooperate with DOT in sounding the area and positioning buoys for coring sites. Hi-Fix in hyperbolic mode was used for positioning with system maintenance performed by CDC technicians. The survey in Sydney Harbour consisted of sounding the outer entrance at the request of DOSCO whose carriers of 40-ft draft will frequent the Port of Sydney from late 1966. A survey of Port Bickerton was undertaken to provide a more detailed chart of the harbour and also to obtain an accurate plan of the channel after dredging to assist DOT in placing appropriate aids to navigation. The Trepassey Harbour survey was undertaken at the request of the Atlantic Development Board, who are looking into the possibility of establishing an industrial site to accommodate a paper mill. Two small projects were carried out in Conception Bay. One, at Harbour Grace, consisted of surveying two wharves and conducting

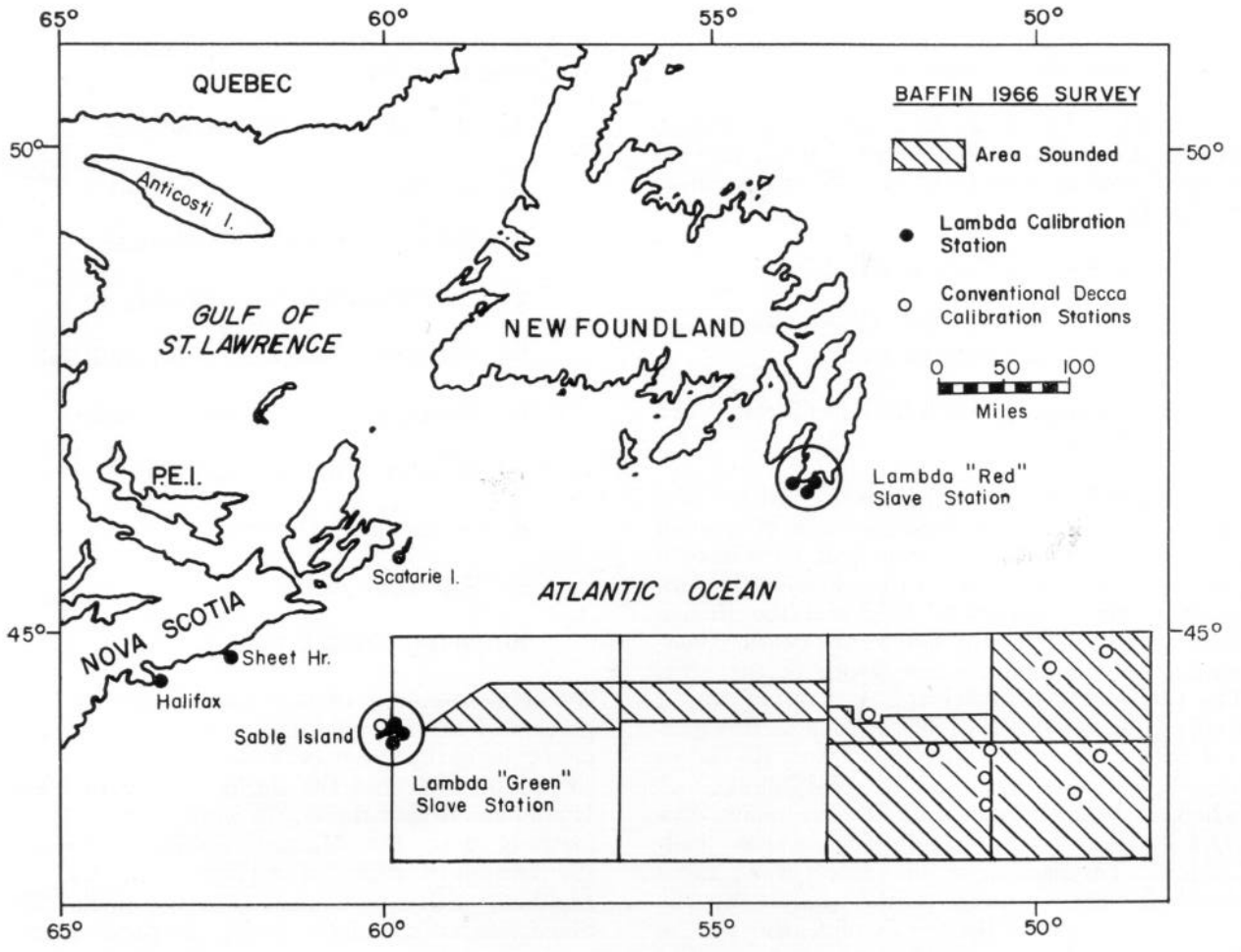


Fig. 13. Grand Banks hydrographic survey.

an examination of a shoal reported by the MV Imperial Quebec; a detailed examination was made but no obstruction found. The second project, resulting from a request by the RCN, was to check the dimensions of the Carbonear Government wharf. A survey was made of recent waterfront construction in the Corner Brook and Curling areas on the south shore of the Humber Arm. The purpose of this project was chart revision. A small sounding project was conducted in the Natashquan area to fill in a blank area of the existing chart. A reported discrepancy in a range bearing at Sept Iles was checked out. A difference of approximately 1¼ degrees was found from the bearing shown on the existing chart. In addition to the foregoing charting projects, this establishment, assisted by the Tidal Group, placed three temporary tide gauges in the St. Lawrence Estuary to fulfill a requirement in the proposed construction of a St. Lawrence River model by the Water Research Branch and National Research Council. All assigned projects were completed.

M. A. Hemphill, as Senior Hydrographer, Eastern Arctic Surveys, conducted surveys in the following areas from July 11 to November 5 (Fig. 14) :

1) St. Lawrence River, Quebec;

2) Milne Inlet, Northwest Territories;

3) Jones Sound, Northwest Territories.

This field establishment left Quebec, P.Q. on July 11 aboard the CCGS *D'Iberville* and the first project was a shoal examination off the northern tip of Hare Island North Reef in the St. Lawrence River. This examination resulted from a report of silting by the CCGS *Sorel.* Lesser depths than those shown on the existing chart were found

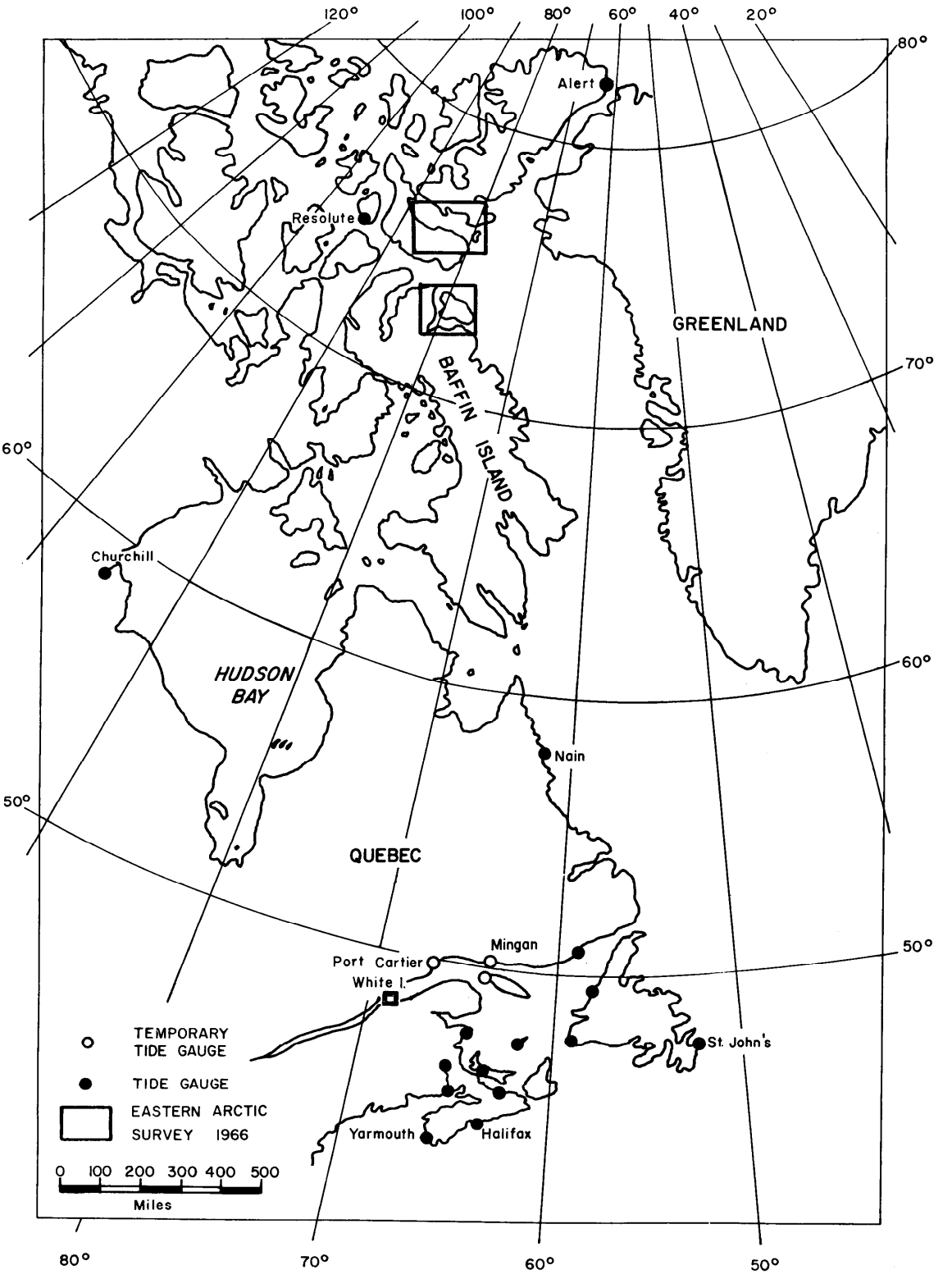


Fig. 14 East Coast tide gauge installations.

and reported to the Dominion Hydrographer for promulgation to shipping. The Milne Inlet project was a continuation of a survey commenced the previous year and was the main project for this establishment. The need for charting this area arises from the development of an extensive high-grade iron ore deposit. This project has been completed to the extent of assuring shipping that safe passage can be made to the proposed dock site at the southern extremity of Milne Inlet. Reconnaissance soundings were taken in Eclipse Sound and Navy Board Inlet, the two passages leading into Milne Inlet. To obtain additional information for Jones Sound, reconnaissance soundings were taken while the ship was there on supply duty. In mid-August a transfer was made to the CCGS *John A. MacDonald* and the surveys conducted from this vessel until the termination of the field season.

Field projects undertaken by the Regional Office (BIO) were as follows (Fig. 12):

1) Halifax Harbour, Nova Scotia;

2) Lake Kejimkujik, Nova Scotia;

3) Tusket Islands, Nova Scotia;

4) Avalon Penninsula, Newfoundland.

D. D. LeLievre, prior to taking up survey work on the CSS *Kapuskasing*, conducted a survey of the deep water channel leading into Halifax Harbour. This survey was undertaken by special request of the DOT and Halifax Port Commissson, and is to assist in future shipping plans for the area. As time would not permit Mr LeLievre to finish the survey, it was taken over and completed by A. L. Adams.

A combined bathymetric and sparker profiling survey of the proposed Halifax Harbour tunnel crossing was conducted jointly by the Marine Geology and Hydrographic Sections. This survey was conducted at the request of the Halifax Port Commission who are concerned with the limitations such a tunnel would place on future shipping.

At the request of Texaco Oil Ltd., a survey was made of their wharf at Eastern Passage. It was found that silting is taking place at a fairly rapid rate about 100 ft off the face of the structure.

The final project undertaken in the immediate vicinity of BIO was a routine revisory survey of the Bedford Basin Chart.

K. T. White carried out a horizontal control survey of Lake Kejimkujik to facilitate the drawing of a topographic plot for the proposed charting of the Lake in 1967. This project was supported by a Bell helicopter on loan from the CSS *Kapuskasing* surveys.

Upon completion of the foregoing project, additional horizontal control and aerial photography identification were made in the Tusket Islands area to facilitate drawing a topographic plot for the charting of the area in 1967.

F. L. DeGrasse, assisted by H. B. Sutherland conducted a short reconnaissance and control survey along the east coast of Newfoundland to assist in organizing the offshore survey planned for 1967.

Field assistance to other BIO undertakings

K. T. White established horizontal control in the George Bay. Nova Scotia area to assist Marine Geology in their positioning requirements. The same hydrographer assisted on a physical oceanographic cruise by keeping a running plot of the ship's track and bathymetry.

R. Douglas assisted with the bathymetric facet of the Mid-Atlantic Ridge Marine Geophysics cruise during the second phase. His chief concern was to observe the Geodal system and other instrumentation.

F. L. DeGrasse conducted a small reconnaissance survey at the Head of St. Margaret's Bay to assist the Applied Oceanography Section.

Field assistance to the Institute of Oceanography, Dalhousie (IODAL)

L. P. Murdock gave field assistance to the IODAL seismic cruise off the northeast coast of Newfoundland by keeping a running plot of the ship's track and bathymetry.

Tidal Group

Regular annual inspections of 23 permanent gauge installations (Fig. 14) were conducted and the upkeep necessary for their continuing operat-ion effected.

A new permanent gauge was established at Yarmouth, Nova Scotia, and four along the Saint John River, New Brunswick at Jemseg, Oak Point, Indiantown and Maugerville.

Field reconnaissance was made of four northern sites for permanent installations, Cape Merry, Manitoba; and Hall Beach, Frobisher, and Cape Dyer, all in the Northwest Territories. All records from the regional permanent gauges are received and annotated by this unit before submission to Ottawa, while tidal data from temporary gauges as collected during the course of charting surveys are received and indexed. A system has been established for the calibration and maintenance of all tide gauges utilized by BIO.

Instrument Evaluation

Hydrodist

An arrangement was made with Tellurometer (Canada) Ltd. to bring a complete Hydrodist system to the Institute for evaluation. A number of field projects undertaken by various BIO groups require a portable short-range positioning device and it was felt that the Hydrodist would be the most suitable. The evaluation, under A. L. Adams, was performed over a 4-day period in Bedford Basin for repeatability and accuracy, and off the Halifax Harbour entrance for distance. The tests indicate that the Hydrodist would meet positioning requirements with a high order of accuracy to a distance of about 12 miles.

Draughting, Illustrations, and Photography Group

The Illustrations and drafting unit, in the charge of T. M. Calderwood, provided the same type of services to all BIO groups as during the previous year, only in greater volume. The main bulk of the work involves the following disciplines: bathymetry, marine geology, marine geophysics, and physical oceanography. GEBCO data compiled from various cruises consisted of 18,700 miles of track sounding. Data applicable to navigational charts is being extracted from reports resulting from scientific cruises and compiled for future chart publications.

The photographic services to the BIO groups increased steadily throughout the year. One additional photographer was engaged during January and production has increased accordingly; however, due to the many requests put to this unit, further increase of staff early in 1967 is warranted. Work on the much needed main photographic laboratory was begun during the latter part of the year. Mr Belanger of this unit participated in the Mid-Atlantic Ridge cruise for its duration and was responsible for the complicated underwater photography.

1967 Hydrographic Field Programs

A training cruise in the Caribbean will be undertaken by the CSS *Baffin* from January 9 to March 17. The purpose is to provide field training for field personnel recruited into the Hydrographic Service during 1966.

The CSS *Baffin* will attend the Ninth International Hydrographic Conference at Monaco for a 4-day period during April. Ship time involved will be from April 5 to May 8, and various parameters of the ocean will be measured during passage.

Charting of the Grand Banks of Newfoundland will be continued northward from the Tail of the Banks, from May 22 to October 27. It is proposed that this be a two-ship operation with launches used as outboard sounding craft. The CSS *Baffin* will be the control ship of the operation, although the CSS *Kapuskasing* will be used in conjunction with it during the summer months (June 27 - September 8) and the CSS *Hudson* during the latter part of the season (September 11 - October 27). As in 1966, geophysical and geological data will be recorded insofar as they are compatible with hydrography.

General charting of Sir Charles Hamilton Sound will be continued by the CSS *Acadia* from May 15 to October 27.

Small conventional type surveys in Nova Scotia, Newfoundland and the Gulf of St. Lawrence will be carried out by the CSS *Maxwell* from May 1 to October 27, as priorities dictate.

From May 15 to October 27, a shore party will continue general charting in the Tusket Islands, Nova Scotia. It will also conduct a survey of Kejimkujik Lake, Nova Scotia at the request of Northern Affairs.

If the availability of field staff permits, a shore party will continue charting the east coast of Nova Scotia in the area from Sheet Harbour to Liscomb from May 15 to October 27.

Surveys in the Eastern Arctic will be undertaken on an opportunity basis from the DOT northern supply vessels from July to October.

A control party will be utilizing a chartered helicopter from May 15 to October 27 to establish horizontal control along the west coast of Newfoundland and along the north shore of the Gulf of St. Lawrence to expedite future hydrographic charting.

Annual inspection will be conducted of all permanent and semi-permanent tide gauges within the region. If time and funds permit, two permanent installations will be made, one at Port Harrison, Quebec, and the other in the Forteau Bay area, Newfoundland.

TABLE 2. Statistical summary of field work - 1966.

	Acadia	Baffin	Kapuskasing	Maxwell	E.A.P.	HQ	Total
N. miles sounded	518	21,988.0	6,497	846	2,100	37	31,986
Track sounding (n. miles)	-	-	-	-	3,200	-	3,200
Area surveyed (sq. n. miles)	21	35,825.0	1,413	36	320	-	37,615
Area triangulated (sq. n. miles)	26	12.0	-	10.0	-	110	158
Tellurometer traverse - (n. miles)	64	21.0	223	50	-	30	388
Shoals examined	569	10	116	317	8	37	1,057
Coastlining (n. miles)	22	-	95	25	-	14	156
Triangulation stations established	132	9	98	105	66	44	464
Stations monumented	23	2	4	40	-	11	80
Conventional Decca calibration checks	35	10	101	-	-	-	168
Tides gauges established	2	2	3	11	2	-	20
Bench marks established	5	-	-	8	3	-	16
Current meters used	3	-	-	-	-	-	3
Current moored stations occupied	3	-	-		-	-	3
Current meter data (days)	29 x 3	-	-	-	-	-	87 (self-recording)
Bottom samples	2,020	412	2,391	919	10	194	5,946
Hi-Fix chains established	-	-	-	3	-	-	3

ToC

Metrology

The Metrological Research Section was formed in April 1966, from the design and development groups of Engineering Services. Its fundamental purpose can be clarified by quoting "Engineering Dimensional Metrology" by L. Miller, p. 1:

"The aims of metrology are to provide and maintain precise definitions of the units of the system of measurement, to decide what is to be measured, to know and to discipline the uncertainties associated with the measurement and, by judicious standardization of procedure, to give universal meaning to the measurement. This demands of the metrologist a very high degree of intellectual integrity and gives to the subject a special place among the educational disciplines".

In terms of oceanography and hydrography, and more particularly of BIO, this implies a variety of interests ranging from the problems of devising, from basic principles, methods of measuring oceanographic parameters, to the construction of equipment and its evaluation under normal

working conditions. In order to devise such equipment adequately, it is normally essential to acquire a full knowledge of the research program, and to verify that the design of the specific experiments meets the requirements necessary to ensure compliance with the Theory of Measurement.

Although the Section is divided into two groups, Electronic and Mechanical, this division is administrative in nature. Most projects involve both groups, and there is very close technical liaison between the groups at all levels; the Section also cooperates with Engineering Services as closely as before the division took place.

The need for a metrological research section may be queried. It is common for such work to be performed by individuals distributed amongst the research groups. This has the advantage of fostering intimate knowledge of the research program in which the instrumentation is to be used, and also tends to make certain that the designer is very completely involved in field evaluation. Some of the advantages of a separate design group are: that the concentration of design talent tends to promote both more competent and more versatile designing, that previous experience may provide the solution to problems which arise in a new area, and, that a known resource of specialist knowledge in the field of metrology can be established. It is our aim to prove, both by the production of equipment and by the tendering of advice to interested oceanographers, that our decision to establish a specialized design team was wise.

Several members of the Section took part in the Mid-Atlantic Ridge cruise of CSS *Hudson* (p. 25), primarily to carry out tests of newly developed equipment at sea. We are glad to acknowledge the very considerable amount of time made available to us on this cruise (together with the preliminary shakedown cruise) and to express the hope that the high level of cooperation achieved may be repeated on future cruises.

Successful trials of the Biodal data-logging system (p. 55), including the printed-circuit card modules (p. 61), and the sediment heat-flow probe (p. 56) were completed; the portable pressure tank (p. 62) and transponder buoys (p. 61) were also satisfactorily evaluated. A great deal of effort went into the trials and development of the rock core drill (p. 59), and it is noteworthy that this project entailed construction of equipment on board ship on a scale much greater than has been previously attempted at BIO. Ship's head and log data were recorded on most of the buoy-controlled survey lines; this data will be analyzed by the Hydrographic Development Group.

R. L. G. Gilbert

Electronics Instrumentation Laboratory

C. S. Mason

A. S. Bennett
D. E. Wells[1]
E. A. Bendell[1]
K. S. Budlong[1]
J. A. Dimmers
H. W. MacPhail
B. B. Hartling
D. R. Harvey
R. Cassivi
G. C. Hicks[1]
P. H. Jollymore[2]
D. Simpson[3]

In the past year, the work of the Design Group has been diversified and expanded. Work on digital systems has proceeded at about the same pace as previously noted and the development of new specialized devices, particularly for measuring and recording oceanographic parameters in situ has commenced. Whilst the professional and senior technical staff has expanded, enabling the design of these systems to progress satisfactorily, support at the junior technical levels has been, and still is, lagging. This has meant that although new projects have been started, few of the older ones have been fully completed due to the lack of junior personnel to complete the routine but essential tasks necessary before the equipment is handed over to the operators. This lack has been partially circumvented by the use of contracts for support to individual projects, but it is hoped that in the next year the Group will become better balanced. The work of the Group is concentrated upon the completion of existing projects rather than the commencement of new ones. The major projects of the past year are described below.

Biodal data-logging system

The prototype data acquisition system intended for a standard recording facility on BIO

[1] Joined BIO in 1966.
[2] Left BIO in 1966.
[3] Graduate student. Institute of Oceanography, Dalhousie University.

ships was completed and taken on the CSS *Hudson* on Mid-Atlantic Ridge cruise (p. 25). Parameters recorded were day number, time, ship's heading, and ship's log. The system performed consistently well, while the clock which was intended to keep time to about 1 sec per month, in fact varied only by 75 milliseconds in 60 days. The easily-read neon-type clock display was found particularly useful and permanent displays are to be installed in the bridge and chart room of CSS *Hudson*.

Construction by outside contract of Biodal systems for CSS *Hudson* and CSS *Buffin* has commenced and both systems should be completed by mid-1967. Preparations for the installation of the Hudson system are being made by Engineering Services. In the next year, a start will be made in the design of matching units to convert shipboard data into the digital format required by the Biodal data logger.

A paper describing this system was presented at the International Oceanographic Congress, Moscow, 1966.

A. S. Bennett
C. S. Mason

Sediment heat probe

Development of a sediment heat-flow recorder, a device for measuring the temperature of ocean floor sediment, is well advanced. The instrument is mounted on a conventional sediment corer and measures and records the temperature at three points along the core barrel. Determination of the thermal conductivity of the sediment column recovered by the corer enables a calculation to be made of the heat flow through the ocean floor.

The original instrument was designed and constructed by C. R. B. Lister, who was consultant for the Marine Geophysics Group. This instrument has been adapted to record digitally on a tape recorder developed by the Mechanical Design Group (p. 61). A second instrument, similar to the first, was completed in August and both instruments were tried at sea with pleasing results. The heat probe was not tried as an attachment to the sediment corer but temperature profiles were obtained by lowering the recorder through the water. Except for minor malfunctions of the digital tape recorder, the instrument performed well on these tests.

A digital magnetic tape reader has been built to translate the heat probe recorder output to punched paper tape and programs have been prepared to process the data on the PDP-8 computer.

D. R. Harvey
C. S. Mason
D. E. Wells

Deep sea precision sounding

Trials of the Gifft precision depth recorder were carried out both in the laboratory and at sea. The writing system of the recorder has proven to be unreliable and is at present being modified by Mechanical Design. A successful recording system employing the EDO transducer, Gifft transceiver and Alpine display unit, was assembled on board CSS *Hudson* during the Mid-Atlantic Ridge cruise. Two transceivers and recorders of these types are now being obtained and will be fitted to CSS Hudson. It is hoped that this installation will become a permanent feature on *Hudson*. The system will be controlled by the Biodal master clock installation (p. 55).

C. S. Mason
P. H. Jollymore

Data processing system

A detailed evaluation of the processing system was carried out early this year by R. H. Loucks of the Air-Sea Interaction Group, primarily to ascertain the accuracy of the sub-carrier discriminators used in the process of transferring data from magnetic tape to paper tape. Once the limitations of the system were determined, it was used to prepare Air-Sea Interaction data for further analysis by computer (p. 15). The analysis of the field results from Aruba, using this system, enabled Mr Loucks to present a paper at the International Oceanographic Congress, Moscow, 1966.

A modification has been added to the system in order that it may be used to digitize analogue chart records and it has been used for this purpose by D. L. Barrett and S. P. Srivastava of the Marine Geophysics Group (p. 27).

Inspite of a succession of minor faults, usually associated with either the discriminators or the multiplexer switch, both known to be unreliable, the system is being used to process data

recorded aboard CSS *Hudson* in gravimeter cross-coupling experiments. Completion of the system is now underway and replacements for the unreliable components are being obtained.

Preliminary investigations of a faster, more versatile and reliable system are now being made and acquisition of this new system will proceed along with the completion of the present one.

E. A. Bendell
C. S. Mason

Magnetic measurement

Development of the portable, self-recording proton precision magnetometers has continued. The digital tape recorder has been overhauled and the storage capacity for data increased tenfold. The tape playback system has been entirely rebuilt and both recorders and playback system are now working reliably.

Redesign of the magnetometer units has commenced, solid state switching and programming has been installed and attempts are now being made to decrease the power consumption and increase the reliability. New circuit diagrams for the instrument have been prepared.

The BIO magnetometers were used to support a joint field program between the Bedford Institute and Cambridge University, England (p. 27) with only modest success.

C. S. Mason
D. E. Wells

Telemetry system

J. A. Dimmers has been seconded to the Air-Sea Interaction Group to provide engineering support (p. 61). A supervisory system has been designed to permit the remote control of the data transmitting station, located approximately two miles offshore. The system will enable a possible total of 720 separate commands to be transmitted from the shore control to the equipment on the stable platform, via a VHF-FM transmission link. The data from the tower will be transmitted to shore by a VHF transmission link, and this link will also be used to indicate the commands actually received at the tower via the command system. The control commands are generated by a telephone dial, and the commands in operation at any instant on the platform are shown (via the re-transmission link) in numerical displays on shore; any errors made from any cause can thus be quickly detected and corrected.

J. A. Dimmers

Radio-controlled launch

A 14-ft radio-controlled launch was acquired in the spring of 1966. It was intended to tow a commercial "V-fin" equipped with echo sounders for use in hydrography. As an unmanned sounding launch, it would permit survey work to be carried out in fairly rough seas when manned launches cannot be safely launched from the mother ship.

The launch, a completely enclosed craft, was intended to be capable of 20 knots while towing the V-fin in calm water. This specification was met only after exchanging the original diesel engine for a more powerful gasoline one. Several modifications of the original control circuit are being made to ensure prompt and reliable fail-safe control should the launch get out of radio range or capsize. Other circuits will prevent the engine from racing if the propeller should come out of the water in rough seas. Trials of this launch at sea are planned for the summer of 1967.

K. S. Budlong
R. L. G. Gilbert

Bathythermograph probe

This probe, developed for the Central Region of MSB consists of a pressure and temperature unit fitted in a water-tight case. A seven-conductor cable is used to lower the unit to a maximum depth of 500 ft. The system was assembled using commercially available equipment and provides a graphical plot of depth versus temperature during the lowering of the sensor, and a printed output of these parameters. The unit was used for about one month on the Great Lakes program, but satisfactory inter-comparisons between reversing thermometers and the auto-bathy unit were not made and malfunctions of the thermistor and vibratron pressure gauge limited the usefulness of the new equipment.

Development of the autobathy unit is continuing and it is hoped to try a rebuilt instrument at sea next June. The Mechanical Design Group at BIO are preparing a towed body for the autobathy transducers which will continually change depth back and forth from the surface to a preset lower limit as it is towed behind the surface vessel. A block diagram of the autobathy is given in Fig. 15.

H. W. MacPhail
R. L. G. Gilbert

Hydrographic Development Group

D. E. Wells has been seconded to this Group to provide engineering support. The Group has only recently been inaugurated, and a detailed work program is being prepared. Work currently in progress includes a reasoned review of the accuracies required in position and depth, for a hydrographic survey; an investigation of the behaviour of CSS *Hudson*, using data collected on the 1966 Mid-Atlantic Ridge cruise; and an evaluation of a new launch echo sounder. Mrs

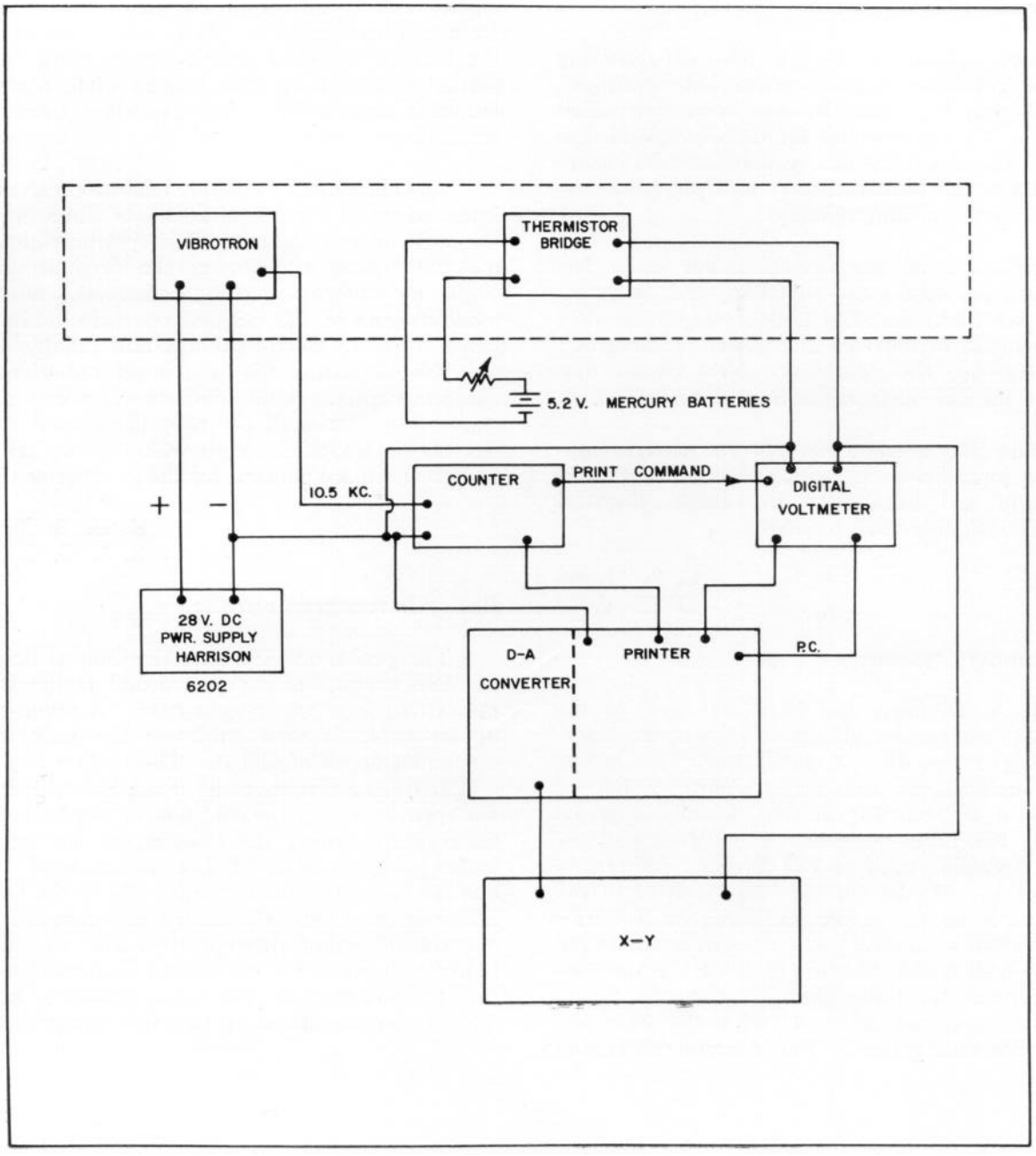


Fig. 15. Block diagram of the electronic components of the autobathy unit being developed at BIO.

K. S. Budlong is refurbishing a Decca digitizing and recording system for trials at sea next June.

D. E. Wells

The BIO plotter

The rehabilitation of the plotting table, originally supplied as part of an automatic shipboard depth plotting system, has been held up for most of the year by the non-delivery of parts and shortage of technician time. B. B. Hartling was seconded for several months to Engineering Services and worked at sea on CSS *Baffin*.

In the meantime, a control unit to permit the plotting of points specified by punched paper tape has been built and partially tested. Final testing awaits the availability of the plotting table in working order.

A. S. Bennett
B. B. Hartling

Low power consumption system

Work began this year on the design of low power consumption circuits for use in buoys and ocean bottom equipment. Initial development work, being carried out in conjunction with D. Simpson of Dalhousie University, centres on clock and time circuits. It is hoped to construct a prototype clock during 1967.

A. S. Bennett
D. Simpson

Mechanical Design and Instrument Shop Group

J. Brooke

Design office	**Instrument machine shop**
J. G. Dessureault[1]	W. W. Hall
R. N. Vine	G. F. Connolly
W. J. Whiteway	R. K. Sawler
D. Chamberlain (Ships Section)	

The work of this Group in the past year has been mainly concerned with projects that had been started in the previous year. The increase in both MSB and FRB staffs has brought about the expected increase in work load particularly of small "in-house" development and prototype jobs, and of advising oceanographers on mechanical matters.

During the winter months the depot workshops were fully occupied with launch repair together with the usual daily maintenance requirements in and around BIO. In April of this year the Depot Workshops became part of the new Engineering Services Section and their activities thereafter are reported elsewhere (p. 64). We should like to thank R. Balfour for his help with past problems when the Depot Shops were part of this Section and for his cooperation since that time.

J. G. Dessureault, a graduate mechanical engineer from Laval University, joined the Section in July of this year. We were also fortunate in having the services of three enthusiastic summer students during our preparations for the Mid-Atlantic Ridge cruise; their presence relieved the shortage of staff caused by the delays in authorization of this year's new positions.

Rock core drill

Work on this project has been continued throughout the year and the results to date are most encouraging. Experience gained on last year's November cruise and experimental testing in the laboratory indicated that modifications to the main control system were required, and that a water/oil mixture could be used to power the drill (Fig. 16). A modified unit (MK. II) was used during the Mid-Atlantic Ridge shakedown cruise during May and its use resulted in the successful drilling of a piece of basalt rock which had been fastened to the drill frame. Several lowerings onto the San Pablo and Kelvin Sea Mounts indicated problems of handling and launching techniques which had to be solved before further progress could be expected. The major problem was to ensure the stability of the rig itself under high current conditions at the sea bed.

During the 6 weeks between the shakedown cruise and the Mid-Atlantic Ridge cruise, three new drills were built: one for experimental work at deeper range and two medium range drills in case of severe damage or loss. A scale model of the rig was built and a series of tests run to investigate the models' behaviour when lowered through a horizontal current. Based upon these tests.

[1] Joined BIO in 1966.

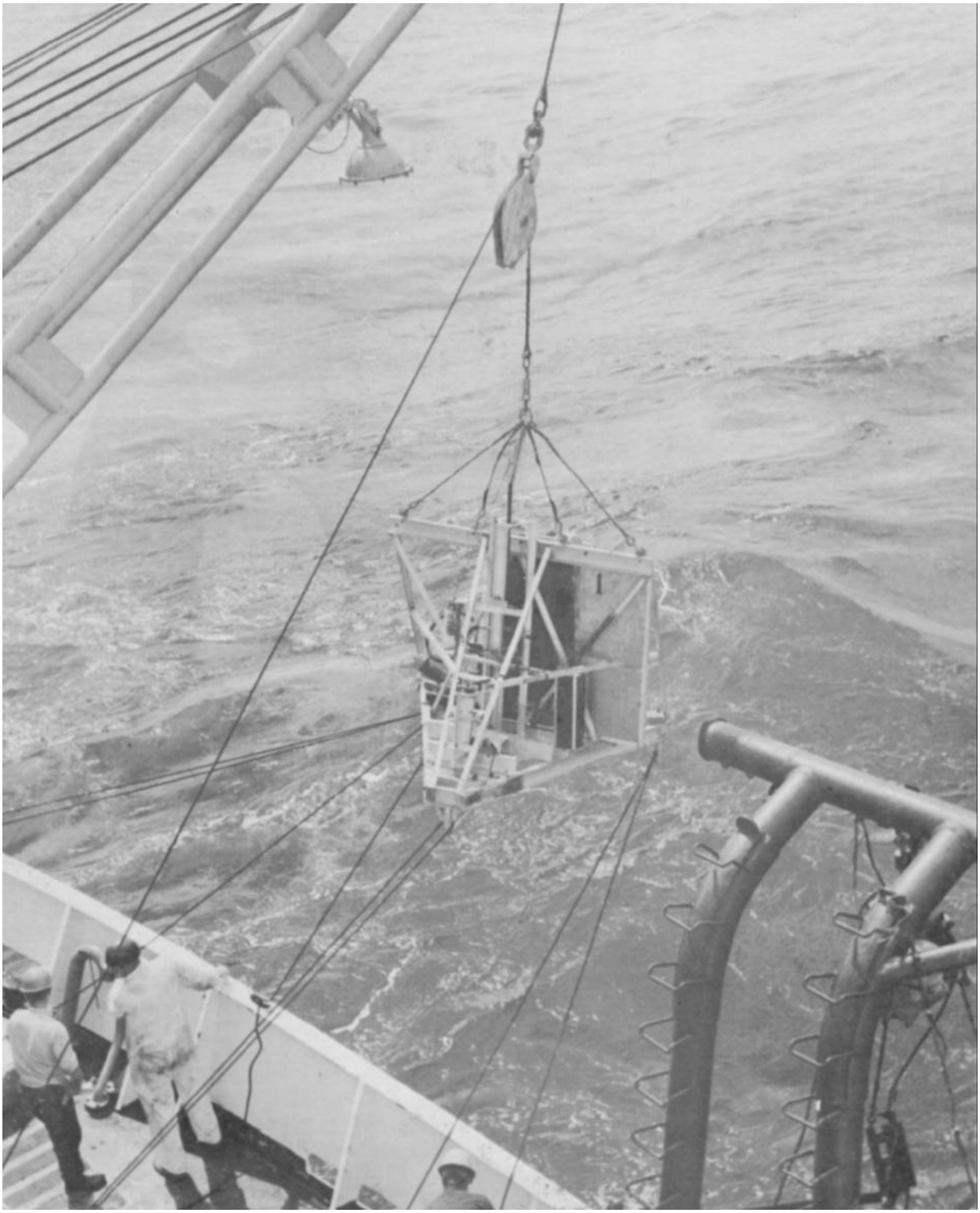


Fig. 16. the rock core drill being lowered for a test on the Mid-Atlantic Ridge cruise, 1966.

modifications were made to the design of the full-scale drill to improve its handling under water.

During Phase II of the Mid-Atlantic Ridge cruise, 26 lowerings of the drill were made, of which 22 were successful in the landing and mechanical operation of the drill. Six samples were retrieved, and, though not "hard rock" samples (i.e., basalt), they appear interesting and are now being studied by the Marine Geology Section. There were strong indications of difficulties being caused by soft sediment covering the bedrock, and of failure of the core retention device. Phase III of the drill development has therefore been started to investigate the design changes required to enable the drill to operate through sediments, improved corecatchers, etc. To assist in the field tests which will be carried out during the coming year, instrumentation is being designed for recording the various parameters that govern the drill's performance.

In summary: the power system of the drill has been proved consistently reliable, and handling problems appear to have been overcome, apart from the difficulties of finding rock outcrops on the sea floor.

A patent application has been made for this device, and a paper concerning its operation is to be submitted for publication.

J. Brooke

Pressure testing equipment

The development of the rock core drill (p. 59) stressed the need for a pressure testing facility. An ex-RCN torpedo air chamber was acquired and modified so that equipment could be quickly placed in the chamber. A Swan hydraulic power unit was used to generate pressure and power for the drill. A complete pressure system has been ordered that will be capable of testing units with dimensions up to 9 inches in diameter by 28 inches in length at pressures up to 10,000 p.s.i. The existing tank is capable of testing objects 20 inches in diameter by 10 ft in length at pressures up to 1,000 p.s.i.

Small tape recorders

The development of small tape recorders continued this year, and two units were tested at sea with the heat probe equipment (p. 56). As a result of these tests, design changes are underway to improve the reliability of the recorders. It is expected that a number of units will shortly be built by a local firm.

J. Brooke

Air-Sea Interaction program

Continued vigorous support has been provided to the Air-Sea Interaction Group. Major projects include modifications to the Doe anemometer Mark V and construction of a complete new instrument, supervision of the design of a new, larger stable platform, and the design and construction of pressurized containers for the platform electronic systems. The latter equipment is described on p. 15.

J. Brooke
R. N. Vine
W. W. Hall

Printed circuit card modules

Design and construction of a mounting system for the printed circuit cards for the Biodal programmer and digital calendar-clock (p. 55) was completed last year and the system was tested at sea this summer. After the cruise, the design was re-examined in the light of field experience and a number of modifications made. It was decided to make manufacturing drawings of all components so that contracts could be allotted to outside firms to meet future requirements. A contract has now been awarded and the completed units will be delivered in December.

R. N. Vine

Transponder buoys

The Group was asked to design and produce radar transponder buoys for the Mid-Atlantic Ridge cruise this year. A prototype was made and tested on the shakedown cruise in May. On return, some modifications were made and several small models were produced in an attempt to arrive at the best compromise between stability and mooring drag. Four buoys were manufactured in time for the cruise and were employed as navigation references during the Geophysics survey on the Mid-Atlantic Ridge. The design of transponder buoys is still an open field for development and we plan to carry out further experiments during 1967.

R. N. Vine
J. G. Dessureault

Study of underwater pressure cases

A study of materials and techniques is being conducted in an attempt to design a range of cases for underwater instruments. It is proposed to build a few prototypes to confirm the theoretical conclusions.

J. G. Dessureault

Current meter turntable

It is desirable to calibrate self-recording current meters periodically in order to apply corrections to the data collected in the field. In the past, a complete check cycle for calibration of the magnetic compass required the attention of a man for nearly 7 hr.

A programmed indexing table has been designed to reduce the manhours required for this work, and it is anticipated that its construction will start soon. The system will rotate the current meter through 10 degrees, pause for 5 min to ensure stabilization, and repeat the rotation, step by step, through a total 0-360° with extra pauses at the 180° and 360° positions. The rotation is then reversed, and the timing system will stop at the end of the completed cycle. When the current meter is fixed in position and the cycle initiated, it can be left unattended for the complete cycle.

J. G. Dessureault

Portable pressure tank

A portable pressure tank has been built to leak-test underwater camera and pinger cases before they are sent down. The tank is made from a gas cylinder which is fitted with a removable lid. Its internal dimensions are 8½ inches in diam, 30 inches in length, and the complete unit weighs about 350 lb. The pressure is provided by a two-speed hand pump up to a maximum of 2,000 p.s.i. An accumulator between the pump and the tank permits the pump to operate with hydraulic oil and ensures clean water in the tank. The tanks was extensively used during the Mid-Atlantic Ridge cruise and was of considerable value in enabling equipment to be pressure-tested while the ship was underway, thus minimizing the time required on station.

J. G. Dessureault

ToC

Engineering Services

A. S. Atkinson

Marine Electronics

C. R. Peck

R. B. Aggas[1]
F. J. Barteaux
J. J. Betlem
D. J. Beazley[1]
J. G. Bruce[1]
C. A. Campbell
V. F. Coady
J. R. Cournoyer
R. O. Dawson
R. E. DeLong[1]
W. W. Goodwin
H. D. Henderson[1]
G. J. MacDonald
G. R. MacHattie[1]
K. E. MacAskill[2]
K. M. Nicholson[1]
A. D. Parsons
C. E. Polson
G. N. Roze[2]
W. F. C. Shearman
S. F. W. Spencer[1]
H. B. Sutherland
G. Weber
S. G. F. Winter[1]
J. G. Vezina

Depot Workshops

R. Balfour

F. C. Armitage
A. S. Gilhen
C. O. Grant
J. E. Horne[1]
H. P. MacDougall
H. W. Marshall
W. A. Moore
C. M. Newell
R. M. Smith
R. E. Underwood

In April 1966, Engineering Services was divided into two sections, with engineering maintenance work being carried out by the new Engineering Services, and research, design and development work by the new Metrology Section, (P. 54). The division of duties outlined above is not rigid, but an indication of primary respons-

[1] Joined BIO in 1966.
[2] Left BIO in 1966.

ibility. Over the past 4 years, Engineering Services had grown from a small nucleus until it was nearly the largest section in BIO. The work load increased at an even greater rate than the growth of the Section, and the desirability of separating maintenance and the research and development functions became steadily more obvious.

I wish to take this opportunity to express formally my gratitude for the vigorous and enthusiastic support given to me in the past by those who constitute the new Engineering Services Section. It is seldom that a service organization receives praise for performing its work competently, even though that work forms the foundation upon which each and every survey or research cruise is built. The Depot Workshops and Electronic Maintenance Groups have built such a foundation, and the rapid international recognition of BIO as one of the major oceanographic institutes is directly attributable to their efforts. R. Balfour and A. S. Atkinson have shown themselves to be extremely capable in the performance of their duties, and have given me far more support than I could reasonably expect.

R. L. G. Gilbert

The staff of Engineering Services is gradually reaching the current proposed strength and this is reflected in the overall efficiency of the Section. For some time it has not been possible to provide all the technical support required for the various programs at BIO, and only recently has it been possible to cope with most of the many demands put on Engineering Services. With the rapid growth of the professional staff, it soon became apparent, that for the Section to operate as an efficient scientific group, there must be a proportionate support staff increase with each addition to the number of scientific personnel.

Providing the variety of skills expected of Engineering Services personnel not only requires a large number of technicians and tradesmen, but also competency on the part of each individual in his chosen field. Since many of the instruments and equipments used in oceanography and hydrography are relatively new and of a specialized nature, experienced personnel are not readily available. It is necessary, therefore, to provide many forms of training, and to recruit applicants who have a good, basic knowledge of advanced technology, so that they may absorb this training and gain worthwhile experience.

The diversity of tasks which Engineering Services at BIO are called upon to perform, and the application shown by the user sections, inspire the interest shown by the staff in their assignments. It is now the belief in this Section that if there is some electrical or electronic equipment that requires repair, overhaul, calibration or maintenance, technicians of Marine Electronics can do it. If it is made of wood, metal or even plastics, the staff of the Depot Workshops can repair it, or make a new one to replace it.

A. S. Atkinson

Marine Electronics

The acquisition of new equipment has made it necessary to form a new sub-group to repair and maintain the shipboard digital computers and to re-arrange other groups according to electronic disciplines rather than job assignments.

Electronic positioning

The Electronic Positioning Sub-Group, with H. B. Sutherland in charge, has been busy with the refurbishing of the various Decca systems for position-fixing and the modifications required for their increased range and reliability. The 12F Lambda system, which is to be used in 1967 on the east coast of Newfoundland, in support of the continuing project for recharting and geophysical surveying of the Grand Banks, is being modified to ensure no interference from the powerful Loran “C” transmitting station operating in the immediate area. The Lambda system was modified this summer to increase its range from the accepted 400 miles, to what proved to be 500 miles under ideal conditions. This was accomplished by increasing the transmitter power and by installing new receiving antennae on the ship and more efficient antennae at the shore station.

The field trials of the modified 6F short-range portable system in the George Bay area during the summer months have proved its practical application. Additional modifications are being performed at present to increase the range and reliability of this portable equipment.

Sonar

The Sonar Sub-Group, under the supervision of W. W. Goodwin, has been actively engaged in the overhaul and repair of echo sounders and associated equipment. To ensure the accuracy of these primary hydrographic instruments, extensive procedures have been developed for the calibration of their various range scales. The hydrographer can now be assured, for example,

that the echo sounder he is about to use has been calibrated on all scales at the accepted standard for the propagation of sound in sea water, i.e., 4,920 ft/sec. This permits him to apply the necessary corrections for salinity and temperature or provides a basis from which to adjust for these corrections.

Communications

W. F. C. Shearman is in charge of the Communications Sub-Group whose responsibility is the efficient maintenance and operation of all the communications systems aboard ships and launches or used by field parties and at BIO. The single-sideband equipment installed in ships, in the field, and at BIO, proved very successful during the past field season and voice communication up to 1,300 miles was realized. Additional installations in ships, launches and shore stations are planned for 1967.

Standards laboratory

The Standards laboratory, under the direction of J. J. Betlem, has been charged with the responsibility of the increased work load arising from the acquisition of many new electronic test instruments. Appropriate electrical standards are being maintained and serve as a basis for many of the facilities used for calibrating electronic test equipment. More equipment is being procured to enlarge these facilities and to maintain standards for other than electrical parameters i.e., temperature, pressure, etc.

Computers and microwave

The new Sub-Group, Computers and Microwave, is headed by A. D. Parsons. It is responsible for the maintenance and repair of the two new PDP-8 shipborne computers, as well as all the radar systems and associated equipment. Radar transponders were used extensively for navigation during the Mid-Atlantic Ridge cruise this summer and are becoming more widely used for station-keeping and survey navigation. The provision for semi-automatic performance monitoring of a ship's radar receiving system was successful, and additional equipment is being procured to permit this modification to be fitted to all major ships. The antenna drive system for the Decca 969 radar on CSS Hudson was modified this summer to provide a sector scan capability which increases the data count on a target, and thus allows an increased range of operation.

Training

A 3-4 week training course on transistors and digital techniques was arranged with the Electrical School at HMC Dockyard, Halifax, for nearly all of the technicians in Marine Electronics. An introductory course on the PDP-8 computer was given to most of the staff in the spring; this was followed in December by a very comprehensive 4-week maintenance course for those technicians who will be maintaining the computers.

Projects

The present special projects of the electronics staff of Engineering Services are as follows:

1) Evaluation of the new Bertram launches to determine the propagation characteristics of the echo sounder and to discuss why the launches will not sound at all speeds in salt water;

2) Evaluation of the new ED0 9040 echo sounder;

3) Improvement of shore telephone facilities for major ships;

4) Development and evaluation of a fibreglass reflector to replace the existing conventional copper unit used in echo sounder transducer installations;

5) Improvement of the H.F. communications antenna system at BIO;

6) The provision of a hydraulic system for lowering an echo sounder transducer below the keel on CSS *Hudson* to improve the sounding capability in rough weather:

7) The design and construction of a low-cost radar transponder system.

C. R. Peck

Depot Workshops

At the Depot Workshops there are one or two skilled tradesmen employed for each of the major trades associated with ship and launch repair, i.e., machining, welding, carpentry, electrical engineering, etc. The principal task of these tradesmen is to repair and overhaul

launches, but there has been an increasing demand for them to repair and fabricate machinery and equipment used in oceanography and hydrography, in addition to maintaining the BIO's buildings and grounds.

During the winter months the Group is mainly employed on launch repair and overhaul, but many special projects have been assigned to them during the other periods of the year. The MV *Brandal* was chartered this summer by the Central Region of MSB and outfitted in the Halifax area before sailing for the Great Lakes. The heavy winches, electrical and hydraulic power sources, and other heavy machinery were overhauled, installed aboard the ship, and tested by the depot staff. The rock core drill, the high pressure testing facility, the portable pressure testing tank, and electronic card racks are a few examples of equipment which was designed by the Metrology Section, and built in the Depot Workshops (see p. 59, 61, and 62 for descriptions of these items). Various wooden structures and small items such as special packing cases, instrument boxes, deck pads, laboratory fittings, and the removal and erection of room partitions are examples of the routine production and duties of the shipwrights. Electrical services ranging from the installation of a 23 HP winch control to wiring in buildings, ships and launches are performed by the electrician. The machinists have produced many mechanical parts from a small (0.003 inches in diam) soluble magnesium pin to a large steel nut for the propeller shaft on CSS *Baffin*. The sheet metal and paint shops are continually producing oddly-shaped items and lettering or painting them to withstand exposure to salt spray. The welders are very proficient in welding steel or aluminum and in using either gas, electric or shielded arc equipment. One welder has been to sea on several occasions and, during the Mid-Atlantic Ridge cruise this summer, contributed greatly to the overall success of the operation. The other support staff, such as the mobile equipment operator, the storekeeper and the labourers, all contribute a great deal to ensuring that the professional staff are able to carry out their research and surveying as planned and obtain the results they desire.

R. Balfour

ToC

Ships

S. W. Howell

D. H. Chamberlain
J. M. Higgins
A. M. Holler
G. Smith

Ship Operations

During 1966 the five ships of MSB of the Department of Energy, Mines and Resources based at BIO met all their planned operational commitments with the exception of CSS *Hudson*. Owing to low electrical insulation on this vessel's main propulsion system, it was decided to reduce the program for the months of October and November and to bring the vessel in earlier for refit and repair. However, while alongside the BIO wharf on October 7, 1966, an engine room fire caused damage to cables which made it necessary to cancel the remaining program. It is anticipated that *Hudson* will complete her refit and repairs by December 31, 1966.

While working out of Antigua in the early months of the year, CSS Baffin provided anchorage, weather and other information to the Royal Yacht *Britannia* on her visit to the island during February 1966 with Her Majesty the Queen and His Royal Highness the Duke of Edinburgh on board. *Baffin* launches also assisted in transporting officials and guests, and in police patrol duties.

The Master, Captain W. N. Kettle, the Chief Engineer, J. F. Boutilier, and the Senior Hydrographer, S. Van Dyck, had the honour of being presented to Her Majesty and His Royal Highness at a reception ashore.

On the departure of the Royal Yacht from Antigua the following message was received:

From : Royal Yacht *Britannia* 210404Z Feb. 1966
To: Master, CSS *Baffin*/ CCGL

The assistance of your boats and your information on Falmouth Harbour have been very much appreciated. I am most grateful for all your help.

(signed) Flag Officer.

In addition to the MSB ships, the MV *Theta* was on charter to DEMR from June 6 to November 9, 1966, CNAV *Sackville* was again

employed on oceanographic research and through the cooperation of the Department of Transport, CCGS *Labrador* was used for physical oceanography and marine geophysics research in the Arctic. Portraits of the eight ships programmed by BIO in 1966 are shown in Fig. 17 and 18; their operational statistics are reported in Table 3, and their general specifications given in Table 4.

Another vessel, the MV *Brandal* was taken on charter for operation in the Great Lakes under the direction of the Central Region. All outfitting and alterations to the vessel, which were considerable, were carried out by BIO depot staff and local contractors, prior to her departure from the local area at the commencement of charter.

Fig. 17. Research and survey ships of BIO.

CCGS Labrador

M.V. Theta

Fig. 18. Other ships programmed by BIO, 1966.

Launches

The 38-ft *Tudlik* was employed by the Marine Geology Section in Northumberland Strait and George Bay during the summer. All other launches were fully employed from major vessels and shore bases, mostly on hydrographic survey duties.

Four new 25-ft Bertram fibreglass launches were received at BIO during the summer and are being given extensive evaluation trials. It is planned to put them to work next year.

Personnel

Five officers were granted educational leave to obtain higher certificates of competency, and 24 ships' personnel have taken a fire fighting and damage control course through the courtesy of the Royal Canadian Navy.

Through the cooperation of The Hydrographer of the Royal Navy, two officers participated in the NAVADO project aboard HMS *Vidal* and one officer aboard HMS *Hecate*

The Regional Engineer Superintendent proceeded to England in December to witness manufacturer's trials on the main propulsion machinery for the new research vessel *Dawson,* presentiy under construction at Lauzon, Quebec.

Search and Rescue

During the year the *Baffin* and *Maxwell* were called into rescue operations by the Search and Rescue Centre, Halifax, N.S. While returning from her West Indies Hydrographic Training cruise, the *Baffin* at 1645 on March 31, 1966, was ordered by the Search and Rescue Centre at Halifax to close, and stand by the disabled fishing vessel *Donna Rae,* located some 60 miles southeast of Shelburne, Nova Scotia. *Baffin* arrived at the scene at midnight and stood by until 0630 the following morning when she was released from the operation by Rescue Centre and proceeded to Halifax. On May 18, *Baffin* assisted the fishing vessel *Agnes* and *Brendon H* in the vicinity of Lance Cove, Newfoundland by providing repair facilities to the fishing vessel's main engines, and on May 21 assisted and refloated the yacht *Carina* which was aground on Sable Island. On May 28, *Maxwell* towed the fishing vessel *Eastern Pride* to safety in Yarmouth Harbour; at the time, the vessel was drifting towards shoal waters with her engines out of commission.

Vessel Modifications

During the brief periods between cruises that the East Coast vessels were alongside BIO, work was carried out by depot staff and outside contractors in preparation for forthcoming cruise requirements.

Much of this work involved fairly extensive modifications, particularly to CSS *Hudson,* the most significant change being an increase in the scientists' accommodation on board, which was made possible by converting six single berth cabins into double berth cabins. This change resulted in an increase of 25% in the number of scientists which the vessel can carry, raising the total to 28.

Other modifications effected on this vessel are as follows:

1) Improved storage and workshop facilities made available by the installation of shelving units in the hangar and in the General Purpose and Oceanographic laboratories;
2) Installation of a 20 HP oceanographic winch in the boat deck laboratory and the extension of boom capacity and oceanographic platforms;
3) Additional floodlights installed in the working areas on the foredeck and boat deck laboratory;
4) Installation of a 15-ton "Grove" crane on the flight deck to facilitate the laying of moorings and equipment;
5) Installation and outfitting of a much needed recreation room for crew and PO's;
6) Installation of a resilient mounting for the foredeck oceanographic winch power unit, in an attempt to minimize the excessive noise produced when this unit is in operation.

The work involved in the foregoing modifications was planned and coordinated so as not to delay or interrupt the previously scheduled program of the vessels.

TABLE 3. Operational statistics of ships programmed by BIO.

Name of vessel	No. of cruises	Days away from base	Mileage steamed
CSS *Acadia*	1	166	4,334
CSS *Baffin*	3	257	43,953
CSS *Hudson*	5	142	27,941
CSS Kapuskasing	9	193	22,996
CSS *Maxwell*	5	192	6,919
MV *Theta* (charter)	4	128	21,300
CNAV *Sackville*	9	158	22,380
CCGS *Labrador*	1	69[a]	15,900

[a] on BIO duty.

TABLE 4. Principal specifications of BIO, DEMR, and other ships programmed by BIO during 1966.

Name of vessel	Built	Length	Breadth	Draft	Displacement	Master
CSS *Acadia*	1913	182'-0"	35'-7"	13'-6"	1,350 tons	Capt. J. W. C. Taylor
CSS *Baffin*	1957	285'-0"	49'-6"	17'-3"	4,420 tons	Capt. P. M. Brick
CSS *Hudson*	1963	293'-6"	50'-0"	20'-6"	4,600 tons	Capt. W. N. Kettle
CSS *Kapuskasing*	1943	222'-0"	35'-6"	12'-6"	1,250 tons	Capt. W. Thorne
CSS *Maxwell*	1961	115'-0"	25'-1"	7'-0"	230 tons	Capt. S. Baggs Capt. M. J. A. Wagner (Relieving Master)
Others						
MV *Theta* (charter)	1952	183'-2"	28'-0"	13'-1"	1,310 tons	Capt. K. Maro
CNAV *Sackville*	1941	205'-3"	33'-1"	13'-9"	1,250 tons	Capt. S. Lillington
CCGS Labrador	1953	269'-0"	63'-6"	29'-1'	6,490 tons	Capt. I. Green

Appendices

Appendix A-1-Publications and Reports

Publications

BARRETT, D. L. 1966. Lancaster Sound shipborne magnetometer survey. *Can. J. Earth Sci.*, 3(2): 223-275. BIO Contrib. No. 46.

The total magnetic field and depth of water were measured along a ship's track of about 1,000 nautical miles in Lancaster Sound, Canadian Arctic Archipelago. A normal fault to the south and folding and thrust faulting to the north indicate that Devon Island has been subjected to major tectonic forces resulting in a relative northward movement of the island of about 8 km.

EWING, G. N., A. M. DAINTY, J. E. BLANCHARD, and M. J. KEEN. 1966. Seismic studies on the eastern seaboard of Canada: the Appalachian system. *Can. J. Earth Sci.*, 3(1): 89-109. BIO Contrib. No. 44.

An anomalous high velocity (8.5 km/sec or greater) through the upper mantle and a thick intermediate layer underlie the Taconic deformed zone within the Paleozoic mobile belt of the Canadian Appalachians.

EWING, G. N., and G. D. HOBSON. 1966. Marine seismic refraction investigation over the Orpheus gravity anomaly off the east coast of Nova Scotia. *Geol. Surv. Can.* Paper 66-38. BIO Contrib. No. 59.

This study shows that the thickness of sedimentary rocks in the area of the central portion of the anomaly is in excess of 3 km and suggests that the anomaly may be due to a graben structure.

GILBERT, R. L. G. 1966. Data collecting systems in oceanography. *Bolletino di Geofisica Teoretica ed Applicata.* (in press). BIO Contrib. No. 66.

The paper discusses methods of recording oceanographic parameters, and in particular, compares the potentialities of various methods of recording, suitable for self-contained moored instruments. General philosophies of shipborne data logging systems are also considered.

GRANT, A. C. 1966. A continuous seismic profile on the continental shelf off northeast Labrador. *Can. J. Earth Sci.*, 3(5): 725-730. BIO Contrib. No. 58.

This profile traverses a deep channel (to 800 m.) that runs parallel to the coast for over 400 km. The shoreward part of the shelf, with respect to this channel, is apparently underlain by Precambrian bedrock. On the outer portion of the shelf, however, the profiler recording shows nearly flat-lying reflecting horizons that are considered to be within a Paleozozc, or younger, bedrock media.

KEEN, C., and B. D. LONCAREVIC. 1966. Crustal structure on the eastern seaboard of Canada: studies on the continental margin. *Can. J. Earth Sci.*, 3(1): *65-76.* BIO Contrib. No. 45.

The combined interpretation of seismic refraction and gravity profiles indicate a mantle density of 3.42 g/cm^3 under the continental shelf and 3.32 g/cm^3 under the ocean basin.

KING, L. H. 1966. Use of a conventional echo sounder and textural analyses in delineating sedimentary facies -- Scotian Shelf. *Can. J. Earth Sci.* (in press). BIO Contrib. No. 60.

The author has made extensive use of echograms in interpreting and mapping sediment type on the Scotian Shelf.

KRANCK, K. M. 1966. Sediments of Exeter Bay, Baffin Island, District of Franklin. *Geol. Surv. Can.* Paper 66-8. (Also BIO Report 64-15). BIO Contrib. No. 22.

Grain-size analysis and petrological studies of bottom sediment samples show the presence of two sedimentological provinces. The onshore region is dominated by locally derived, current-transported, medium to fine sand. The outer shelf and slope is covered by gravel ice-rafted into the area via the south flowing Canadian Current from northern Baffin Bay.

LEWIS, E. L. 1966. Heat flow through winter ice. *Proc. Intl. Conf.* on *Low Temp. Sci.*, Hokkaido University, Sapporo, Japan, August 1966. BIO Contrib. No. 62.

The heat flow through a growing sheet of sea ice is discussed; experimental data on the temperature distribution in an Arctic ice sheet is

presented as a function of time, and thermal constants of ice are evaluated.

LONCAREVIC, B. D., and G. N. EWING. 1966. Geophysical study of the Orpheus gravity anomaly. *Proc. 7th World Pet.* Cong., Mexico City, April 1967. (in press). (Also BIO Report 66-7). BIO Contrib. NO. 69.

The observed anomaly can be caused by a sedimentary sequence of Windsor evaporites deposited in a steeply-sided basin, 3-5 *km deep.*

LONCAREVIC, B. D., C. S. MASON, and D. H. MATTHEWS. 1966. Mid-Atlantic Ridge near 45° N: the Median Valley. *Can. J. Earth Sci.,* **3** (3): *327-349.* BIO Contrib. No 56.

A detailed survey of 1,000 *sq miles shows strong lineations of the topography and magnetic anomaly. The magnetic pattern can be explained by assuming that the Mid-Atlantic Ridge grows by continuous dyke intrusion in the centre.*

MCMULLEN, R. M. 1966. Surface sediments on the Newfoundland Grand Banks -- a progress report. *Maritime Sed.,* **2** (3) *:* 131-132. BIO Contrib. No. 64.

Bottom samples from the Grand Banks area off Newfoundland have been studied as to their size distribution and heavy and light mineral composition. Most of the samples are composed of sand-size or larger materials and the heavy mineral suites indicate that the sediments have a complex provenance. There is evidence of a stillstand of the sea at about 75 *m.*

MCMULLEN, R. M., and D. J. P. SWIFT. 1966. Intertidal sand bodies in the Bay of Fundy (Abstract). *Trans. Geol. Soc. Amer.* (in press). BIO Contrib. No. 71.

Intertidal sand bodies in the Minas Basin, as illustrated by the Windsor Bay and Cobequid Bay sand bodies, are products of the hydraulic regime peculiar to the area. Strong tidal currents, asymmetrical tidal cycles and a complex pattern at mutually evasive ebb-flood channels formed and maintain these bodies.

MCMULLEN, R. M. and D. J. P. SWIFT. 1966. An occurrence of large-scale Rhomboid ripples, Minas Basin, Nova Scotia. *J. Sed. Pet.* (in press). BIO Contrib. No. 72.

Some large-scale Rhomboid ripples were observed and photographed during a flight over the emergent intertidal sediments of the Minas Basin, Nova Scotia. Their origin may be due to simultaneous exposure of the entire sand bar by the ebb tide, with the surface runoff and released pore water flowing swiftly downslope.

MARLOWE, J. I. 1966. Mineralogy as an indicator of long-term current--fluctuations in Baffin Bay. *Can.. J. Earth Sci.,* **3** (2): 191-201. BIO Contrib. No. 48.

Vertical variations in the distribution of limestone fragments in core samples from Baffin Bay reflect fluctuations in the numbers of icebergs moving through the Bay from areas where limestone outcrops occur. On an areal basis, these fluctuations show that water masses coming from the Arctic Ocean travelled more easterly tracks in the past than they do at present. The apparent westward movement with time of this cold current may have been caused by variations in the relative amounts of southward and northward moving currents entering Baffin Bay, or by a deepening of the water in the Bay.

MARLOWE, J. I. 1966. A piston corer for use through small ice holes. *Deep Sea Res.* (in press). BIO Contrib. No. 61.

A short-radius piston corer and release, designed for use through holes as small as 8 *inches in diameter in ice, is described.*

MARLOWE, J. I., and G. A. BARTLETT. 1966. Oligocene-Miocene strata in a submarine canyon off Nova Scotia. (Abstract). Trans. *Geol. Soc. Amer.* (in press). BIO Contrib. No. 70.

Microfaunal and other stratigraphic data indicate the presence of marine sedimentary rocks ranging in age from Upper Oligocene to Recent on the outer continental shelf off Nova Scotia. The section as now known contains as much as 800 *m of Miocene strata.: a thickness much greater than that of rocks of similar age elsewhere along the eastern margin of North America.*

MASON, C. S. 1966. A geophysical data logging system for shipboard use. *J. Ocean. Tech.,* vol. 1, 1966, p. 35-44. BIO Contrib. No. 35.

This paper describes the "Geodal" semi-automatic data logging system, developed by the BIO electronics design laboratory. The outputs of a shipborne magnetometer and gravimeter are recorded on punched paper tape along with the day, number and time of the reading. Three systems have been assembled, one of these a more elaborate installation which also records Decca coordinates and very low frequency radio navigational data.

NEEDLER, G. T. 1966. A model for thermohaline circulation in an ocean of finite depth. *J. Mar. Res.* (in press). BIO Contrib. No. 63.

A theoretical study is made of the density field, pressure field, and velocity fields in an unbounded ocean driven by differential heating of the surface and the divergence or convergence of the Ekman layer. The density is assumed to vary exponentially in the vertical and an exact solution is presented which satisfies boundary conditions on a surface below the Ekman layer and on the ocean floor.

PELLETIER, B. R. 1966. Canadian Arctic Archipelago and Baffin Bay: Part B-Bathymetry and geology. *Ency. Oceanog.*, Ency. Earth Sci., series, vol. 1, p. 160-167. BIO Contrib. No. 26.

This is a summary of marine geological projects undertaken in Arctic waters, and describes various bottom physiography, sediments and fauna in areas of study.

PELLETIER, B. R. 1966. Hudson Bay and approaches : Part B-Bathymetry and geology. *Ency. Oceanog.*, Ency. Earth Sci. series, vol. 1, p. 359-363. BIO Contrib. No. 23.

This is a summary of marine geological projects undertaken in Hudson Bay, and describes bottom physiography, sediments and fauna in various areas of study.

PELLETIER, B. R. 1966. Development of submarine physiography in the Arctic Archipelago and its relation to crustal movements. *Roy. Soc. of Can.* Symp. on Continental Drift, Spec. Publ. No. 9. BIO Contrib. No. 29.

The Arctic Archipelago has a geological unity. The former land mass was dissected by pre-Pleistocene rivers, modified by glacial erosion, submerged several hundred metres so that only interfluvial areas remained emergent as scattered islands, and is now emerging. About 800 m of vertical crustal movement, relative to sea level, is involved. Raised beaches are 300 m above sea level and drowned valleys are 500 m below.

PELLETIER, B. R. 1966. Submarine physiography and sediments of Hudson Bay, District of Keewatin. *Geol. Surv. Can.* Econ. Geol. series. (in press). BIO Contrib. No. 67.

This is a summary of marine geological projects undertaken in Hudson Bay and approaches, and describes bottom physiography, sediments, and fauna in these areas.

PELLETIER, B. R. 1966. The Hudson Bay oceanographic project of 1965. *Can. Geograph. J.* (in press). BIO Contrib. No. 68.

This is an operational account of an interdisciplinary oceanographic project involving shallow and crustal seismics including explosive refraction studies and electrical profiling; bottom and surface gravity; air and sea magnetics ; physical oceanography, bathymetry, biology, paleontology, sedimentology and bedrock geology.

ROSS, D. I.* 1966. The earth's total magnetic field between New Zealand and Antarctica. *New Zeal. J. Geolog. Geophys.* (in press).

A total magnetic field map of the southwest Pacific Ocean between New Zealand and Antarctica for epoch 1964-65 *has been drawn from measurements made aboard HMNZS Endeavour. A comparison is made with earlier magnetic measurements and a value for the westward drift of the field pattern is estimated.*

ROSS, D. I.*, and D. A. CRISTOFELL. 1966. Magnetic anomaly patterns across the southwest Pacific Basin. *J. Geophys. Res.* (in press).

Results of nine total magnetic field profiles across the southwest Pacific Basin between long 170° *and* 180° *E are discussed. The extremely good correlation of anomalies across all tracks has made it possible for an anomaly contour map of this part of the basin to be drawn. A*

* Submitted for publication prior to joining BIO staff.

major discontinuity in the magnetic pattern is observed along a "fault" striking 9° *E of S and meeting the New Zealand plateau at approximately* 50°20' *S,* 176° *E. The pattern observed suggests differential movement of the ocean crust across the "fault".*

VILKS, G., *et al.* 1966. Ecological studies of Foraminifera: I. Application of association analysis to a survey of the sediment fauna of an Arctic basin. *Limn. & Oceanog.* (in press). BIO Contrib. No. 75.

Foraminiferal distribution was analyzed using multivariate statistics. The results confirmed previous findings besides pointing out previously undetected correlations of species and the environment.

WESTPHAL, K. O. 1966. On the solidification of substances due to radiative cooling. *Intl. J. Heat & Mass Transf.* (in press). BIO Contrib. No. 65.

Under the assumption that the temperature-depth relationship inside the solid part of a solidifying substance has the form of a second order polynominal, the position of the progressing phase change front has been obtained as a function of time for the case that heat is removed from the fixed surface by radiation (Stefan-Boltzmann). The derived formulae have been applied to the solidification processes of water, steel and aluminum.

BIO Reports

BIO 66-1	G. T. Needler	An exact solution to the problem of thermal circulation on a rotating sphere. *An exact solution is presented to the equations governing thermohaline circulation in the interior of the ocean.*
BIO 66-2	G. A. Bartlett	Distribution and abundance of Foraminifera and Thecamoebina in Miramichi River and Bay. *Four of the* 35 *species of Foraminifera and Thecamoebina in the Miramichi Estuary dominate the faunal assemblage. Two are arenaceous - Miliammina fusca and Eggerella adrena - and two are calcareous - hyaline - Elphidium incertum "complex" and E. orbiculare. The four species are major constituents of two well defined biofacies within the Estuary.*
BIO 66-3	C. K. Ross, and R. F. Reiniger	A method of interpolation with application to oceanographic data. *The paper presents an interpolation routine for a single valued function of one independent variable.*
BIO 66-4	K. M. Kranck	Sediments and bedrock of Kouchibouguac Bay, New Brunswick. *Bottom samples and sounding traces are used to map outcrops of local bedrock formations separated by areas of sand and gravel. Textural parameters of the sand fraction indicate the presence of ancient stream channels.*
BIO 66-5	R. R. Weiler, J. Butters, and W. B. Bailey	The thermal structure of the surface layers in April 1965 of an area south of Nova Scotia. *This report depicts the complicated thermal structure down to* 250 *m in an area where the Gulf Stream, slope and coastal waters mix. The structure is compared with previous investigations of the same area.*

BIO 66-6	W. I. Farquharson	St. Lawrence Estuary current survey. *A current survey in the vicinity of Pointe des Monts in June-July* 1963 *is analyzed for tidal constituents and residual currents. Results of a similar survey in* 1962 *near the seaward end of the Gaspe current are compared and contrasted with those of the* 1963 *survey.*
BIO 66-7*	B. D. Loncarevic, and G. N. Ewing	Geophysical study of the Orpheus gravity anomaly. *The observed anomaly can be caused by a sedimentary sequence of Windsor evaporites deposited in a steeply-sided basin, 5-3 km deep.*
BIO 66-8	S. D. Smith	Thrust anemometer measurements of wind velocity fluctuations, spectra and stress over the sea. *Wind velocity spectra and co-spectra were analyzed by analog techniques for 32 of the many thrust anemometer data runs recorded at the Spanish Banks experimental site of the Institute of Oceanography, University of British Columbia. Tests of thrust anemometer performance by comparison with recordings from other wind-measuring instruments were encouraging, and wind stress measurements were compared with results of workers in other countries.*
BIO 66-9	W. I. Farquharson, and W. B. Bailey	Oceanographic study of Belle Isle Strait, 1963. Part I: Tidal and current survey by W. I. Farquharson; Part 2: Temperature and salinity distribution by W. B. Bailey and W. I. Farquharson. During *August-September* 1963 *the currents through a cross-*section *of Belle Isle Strait were measured. Data were analyzed* for *tidal* stream and residual currents. *The residual* current *pattern was found to fluctuate* markedly from *time to time. The direction of predominant flow through the Strait was correlated with the North-South barometric pressure gradient.* Ternpera*ture and salinity data* taken during *the* survey are also reported.
BIO 66-10		Fifth Annual Report.

BIO Internal Notes

BIO Internal Notes, formerly known as Institute Notes, are unpublished, unedited notes intended for internal circulation. They are encouraged as a first step in the preparation of a manuscript or as a first record of work, which may be unfinished or incompletely considered. External distribution, if any, is at the author's discretion.

BIO 66-l-I P. H. Bridge, and E. J. Gougeon. Simplified wide range thermistor.

BIO 66-2-I R. H. Loucks. Notes on an FM digital system.

BIO 66-3-I L. P. Murdock. National Boat Show, New York City, January 1966.

---

* Also BIO Contrib. No. 69 (p. 71).

BIO 66-4-I R. L. G. Gilbert, R. C. Melanson, R. M. Eaton, D H. Loring, and L. H. King. An experimental evaluation of the Kelvin-Hughes horizontal echo sounder off the east Canadian coast.

BIO 66-5-I D. J. Brooks. Notes on a visit to German instrument manufacturers - February 1966.

BIO 66-6-I L. J. Fitzgerald. An underwater analog RPM indicator.

BIO 66-7-I J. J. Betlam. Notes on Standards Laboratory.

BIO 66-8-I R. L. G. Gilbert. The BIO Lebus spool winch.

BIO 66-9-I P. H. Bridge. Automatic safety surveillance system.

BIO 66-10-I R. H. Loucks. A record of some measurements of atmospheric turbulence over water.

BIO 66-11-I H. W. MacPhail. Pressure testing of small light bulbs.

BIO 66-12-I D. J. Lawrence. Analysis of some Braincon current meter data from ocean moorings in a search for intertidal oscillations.

BIO 66-13-I A. L. Adams. A three-day evaluation of the tellurometer hydrodist system, Model MRB 2.

BIO 66-14-I H. B. Sutherland. Use of Decca (12f) Lambda, 1963-1966.

BIO 66-15-I K. O. Westphal. Arc-length of a geodesic on an ablate spheroid.

BIO 66-16-I Summer Assistants' Reports - 1966.

BIO Computer Notes

BIO 66-l-C R. F. MacNab. Magnetic effects of two-dimensional structures.

BIO 66-2-C R. F. MacNab. Gravitational effects of two-dimensional structures.

BIO 66-3-C R. H. Loucks. Notes on a set of programs for power spectrum analysis.

BIO 66-4-C M. Friedlaender. Calculation of total magnetic intensity in the North Atlantic.

BIO 66-5-C F. K. Keyte. A computer program to reduce and edit hydrographic station data

BIO Data Reports

BIO 66-l-D R. Cormier, and G. Duncan. Data compilation - Bay of Fundy, 1964.

BIO 66-2-D C. J. Langford. Bay of Fundy tidal report on tidal and current survey, 1965.

BIO 66-3-D G. J. Gibson, and C. R. Mann. Canadian East Coast standard sections.

Appendix A-2 - Lectures and Talks

The following is a partial list of scientific presentations by members of staff:

BARTLETT, G. A. Presented paper entitled “The significance of foraminiferal distribution in waters influenced by the Gulf of St. Lawrence” at the Second International Oceanographic Congress, Moscow, in June 1966.

BARTLETT, G. A. Presented paper entitled “Recent foraminifera and the camoebina in Miramichi estuary” at Annual Meeting of the Geological Association of Canada and the Mineralogical Association of Canada, Halifax, N.S., in September 1966.

BENNETT, A. S., and C. S. MASON. Paper entitled “A data logging system for shipboard use” presented by C. S. Mason at Second International Oceanographic Congress, Moscow, in June 1966.

DOE, L. A. E. Presented paper entitled “A new model of spherical thrust anemometer for wind stress measurements” at Second International Oceanographic Congress, Moscow, in June 1966.

FORRESTER, W. D. Invited paper entitled “Geostrophic approximation in coastal waters” presented at meeting of Royal Society of Canada, Sherbrooke, Quebec, in June 1966.

FORRESTER, W. D. Public lecture on “Geostrophic approximation in coastal waters” given at Memorial University, St. John’s, Newfoundland, in November 1966.

GILBERT, R. L. G. Paper entitled “Data collecting systems in oceanography” presented by C. S. Mason at Second International Oceanographic Congress, Moscow, in June 1966.

GRANT, A. C. Presented paper entitled “Distributional trends in the Recent marine sediments of northern Baffin Bay” at Annual Meeting of the Geological Association of Canada and the Mineralogical Association of Canada, Halifax, N. S., in September 1966.

KING, L. H. Presented paper entitled “On the sediments and stratigraphy of the Scotian Shelf” at Annual Meeting of the Geological Association of Canada and the Mineralogical Association of Canada Halifax, N.S., in September 1966.

KRANCK, K. M. Presented paper entitled “Sediments of Exeter Bay area, Baffin Island” at Annual Meeting of the Geological Association of Canada and the Mineralogical Association of Canada, Halifax, N.S., in September 1966.

LEWIS, E. L. Presented paper entitled “Heat flow through winter ice” at International Conference on Low Temperature Science, Hokkaido University, Sapporo, Japan, in August 1966.

LOUCKS, E. L., and L. A. E. DOE. Paper entitled “Some measurements of wind stress over water” presented by R. H. Loucks at Second International Oceanographic Congress, Moscow, in June 1966.

MANN, C. R. Presented paper entitled “The path of the Gulf Stream after it passes the Tail of the Grand Banks of Newfoundland” at Second International Oceanographic Congress, Moscow, in June 1966.

MARLOWE, J. I. Presented paper entitled “Subsurface stratigraphy of the outer continental shelf near Sable Island” at Annual Meeting of the Geological Association of Canada and the Mineralogical Association of Canada, Halifax, N.S., in September 1966.

PELLETIER, B. R. Presented paper entitled “Development of marine geology and geophysics in eastern Canadian waters” at Annual Meeting of the Geological Association of Canada and the Mineralogical Association of Canada, Haliax, N.S., in September 1966.

PELLETIER, B. R. Presented paper entitled “The marine geology of the Arctic continental shelf” to the University of Southern California, Los Angeles, in November 1966.

PELLETIER, B. R. Prseneted paper entitled “Marine geological and geophysical programs in the Canadian Arctic” to regular meetings of the Alberta Society of Petroleum Geologists, Calgary, and Saskatchewan Geological Society, Regina, in November 1966.

VILKS, G. Presented paper entitled “Quantitative analysis of foraminifera in Bras D’Or Lakes” at Annual Meeting of the Geological Association of Canada and the Mineralogical Association of Canada, Halifax, N.S., in September 1966.

Aside from these and other scientific lectures to outside groups, many of the staff reported on their work to BIO and Institute of Oceanography of Dalhousie University (IODAL) seminars. Staff members also addressed service clubs, university and high school student groups, and the public through television and radio, on various aspects of the work of the BIO.

Appendix A-3 - Affiliation with Dalhousie University

Close and highly valued working relationships are maintained with those of Dalhousie departments interested in marine research and especially with IODAL. Particular value is attached to the honourary faculty appointments granted by the University to Dr Doe, Loncarevic, and Mann.

Dr Mann gave a graduate course in fluid mechanics in the Department of Physics, Dr Loncarevic contributed a series of lectures to a graduate course on the physics of the earth and Dr Doe with Dr R. W. Trites, FRB, and Dr S. D. Smith offered an introductory course in oceanography. Dr S. P. Srivastava gave part of the graduate seminar course in advanced geophysics.

Appendix A-4 - University Faculty and Students on Seasonal Staff, 1966

Name	University or Institute	Allocation in BIO	Remarks
Hooper, Prof. K.	Carleton	Marine Geology	Faculty member
Armstrong, W. B.	Acadia	Frozen Sea Research	
Babij, G. P.	Man. Inst. of Tech.	Hydrography	
Baker, R. A.	Carleton	Marine Geology	
Baltzer, F. M.	N.S. Land Survey School	Hydrography	
Battist, B.	N.S. Land Survey School	Hydrography	
Bergevin, A.	Eastern Ont. Inst. of Tech.	Hydrography	
Bishop, W. E.	N.S. Tech. Coll.	Electronics Design	
Blunden, S. J.	Memorial	Ocean Circulation	Graduate
Bohatyritz, N.	Eastern Ont. Inst. of Tech.	Hydrography	
Calder, J. A.	Carleton	Marine Geology	

Name	University or Institute	Allocation in BIO	Remarks
Castell, M.	Dalhousie	Chem. and Radiochemistry	
Crerar, D. A.	Toronto	Marine Geology	
Crosby, R. M.	New Brunswick	Marine Geology	
DeVille, B. N.	Dalhousie	Marine Geology	
Dugal, F.	Lava1	Mechanical Design	
Eidsforth, B.	Eastern Ont. Inst. of Tech.	Hydrography	
Elliott, K. H.	McGill	Marine Geology	Graduate
Francis, R.	Coll. Trades & Tech., St. John's	Hydrography	
Friedlaender, M.	Dalhousie	Marine Geophysics	
Golding, G. R.	New Brunswick	Marine Geology	
Green, D. G.	Eastern Ont. Inst. of Tech.	Hydrography	
Guptill, L.	Dalhousie	Applied Oceanography	
Heffler, D.	Dalhousie	Marine Geophysics	
Hirtle, C. A.	N.S. Inst. of Tech.	Engineering Services	
Hoar, I'. C.	Queen's	Computing Services	
Hudson, D.	Carleton	Frozen Sea Research	
Jockel, P. F.	Dalhousie	Marine Geology	
Johnson, A. E.	N.S. Inst. of Tech.	Mechanical Design	
Kirby, J. E.	N.S. Inst. of Tech.	Hydrography	
Lowe, W. A.	Eastern Ont. Inst. of Tech.	Hydrography	
MacDonald, S. D.	N.S. Inst. of Tech.	Engineering Services	
MacDougall, J. D.	Toronto	Marine Geology	
MacNab, R. F.	Dalhousie	Marine Geophysics	
McRoberts, J. H. E.	Queen's	Marine Geology	
Meadus, W. D.	Coll. Trades & Tech., St. John's	Mechanical Design	

Name	University or Institute	Allocation in BIO	Remarks
Pauksens, J.	Carleton	Electronic Design	
Perry, M. H.	Manitoba	Ocean Circulation	
Roebuck, W.	Inst. of Tech., Hamilton	Applied Oceanography	
Shearer, J. M.	Memorial	Marine Geology	Graduate
Stephenson, D. B.	Mount Allison	Marine Geology	
Sweet, L. G.	Acadia	Air-Sea Interaction	Graduate
Taylor, B. W.	N.S. Inst. of Tech.	Engineering Services	
Wilson, M. V. H.	Toronto	Marine Geology	
Wolfe, M.	Dalhousie	Ocean Circulation	
Young, S. W.	N.S. Inst. of Tech.	Engineering Services	
Yorath, C. J.	Queen's	Marine Geology	Graduate
Zahradnitzky, A. Z.	Ottawa	Chem. and Radiochemistry	

Appendix A-5 - Directory of Professional and Senior Technical Staff as at December, 1966

Wm. L. Ford.	Director	B.A., M.A., British Columbia, Ph.D.,Northwestern, Illinois.
A. S. Atkinson	Engineer-in-charge	B. Eng. (Elect.), Dalhousie and Nova Scotia Technical College.
R. L. G. Gilbert	Head, Metrology	B.A., M.A., Ph.D., Cantab.
S. W. Howell	Regional Marine Superintendent	Master Mariner (Foreign Going), Cdr. CD., RCN (Ret'd.)
C. D. Maunsell	Senior Oceanographer	B.A., M.A., British Columbia, Ph.D., California (Berkeley).
R. C. Melanson	Regional Hydrographer	Prov. Land Surveyors Cert., Nova Scotia.
B. R. Pelletier	Head, Marine Geology	B.Sc., McGill, M.Sc., McMaster, Ph.D., Johns Hopkins.
S. H. Scott	Administrative Officer	3 years Eng., Dalhousie
R. W. Trites[3]	Head, Applied Oceanography	B.Sc., New Brunswick, M.A., Ph.D., British Columbia.

[3] FRB Staff.

C. S. Allan (Miss)	Librarian	B.A., Dalhousie, Lib. Sc. Cert., Dalhousie, B.L.S., Toronto.
R. C. Amero	Hydrography	Prov. Land Surveyors Cert., Nova Scotia.
W. B. Bailey	Applied Oceanography	B.Sc., Acadia.
R. Balfour	Engineering	1st Class Eng. (Marine), Cdr. (Eng.), RCN (Ret'd).
D. L. Barrett	Oceanographic Research	B.A., M.Sc., Dalhousie.
G. A. Bartlett	Marine Geology	B.Sc., Mount Allison, M.Sc., Carleton, Ph.D., New York.
E. A. Bendell[1]	Metrology	B.Sc. (Elect. & Eng.), Alberta.
A. S. Bennett	Metrology	B.A., Ph.D., Cantab.
J. J. Betlam	Engineering	3 years Dip. (Elect. & Math.), Tech. School, Holland.
P. H. Bridge[2]	Oceanographic Research	B.A., M.A., Cantab.
J. Brooke	Metrology	P. Eng. (Ont.).
D. E. Buckley	Marine Geology	B.Sc., B.Sc. (Hons), Acadia, M.Sc., Western Ontario.
K. Budlong (Mrs)[1]	Metrology	B.A., Grinnell, B.Sc., Case Inst. of Tech.
J. Butters	Applied Oceanography	Master Mariner (Foreign Going).
T. M. Calderwood	Hydrography	Ottawa Tech. Dip. (Aeronautics).
R. M. Cameron	Hydrography	3 years Civil Eng., Mount Allison.
A. R. Coote	Oceanographic Research	B.A., M.Sc., British Columbia.
P. L. Corkum	Hydrography	
F. L. DeGrasse	Hydrography	2 years Civil Eng., Mount Allison.
J. G. Dessureault[1]	Metrology	B.Sc. (Mech. Eng.), Laval.
J. A. Dimmers	Metrology	Dip. (Elect. Eng.), Adelaide.
D. Dobson	Applied Oceanography	Master Mariner (Foreign Going).
L. A. E. Doe	Oceanographic Research	B.A., M.A., Toronto, Ph.D., New York.
R. G. Douglas[1]	Hydrography	1 year Univ. Saskatchewan, 2 years rov. Inst. Tech. & Art, Land Surveying Dip.
S. S. Dunbrack	Hydrography	Prov. Land Surveyors Cert., Nova Scotia.

[1] Joined BIO in 1966.
[2] Left BIO in 1966.

R. M. Eaton	Hydrography	
J. A. Elliott	Oceanographic Research	B. Eng., Saskatchewan, M.Sc., British Columbia.
G. N. Ewing	Oceanographic Research	B.Sc., St. Francis Xavier, M.Sc., Dalhousie.
W. I. Farquharson[2]	Applied Oceanography	Honorary M.Sc., Liverpool.
T. R. Foote	Applied Oceanography	2 years Mount Allison.
W. D. Forrester	Oceanographic Research	B.A., Toronto, M.Sc., British Columbia.
V. J. Gaudet	Hydrography	Prov. Land Surveyors Cert., Nova Scotia.
A. B. Grant	Oceanographic Research	
A. C. Grant	Marine Geology	B.A., Acadia, B.Sc., Dalhousie, M.Sc., New Brunswick.
W. W. Hall	Metrology	Nat. Cert. of Mech. Eng.
B. B. Hartling	Metrology	Cert. Radio Constr. & Repair, Nova Scotia Technical College, Dip. Advanced Elect., Capital Radio Eng. Inst., Washington.
J. M. Higgins	Ships	1st Class Eng. (Marine), Lt. RCNR (Ret'd).
A. M. Holler	Ships	Master Mariner (Foreign Going).
A. D. Kenney	Hydrography	2 years Pre-Eng., Acadia.
F. K. Keyte	Applied Oceanography	B.A., Sydney, Australia, B.A. (Hons), Alberta, M.A., Toronto.
L. H. King	Marine Geology	B.Sc., Acadia, Ph.D., M.I.T.
K. M. Kranck (Miss)	Marine Geology	B.Sc., McGill, M.Sc., Uppsala, Sweden.
C. J. Langford	Hydrography	3 years Holcomb Tech. Eng., Merchant Navy Naval School.
D. J. Lawrence	Applied Oceanography	B.Sc., M.Sc., Dalhousie, Ph.D., Queen Mary College.
J. R. N. Lazier	Oceanographic Research	B.A., Toronto, M.Sc., British Columbia.
D. D. LeLievre	Hydrography	Prov. Land Surveyors Cert., Nova Scotia.
E. L. Lewis	Oceanographic Research	B.Sc., M.Sc., Ph.D. London, England.
B. D. Loncarevic	Oceanographic Research	B.A., B.Sc., M.A., Toronto, Ph.D., Cantab.
R. H. Loucks	Oceanographic Research	B.Sc., M.Sc., British Columbia.

[2] Left BIO in 1966.

R. M. McMullen	Marine Geology	B.Sc., M.Sc., Alberta, Ph.D., Reading, England.
B. MacLean[1]	Marine Geology	B.A., Acadia.
H. W. MacPhail	Metrology	1 credit Elect. Eng., I.C.S.
S. B. MacPhee[1]	Engineering	Eng. Dip., St. Francis Xavier, B. Eng., Nova Scotia Technical College.
K. S. Manchester	Oceanographic Research	B.Sc., Connecticut, M.Sc., Dalhousie.
C. R. Mann	Oceanographic Research	B.Sc., M.Sc., New Zealand, Ph.D., British Columbia.
J. I. Marlowe	Marine Geology	B.Sc., Florida State, Ph.D., Arizona.
C. S. Mason	Metrology	B.Sc., M.Sc., Western Ontario, Ph.D., Cantab.
L. P. Murdock	Hydrography	5 credits B.Sc.
G. T. Needler	Oceanographic Research	B.Sc., M.Sc., British Columbia, Ph.D., Mc Gill.
I. M. H. Pagden	Oceanographic Research	B.Sc. Ph.D., Exeter.
C. R. Peck[1]	Engineering	1 year 2nd Class Radio Operator, 4 years Canadian Institute Science & Technology.
J. M. R. Pilote	Hydrography	Navigation Course, Tech. Inst., Rimouski.
W. J. Probert[1]	Hydrography	Prov. Land Surveyors Cert., Nova Scotia.
L. D. Quick	Hydrography	Master Mariner (Foreign Going), 2 years Navigation.
C. Quon	Oceanographic Research	B.Sc., M.Sc., Alberta.
M. A. Rashid[1]	Marine Geology	B.Sc., Hyderabad, India, M.S., Oklahoma, Ph.D., Utah
R. F. Reiniger	Oceanographic Research	B.Sc., Saskatchewan, M.A., Toronto.
R. C. Richards	Oceanographic Research	B.Sc., British Columbia.
C. K. Ross	Oceanographic Research	B.Sc., M.A., Toronto.
D. I. Ross[1]	Oceanographic Research	B.Sc., M.Sc., Ph.D., Victoria, New Zealand.
H. Sandstrom	Oceanographic Research	B.A., Toronto, M.A., Ph.D., California..
J. G. Shreenan	Hydrography	B.Sc. (Forestry), New Brunswick, 1 year Teacher Training.

[1] Joined BIO in 1966.

G. Smith	Ships	Naval Architect, SNAME, Nat. Cert. Architecture.
S. D. Smith	Oceanographic Research	B. Eng., McGill, Ph.D., British Columbia.
T. B. Smith	Hydrography	Prov. Land Surveyors Cert., Nova Scotia.
S. P. Srivastava	Oceanographic Research	B.Sc., IIT, India, Ph.D., British Columiba.
H. Steeves[2]	Oceanographic Research	B.Sc., New Brunswick.
R. G. Stevens[1]	Oceanographic Research	B.A., Iowa, Ph.D., New York.
M. G. Swim	Hydrography	1 year Acadia.
H. B. Sutherland	Engineering	2 credits Math., Dalhousie.
G. Vilks	Marine Geologv	B.Sc., McMaster, M.Sc., Dalhousie.
R. N. Vine	Metrology	Ord. Natl. Cert., Southampton Tech. Col England.
F. J. E. Wagner (Miss)	Marine Geology	B.A., M.A., Toronto, M.S., Ph.D., Sanford.
R. R. Weiler	Oceanographic Research	B.A., M.A., Toronto, Ph.D., Dalhousie.
D. E. Wells[1]	Metrology	B.Sc., Mount Allison, B.A.Sc., M.A.Sc., British Columbia.
K. O. Westphal[2]	Oceanographic Research	Dip., Wurzburg, M.A., Toronto, Ph.D., British Columbia.
R. K. Williams	Hydrography	

[1] Joined BIO in 1966.
[2] Left BIO in 1966.

Appendix A-6 - Administration Staff

S. H. Scott

Library

Miss C. S. Allan
Mrs I. Ineson

Finance

V. W. Hilchey
W. A. MacDonald[2]
Miss F. G. MacLaren
Mrs S. G. Furlong

Personnel

Mrs M. Dalzell
Mrs S. J. Jones
Mrs C. Leveck[1]

Ships

G. W. Booth
R. H. Stone
J. F. MacLean
G. Y. Hare[2]
F. W. Grant
J. G. Arnold[2]

Stores

B. G. Martin
R. W. Fudge
R. Jollymore[1]
M. W. Campbell
S. P. Hartling
E. C. Tupper[2]
R. Josey[1]
W. Lovett

Central Registry

Mrs C. E. Gallant
Mrs D. M. Fultz
Miss G. P. Sanford[1]
D. Hendsbee[1]

P.B.X.

Miss J. E. Gavan

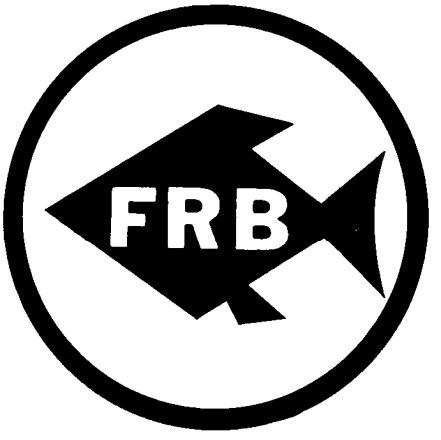
Heating Plant

J. F. Greig
G. E. Higgins
C. E. Rose
H. L. Gorman

Mrs V. C. Kerr, Sec., Director.
Miss C. J. Forsythe, Sec., Marine Geology and Administration.
Mrs J. Sim, Sec., Oceanographic Research.
Mrs M. L. Smoth, Sec., Regional Hydrographer.
Mrs G. Graham[2], Sec., Metrology.
Miss M. T. Bidart[2], Sec., Engineering Services.
Miss V. E. Clarke[1], Sec., Ships.
Mrs A. J. Cowan, Tides and Currents.
Mrs C. A. Webber[1], Sec., Hydrography.
Miss P. L. MacLeod[1], Sec., Ships.
Mrs J. Hackney[2], Sec., Frozen Sea Research.
Miss V. J. Edwards[1], Sec., Frozen Sea Research.

---

[1] Joined BIO in 1966.
[2] Left BIO in 1966.



Part B

The Annual Report for 1966 of the Dartmouth Laboratory of the Fisheries Research Board of Canada

(This page Blank in the original)

Part B

The Annual Report for 1966 of the Dartmouth Laboratory of the Fisheries Research Board of Canada

Director's Remarks

During 1966, the Dartmouth Laboratory of the Fisheries Research Board began the development and expansion of its program of studies of biological and physical processes underlying marine production. Of particular interest to the laboratory staff are the major physical systems of the Continental Shelf and open Northwest Atlantic ocean from which, during the year, some 14 countries of Europe and North America took 7,000 million pounds of marine fish. However, the size and complexity of such areas pose formidable problems in adequate description, let alone in the understanding of regulatory mechanisms. For this reason, the Dartmouth oceanographic programs are laying the groundwork for the larger-scale studies by detailed investigation of smaller systems. In 1965 St. Margaret's Bay (Fig. 19) a small (6 x 10 mile) embayment about 25 miles west of Halifax, was selected as a model, and, during 1966, this area served as a focus for investigations by most of the disciplines in the laboratory. These included physical oceanographic observations of water exchange through the entrance of the bay, studies of the microstructure of the surface layers in relation to wind stress and zooplankton distribution, observations of physical and nutrient chemistry of the water, a 2-month Eulerian-type study of the phytoplankton production, collections of zooplankton, sampling for abundance and studies of caloric contents of benthic invertebrates and observations on the abundance, foods, and physiology of the American plaice populations.

While studies of St. Margaret's Bay will be increased in scope and intensity, our interest in it is primarily as a model of the larger systems in which we propose to develop our studies. With this in mind, our 1966 operations also included a summer-time two-ship oceanographic study in the Laurentian Channel at the entrance of the Gulf of St. Lawrence, and work on the geology and geochemistry of the Gulf. Field trials of parts of the newly-developed electroacoustic fish-counting system were also carried out in the Gulf in September. It is expected that the methods and instruments developed in the laboratory and in the St. Margaret's Bay program in 1966 will provide a good basis for pilot biological and fisheries oceanographic observations in the Gulf and on the Scotian Shelf during 1967.

The field programs of the laboratory require considerable laboratory support and data analyses. During the year increases in staff, training, and equipment considerably improved and expanded our capacity for biological, biochemical, and physical analyses, despite the difficulties attendant on overcrowding. In addition, certain aspects of our studies of the marine eco-systems are carried on primarily in the laboratory. Major laboratory studies of the relations between the metabolism of animals and the activity of certain enzymes have been undertaken, and basic studies of the physical chemistry of seawater have been expanded. In addition, the Bedford Institute of Oceanography (BIO) computer (CDC-3100) makes it possible to complete some analyses of physical oceanographic data which would not otherwise be undertaken, and consideration is being given to enlarging its storage capacity to allow theoretical study of a wider range of population dynamics and biological production problems.

While St. Margaret's Bay offers our own staff an opportunity for detailed integrated study of a production system, it also has the decided advantage of lending itself well to the development of short-term projects for graduate students and post-doctoral fellows, whose time for field work may be limited. The staff of the Dartmouth Laboratory feel strongly that such encouragement of graduate research and assistance in graduate training is a responsibility as well as an opportunity to maintain contact with the stimulating university environment. Considerable attention is therefore devoted to fostering association with universities as well as other research establishments. Especially close associations are maintained with Dalhousie University. Three of the senior professional staff of the Dartmouth Laboratory hold appointments at the University, participating in course instruction and graduate student direction in the Departments of Biology and Geology and in the Institute of Oceanography. One graduate student from McGill and one from

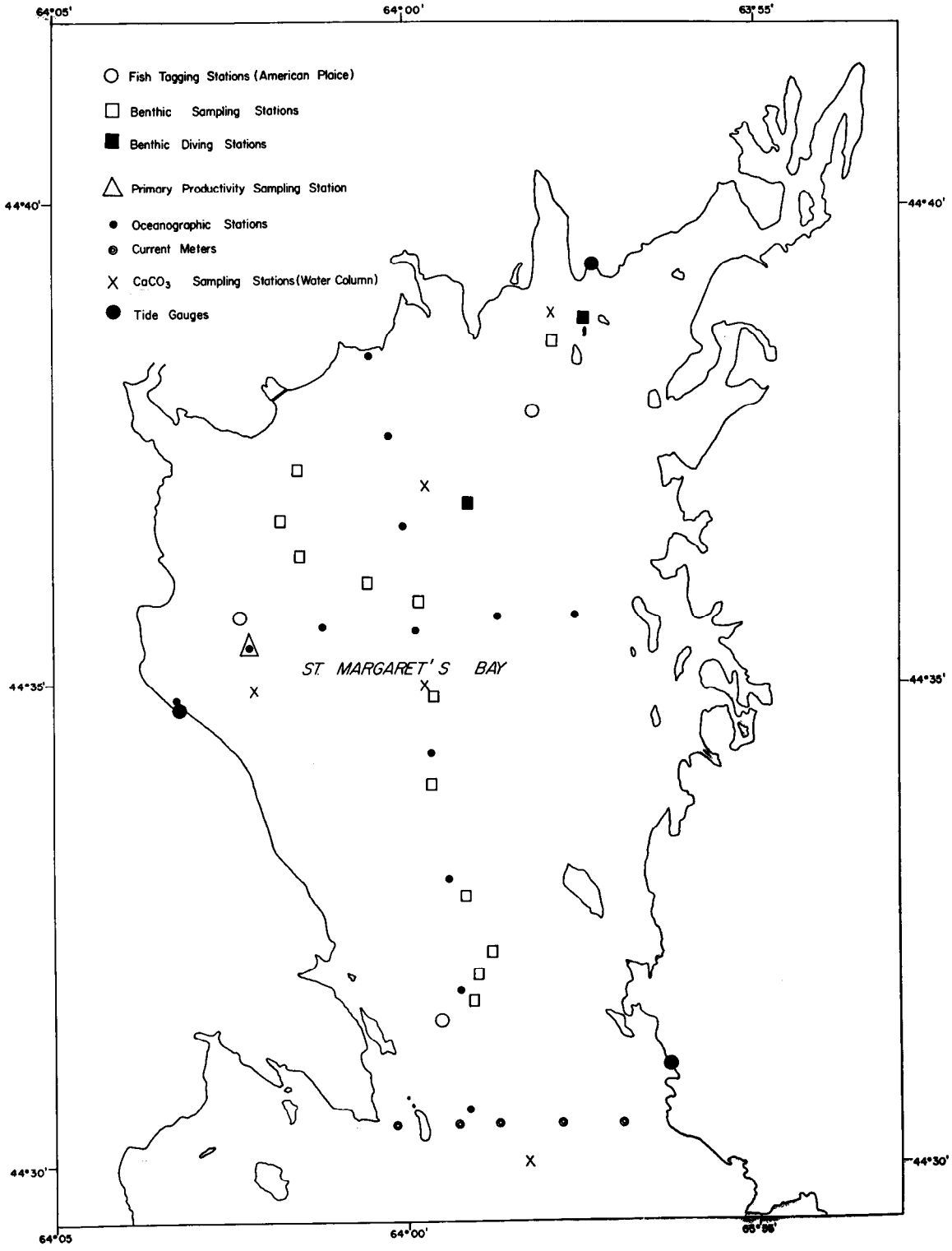


Fig. 19. St. Margaret's Bay.

Queen's University worked on Ph.D. projects at the Laboratory during the summer under joint direction of the University and Dartmouth staff, and a number of graduates and undergraduates from various universities, as well as professional staff from sister research institutions have worked at the Laboratory during the year as assistants or guests. Staff consultations, seminars and symposia have been conducted at the Laboratory with visiting associates from UK, Canadian and USA universities, and research institutes. During 1966 we were particularly fortunate to have guests lecturers and seminars from:

Mr C. S. Yentsch, Woods Hole Oceanographic Institution, Woods Hole, Mass;

Dr E. R. Baylor, Woods Hole Oceanographic Institution, Woods Hole, Mass.

Dr P. Hochachka, Dept. of Zoology, University of British Columbia, Vancouver, B.C.

Dr S. M. Marshall, Marine Station, Millport, Isle of Cumbrae, Scotland.

Dr G. B. Deevey, Bingham Oceanographic Laboratory, Yale University, New Haven, Conn.

Dr K. H. Mann, Dept. of Zoology, the University, Reading, England.

Thus, the year has been a scientifically active one for the small staff of 25 who started the year at the Laboratory. During the year additions to the staff have been made, the present total being 37. This group now forms the nucleus of the integrated but specialized staff in the fields of biology, chemistry, economics, geology, mathematics, physics, and oceanographic instrumentation necessary for study of the many aspects of production in marine eco-systems. Office and laboratory accommodation for the group have been provided up to now in BIO. As a result of this satisfactory experience in cooperation it was decided early in 1966 that the FRB Laboratory should continue to be located on the campus of BIO. Plans have therefore been undertaken to provide additional laboratory and office space to support our expansion. After some delays, tenders have been called for construction of a

Fig. 20. MV A. T. *Cameron.*

small laboratory which will contain urgently needed special facilities for physiological and behavioural studies of fish and lower organisms. Preliminary discussions for a forward field base to support operations in St. Margaret's Bay have begun, and consideration is being given to the specifications and requirements for a separate main laboratory building at BIO.

During 1966, as in the past, the Canadian Naval Auxiliary Vessel *Sackville* (Fig. 18 - Part A) and the research ships of the Marine Sciences Branch (MSB) of the Department of Energy, Mines and Resources, continued to support the main large ship requirements of the Laboratory. By arrangement with the St. John's Station of FRB, the M/V A.T. *Cameron* (Fig. 20) was also employed for instrument evaluation during short periods in July and September. In addition, the 48-ft fishing vessel *Sigma-t* (Fig. 21) was purchased and converted to biological and physical oceanographic work in nearshore waters and the Hydrographic Survey Launch *Redhead,* supplied on loan from the Department of Energy, Mines and Resources, (DEMR) was converted for local plankton collecting and water sampling. Other small vessel support was provided by chartering of a local small fishing craft. Through the cooperation of the Department of National Defence, helicopter support was provided in mid-summer for physical oceanographic studies in St. Margaret's Bay, and the Naval Research Establishment of the Defence Research Board provided facilities for the calibration of oceanographic instruments. This generous support of outside agencies expedited our preliminary investigations. Plans are underway to construct one small and one large vessel to support future work.

During 1966, an experiment was made in the cooperative integration of administrative and operational research staff. Several diverse units from MSB of DEMR and the Dartmouth Laboratory of FRB were combined in a newly created Applied Oceanography Section of BIO. This unit, under the direction of Dr R. W. Trites, has

Fig. 21. MV *Sigma-t.*

assumed responsibility for studying a number of continuing oceanographic problems of interest to fisheries, transport and national defence, and has, in addition, supplied assistance to the Federal Department of Public Works and the Department of Fisheries in solving problems concerned with highway and dam construction, and in preventing potential pollution hazards. This type of organization, while new to us, appears to be well past experimental stages and its success may set a useful precedent for future cooperative ventures.

In the sections which follow this introduction, members of the staff have outlined specific scientific investigations in more detail.

L. M. Dickie

Staff List

Director and Administration

L. M. Dickie, B.Sc. (Acadia), M.Sc. (Yale), Ph.D. (Toronto)

M. Blaxland

Hilda K. Gamester

Sandra H. M. Rushton

Sylvia M. Smith

C. J. Bayers

H. S. Glover (from 1 February 1966)

K. B. Grace (from 1 April to 30 November 1966)

Environmental Oceanography

R. W. Trites, B.Sc. (UNB), Ph.D. (UBC)

D. H. Loring, M.Sc. (Acadia), Ph.D. (Manchester)

R. F. Platford, M.Sc. (UBC), Ph.D. (Saskatchewan)

I. W. Duedall, M.Sc. (Oregon State University) (from 30 June 1966)

G. B. Taylor

C. C. Cunningham

J. P. Budlong, B.Sc. (Case Institute of Technology) (from 29 June 1966)

T. A. Grant

J. J. G. Major (from 11 August 1966)

D. P. Krauel, B.Sc. (McMaster) (from 9 May 1966)

S. B. McHughen

R. R. Lively (from 12 July to 31 August 1966)

Biological Oceanography

R. J. Conover, B.A. (Oberlin), Ph.D. (Yale), (from 1 Sept. 1966)

A. Prakash, B.Sc. (Delhi), M.Sc. (Allahabad), Ph.D. (UBC)

Vivien M. Brawn (Srivastava), B.Sc. (Reading), M.Sc. (Durham), Ph.D. (UBC)

E. Kott, Ph.D. (Toronto)

D. L. Peer, B.Sc. (UNB), M.Sc. (Saskatchewan)

T. C. Platt, B.Sc. (Nottingham), M.A. (Toronto)

M. Hodgson, B.Sc. (Dalhousie)

J. C. Smith, M.Sc. (UBC) (from 18 July 1966)

R. J. Bentley, B.Sc. (Reading)

B. D. Irwin (from 2 May 1966)

Alma M. Major, B.Sc. (Memorial)

E. P. Anderson, B.A. (Harvard) (from 30 September 1966)

Fisheries Oceanography

J. E. Paloheimo, Mag Phil (Helsinki), M.A. (Toronto) (from 15 August 1966).

E. Bakken, Cand. real (Bergen) (from 30 May 1966)

K. J. Brewer, M.A. (Oxon), M.A. (Alberta) (from 30 December 1966)

S. Paulowich (from 28 April 1966)

R. G. Dowd (from 1 February 1966)

W. B. Fraser

Short-term Associates and Assistants

Mary E. Caldwell

S. D. Deleu

R. J. Harrison

A. A. Longard, B.Sc. (Dalhousie)

H. G. Miller

D. J. G. Nota, M.Sc. (Leiden), Ph.D. (Utrecht)

Patricia F. Nelson

C. B. Purcell, B.Sc. (Dalhousie)

1966 Publications

BAKKEN, E. 1966. Influences of hydrographical and meteorological factors on catch and recruitment strength of the sprat stock in western Norway. *Fiskdir. Skr. Ser. Hav-Unders.,* **14** : 61-71.

BEAMISH, F. W. H[1]., and L. M. DICKIE. Metabolism and biological production in fish. In A symposium on freshwater fisheries production (Provisional title). Blackwell Sci. Publ. (In press).

BLACKFORD, B. L.[2] 1966. A simple two-dimensional electrical analog model for wind-driven circulation in the Gulf of St. Lawrence. *J. Fish. Res. Bd. Canada,* **23** (9): 1411-1438.

DICKIE, L. M. Mathematical models of growth. Appendix to Chapter 5 In Handbook of methods for studying freshwater fish production. (In press).

DUEDALL, I. W., and P. WEYL. 1965. Apparatus for determining the partial equivalent volumes of salts in aqueous solution. *Rev. Sci. Inst.* **36:** 528.

DUEDALL, I. W. 1966. The partial equivalent volumes of salts in seawater. Oregon State University, M.Sc. Thesis, June, 1966.

DUMBROWSKI, H., C. G. I. FRIEDLAENDER, R. KUHN, and D. H. LORING. 1966. Bacteriological investigations of carboniferous rock salt from Pugwash, Nova Scotia. *Ecologae,* **58:** 967-974, BIO Contrib. No. 51.

LORING, D. H., and D. J. G. NOTA. 1966. Sea floor conditions around the Magdalen Islands in the southern Gulf of St. Lawrence. *J. Fish. Res. Bd.* Canada, **23** (8) : 1197-1207, BIO Contrib. No. 57.

LORING, D. H., and F. M. BROADHURST. Sedimentation of a coal measure succession in Lancashire, England. Palaeo 3, Elsevier, Amsterdam (In press).

PALOHEIMO, J. E., and L. M. DICKIE. 1966. Food and growth of fishes. II. Effects of food and temperature on the relation between metabolism and body weight. *J. Fish. Res. Bd. Canada,* **23** (8): 869-908.

1966. Food and growth of fishes. III. Relation among food, body size and growth efficiency. *Ibid.* **23** *(8):* 1209-1248.

PEER, D. L. 1966. Relationship between size and maturity in the spottail shiner, *Notropis hudsonius. J. Fish. Res. Bd. Canada,* **23** (3): 455-457.

PLATFORD, R. F. Activity coefficients in the system H_2O-NaCl-$MgSO_4$ at 25°C. *Can. J. Chem.* (In press), BIO Contrib. No. 73.

PRAKASH, A., and F. J. R. TAYLOR. 1966. A 'red water' bloom of *Gonyaulax acatenella* in the Strait of Georgia and its relation to paralytic shellfish toxicity. *J. Fish. Res. Bd. Canada,* **23** (8): 1265-1270.

PRAKASH, A. 1966. Growth and toxicity of a marine dinoflagellate *Gonyaulax tamarensis. J. Fish. Res. Bd. Canada* (In press).

PYTKOWICZ, R. M., I. W. DUEDALL, and D. N. CONNORS. 1966. Magnesium ions; Activity in seawater. *Science* **152:** 640.

[1] Member of staff of Dept. of Zoology, Guelph University, Guelph, Ontario.
[2] Member of Dartmouth staff to September, 1965.

Investigators' Summaries of Current Research

Researches in Primary Production

A description of the energy flow through a marine production system involves a knowledge of the amount of energy made available to the system by the primary producers. Studies of primary production at Dartmouth have emphasized the importance of field observations. A pilot study was made in St. Margaret's Bay from July to August, 1966 (Fig. 19). The investigation employs bi-weekly sampling at various depths to observe the photosynthetic rate, phytoplankton biomass, nutrients and related physical factors. An exploratory study was made of the local horizontal variations in phytoplankton biomass and their relation to water structure. The analysis of these data is continuing. A concurrent study of species succession of phytoplankton was made by S. M. Saifullah, a graduate student of McGill University.

Beginning in January, 1967, a 12-month sampling program will be started to provide data on the annual primary production cycle. The scope of the investigation will be broadened to include a preliminary study of the relationship between primary and secondary producer abundances. In May, 1967, a start will be made on the study of primary production in the Gulf of St. Lawrence. In this latter case the experiment will be Lagrangian rather than Eulerian in character.

T. C. Platt

Physiological Ecology of Marine Dinoflagellates

Attempts to explain the distribution and variation in abundance of primary producers in the sea are often hampered by lack of information about their physiology and environmental responses. To identify the ecological factors that influence and control their growth and distribution it has been necessary to bring the organisms into the laboratory and maintain them under artificial conditions. In spite of its many pitfalls, this approach has yielded valuable information about some of the factors which either control or limit the production of a number of protoplankton species. Little is known about the growth requirements and ecological interactions of marine dinoflagellates which show significant seasonal pulses in temperate waters. With this in mind, studies are being carried out on physiological ecology of marine dinoflagellates of the genus *Gonyaulax*. Four species of *Gonyaulax* from diverse geographic locations in North America and known to synthesize potent biotoxins are being maintained in unialgal cultures in artificial and enriched sea water media.

During the past year most of our attention has been devoted to field observations and laboratory studies of the growth requirements of *G. tamarensis* which appears in significant numbers in the Bay of Fundy during the summer months. The field observations have indicated that the seasonal maximum for *G. tamarensis* in the Bay of Fundy is correlated with the occurrence of low-salinity and high-temperature water. Laboratory experiments with unialgal cultures have indicated a salinity tolerance range of 7-40‰ and an optimum around 20‰. Likewise the lower and upper limits of temperature for growth were found to be 5° and 25°C respectively with an optimum between 15-19°C. Although high temperature and low salinity have both been found to promote growth in cultures, there appears to be a greater response to variation in salinity of the order found during the summer thereby suggesting that it is a big factor in determining the summer abundance of this dinoflagellate in the Bay of Fundy. Temperature undoubtedly plays an important role in controlling the abundance of *G. tamarensis* after the summer months. Of the various factors examined which induce cyst formation in cultures, temperature was found to be most significant. From the field observations there is little doubt that light is also an important factor and laboratory studies of this parameter are beginning.

Under standard culture conditions in the laboratory, maximum cell yield in mass cultures was found to be between 4.5-6 X 10^4 cells/ml, with mean generation time (tg) around 60 hr, and growth constant (K^{10} $(days)^{-1}$) equal to 0.12. A distinct increase in cell size was observed at the end of the exponential phase of growth in *G. tamarensis.*

Detailed studies on specific nutrient requirements of *G. tamarensis* are in progress. Preliminary observations based on differential enrichment experiments have indicated that growth in cultures is limited by nitrate, vitamin B^{12} and thiamine. It appears that vitamin B^{12} and thiamine influence the growth of the dinoflagellate only if present in combination, since addition of these vitamins singly in varying concentrations

did not support any growth. Additional experiments have indicated that some organic factor or factors other than vitamins, associated with the 'humic' fraction of soil humus, have a marked stimulatory effect on the growth of *G. tamarensis.* This growth response is best seen in the dosage-yield curve (Fig. 22). Whether the increased growth response of the dinoflagellate in the presence of humic acids fraction is simply due to chelation processes or to influence on the metabolic processes of the cell is not known.

Substantial amounts of humic matter enters the inshore waters of the Bay of Fundy as a result of the spring land drainage, just prior to the onset of the dinoflagellate maxima. Humic acids and other associated fractions of the soil humus therefore appear to be one of the ecologically significant entities which chemically condition the sea water for or against a particular group of protoplankton, and may thus be involved in establishing seasonal abundance and species succession in nature. Further work in this direction is being pursued in collaboration with Dr M. A. Rashid of DEMR at BIO and Dr L. Provasoli of the Haskins Laboratories, New York.

A. Prakash

Other Dinoflagellate Studies

Earlier studies had indicated that tintinnids exert a substantial grazing pressure on dinoflagellate populations and may be an important factor in limiting the size of the standing stock in the Bay of Fundy in certain seasons. Grazing studies using laboratory cultures of dinoflagellates have not been successful chiefly due to difficulties in maintaining an adequate population of tintinnids. However, attempts to use copepods as grazers have met with some success and further work along this line is contemplated.

Last summer, a short project on induced detoxification of shellfish was carried out at the Biological Station, St. Andrews, N.B. The experiments conducted showed promising results and demonstrated the feasibility of the flushing out of the toxin from shellfish by subjecting live animals to certain physiological stresses.

A program of weekly sampling for phytoplankton was started in March, 1965 in Bedford Basin to investigate the annual phytoplankton cycle and to evaluate the environmental and biological factors which influence the growth and

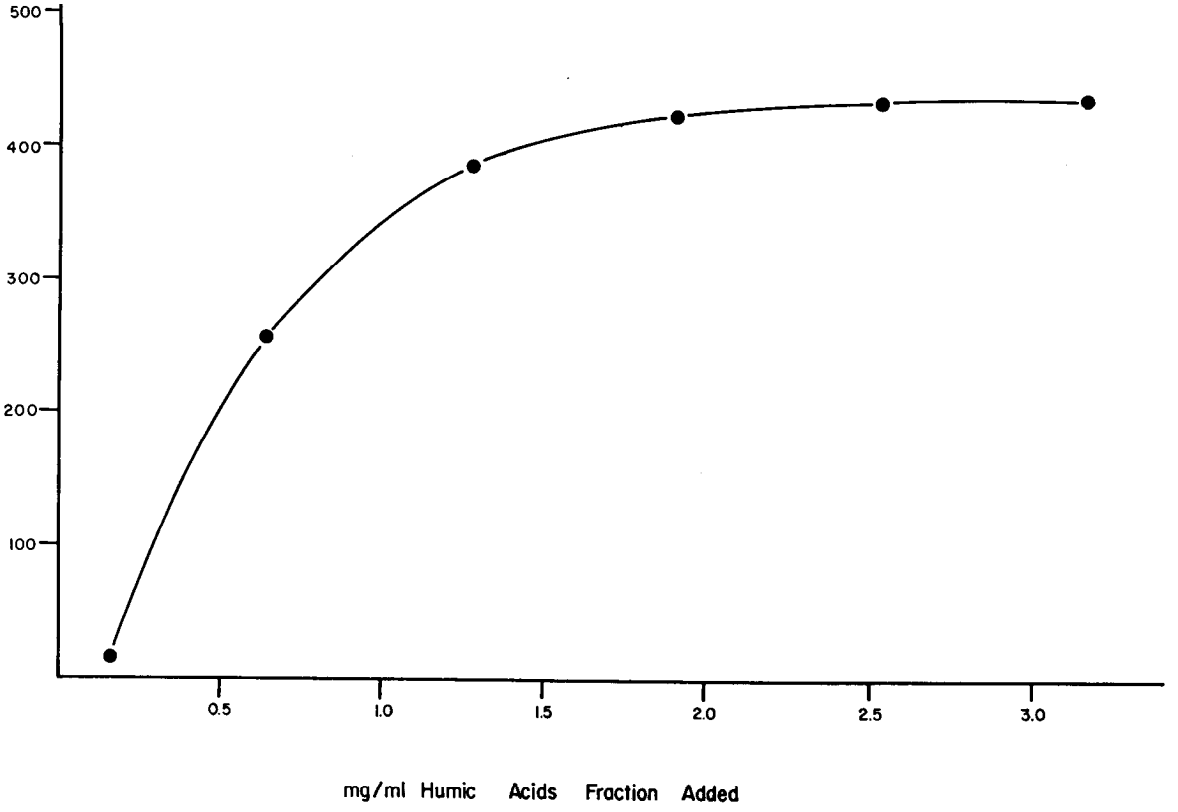


Fig. 22. Relation of final yield of G. *tamarensis* to concentrations of the humic acids fraction of soil humus.

succession, particularly of armoured dinoflagellates. The sampling to date has been largely qualitative but with the recent acquisition of a better equipped vessel, the program has been developed on quantitative lines and includes measurements of the various hydrographic parameters. Preliminary analysis has indicated that although the standing crop of phytoplankton is fairly high in the Basin, species diversity is low in most of the samples collected so far. Dinoflagellates appear to be quantitatively more important than diatoms during the summer months. A conspicuous diatom-dinoflagellate succession was noticed from April to November when a *Rhizosolenia* bloom was followed by successive dominance of *Dinophysis, Peridinium* and *Ceratium.*

A. Prakash
M. Hodgson

Oxygen Utilization and Nitrogen Excretion in Relation to Life Cycles and Production Cycles in Marine Zooplankton

In the oxidation of organic matter containing a mixture of carbohydrates, lipids, and protein, about 16 atoms of oxygen would be necessary to release a single atom of reduced nitrogen. If only carbohydrates or fat were being burned, no nitrogen would be produced. On the other hand, if only protein were being used as an energy substrate, a ratio considerably less than 16 would be expected.

The simultaneous measurement of respiration and nitrogen excretion by plankton animals can be made quite easily in tightly sealed, glass-stoppered water bottles (reagent bottles) of appropriate size. When Harris[3] carried out experiments of this sort over a three-month period in summer, he found a considerable variation in ON ratios for plankton animals but most of his experiments yielded ratios significantly less than 16 (mean 7.7). On the other hand Corner, *et* al.[4] found a mean of 13.5 for *Calanus helgolandicus* in four experiments.

Preliminary experiments with the large cold water copepod *Calanus hyperboreus* during the the fall of 1964 produced ON ratios between 30-40. *Calanus hyperboreus* stores large amounts of lipid during the spring and early summer but does not feed appreciably in the fall. The low excretion encountered at this season must be attributed to lipid metabolism. Consequently, a seasonal study of respiration and nitrogen excretion was initiated using this and several other common temperature copepod species, *Calanus finmarchicus, Metridia lucens* and *Paraeuchaeta norvegica.* Dry weight, nitrogen and lipid content were also determined.

A similar seasonal pattern for respiration and excretion emerged for all the species. Respiration was low in the fall and winter, increasing gradually through the spring to a peak in May. Nitrogen excretion was similarly low in the fall and gradually increased in late winter to a maximum in March or April. However, the relative proportion of oxygen utilization and nitrogen excretion varied at different seasons and for the different species. The interpretation of these differences depends in part on an understanding of the life cycle of the animals.

Calanus hyperboreus, a large herbivore which produces a single generation a year and which depends almost exclusively on energy in the form of lipid stored during the spring bloom to complete its annual cycle, showed the largest range of ON values. These were highest in spring (> 150) just after the spring flowering when the animals were packed with fat, then declined gradually to become lowest (< 10) just before the next flowering when the population consisted primarily of spent females of the older generation and lean younger stages of the *new. Calanus finmarchicus,* a smaller relative which may produce several generations in one season, demonstrated a similar pattern except that during the summer the ratio remained near the expected level (16) and did not increase until the stage **V** of the overwintering generation appeared.

Metridia longa is an omnivore and its ON ratio did not go above 20 except for the period immediately following the spring bloom. Its lipid content was generally less than 20% and its general level of metabolic activity higher than for the *Calanus sp.* The last species *Paraeuchaeta norvegica* is a carnivorous animal which is morphologically poorly adapted for eating small particules. About the same size as *C. hyperboreus* it also contains relatively high levels of lipid which it doubtless obtains directly from its principal food source, *Calanus.* There was little seasonal

[3] Harris, E. 1959. The nitrogen cycle in Long Island Sound. *Bull. Bingham. Oceanogr. Coll.,* **17:** 31-65.
[4] Corner, E. D. S., C. B. Cowey, and S. M. Marshall 1965. On the nutrition and metabolism of zooplankton III. Nitrogen excretion by *Calanus. J. Mar. Biol. Ass.* U.K. **45:** 425-442.

variation in the metabolism of this animal and the ON ratio changed only slightly with the seasons.

The ON ratio may prove useful in understanding and perhaps even predicting production by animals of second and higher trophic levels. This hypothesis should be tested with a zooplankton population, either in culture, or better still, in a confined basin such as Bedford Basin or St. Margaret's Bay, where specific events in the production process can be identified more easily.

R. J. Conover

Benthic Communities -- Gulf of St. Lawrence

The first phase of the benthic sampling program in the Gulf of St. Lawrence has been completed. At present quantitative data from nine stations are available. At each of these stations 10 samples were taken with a 0.1 m^2 Van Veen bottom grab. Eight similar stations have been sampled but remain unsorted. No new samples were taken during 1966.

Of approximately 50 groups of animals from these samples, 13 are common enough to provide quantitative informstion on distribution. Three types of distribution are evident:

1) species whose members are large, poorly represented in samples, and appear to be randomly distributed;

2) species whose wet weight biomass and numbers show major station-to-station differences;

3) species whose wet weight biomass and numbers are not significantly different between stations but whose distribution, rather than being random showed a high degree of contagion.

The first group consists of the mollusk *Clinocardium ciliatum,* and the polychaetes *Pherusa plumosa* and *Nepthys ciliata.* These three species attain a large but variable size and were relatively rare having a mean number per sample of less than one. The x^2 values based on a comparison of the observed with a Poisson frequency distribution were all low. While this can be interpreted as a random distribution with respect to the sample size used, it is difficult to demonstrate nonrandomness with such a small mean. Clearly a larger sampling unit is necessary for the study of animals of this type.

The second type of distribution included six species : *Eudorellopsis sp., Diastylis rathkei, Harpinia sp., Echinarachnius parma,* Pectinaria *hyperborea, Phyllodoce mucosa;* and the group Gephyrea. Three of these are small crustaceans probably capable of moving about the sediment surface while the remainder have pelagic larvae. *Pectinaria* larvae are believed to be able to postpone metamorphosis until a suitable substrate is encountered. The capacity for dispersal, although limited, seems likely to explain the low variance between replicate samples within a station. The relatively high variance between stations may be related to our previous findings that there is a correlation between the total size of biomass and the sorting coefficient and median particle size of the sediment.

The third group includes three species of polychaetes, *Goniada maculata, Scoloplos armiger, Lumprineris sp.,* all of which show a high variance between samples within stations. The biomass distribution of all these species corresponds well with the negative binomial distribution, the parameter values giving indication of a high degree of contagion. It is possibly of significance that these small animals do not appear to have pelagic larvae and are not known to be pelagic as adults; that is, they have limited opportunity for dispersal.

D. L. Peer

Benthic Communities - St. Margaret's Bay

As part of the integrated marine production study of St. Margaret's Bay, quantitative benthic samples were taken at 15 stations in the bay during the summer (Fig. 19). The stations were arranged so as to sample as many sediment types as possible. Preliminary examination of the samples has shown several different associations of invertebrates to be present.

Special studies of distribution are being undertaken at two of the quantitative stations. At each station 25 samples were taken in groups of five. Groups were spaced approximately 60 ft apart, permitting a description of distribution within relatively small areas.

Using scuba equipment, an attempt was also made to investigate the size, shape, and volume of the samples taken by a 0.1 m^2 Van Veen grab. Ten samples were first taken on a mud bottom which was of a consistency similar to that on which the quantitative sampling was done. Due to the yawing of the vessel at her anchor only

three of these were found and as the grab landed on its side on one, accurate measurements were made on only two. Observations on the holes made by the Van Veen on this and other occasions showed them to be square in plan view with straight sides and flat bottoms of uniform depth.

D. L,. Peer

Biochemical Ecology

Since changes in enzyme activity can be associated with temperature acclimation, and gross changes in the activity of some enzymes are associated with gross metabolic disturbances, studies of the activities of two enzymes have been started to discover if variations in levels of the activities of these two enzymes can be correlated with the metabolic level of individual fish. The aim is to develop a technique of determining metabolic levels of populations in the field, and hence to avoid having to resort to dependence on oxygen consumption or carbon dioxide production measurements of individuals under simulated field conditions in the laboratory.

A relatively simple technique for measuring the activity of carbonic anhydrase, an enzyme in the red blood cells involved in carbon dioxide transport, has been established. Work on plaice blood has shown that the red blood cells have a high level of activity. However, there is an inhibitor of the enzyme present in the protein fraction of the serum. Blood samples that have been collected in the field have shown a high activity as have samples that have been sent from the Biological Station at St. Andrews, N.B., by Mr A. Tyler and Mr R. Dunn. There seems to be very little problem associated with bringing adequate field samples into the laboratory. Data on hematocrits and the blood cell counts of plaice have also been obtained.

To complement the carbonic anhydrase studies preliminary work has been started on the measurement of cytochrome oxidase activity in the heart muscles of fish.

Edward Kott

Fish Physiology and Behaviour

In preparation for studies on the growth rate in relation to feeding of marine fish, the caloric content of various bottom-living invertebrates forming their food was determined using a Parr adiabatic oxygen bomb calorimeter. Arthropods (3 species) had between 1,100-1,300 calories per gram live weight; annelids (9 species) 400-1,100 calories; molluscs (6 species) 400-800 calories; echinoderm starfish (2 species) 600 calories but sea cucumbers only 100-300 calories. Thus considerable variation is evident both within and between phyla. A significant difference was found between egg-bearing females and other adults in one of the species of shrimp tested. The results, besides allowing the caloris contents of various fish diets to be calculated, will be used in conjunction with the investigation of the abundance and distribution of bottom-dwelling invertebrates of St. Margaret's Bay to determine the total potential food available per unit area of mud and sandy bottom.

Vivien M. Brawn (Srivastava)

Fish Populations

The organization of plant and animal communities has been the subject of numerous studies, but relatively few of these concern fish populations. Many fish species form schools and aggregations, and observations indicate that these distributional patterns are of considerable ecological significance. The varying patterns may be the result of different environmental and social influences. Information about dispersal parameters in addition to other population parameters is necessary when interpreting fishery population dynamics.

Initial studies of the distribution and abundance of some fish species were started in St. Margaret's Bay in the summer of 1966 (Fig. 23). This bay has certain advantages for investigation on marine fish populations: it is relatively small and can be sampled in detail; yet is large enough to have selfsustaining fish stocks, different environments, and depths greater than 50 fathoms. Since the bay is closed to commercial trawling, groundfish stocks, especially flat-fish stocks, are almost unexploited.

A preliminary survey revealed that the American plaice *(Hippoglossoides plattessoides)* was predominant among the demersal species all over the bay, so this species became the main focus of the study. About 100 samples have been collected with a small flat-fish trawl operated from a chartered dragger. The samples will be analyzed in an attempt to describe the distribution of the plaice and will provide basic biological information about the stocks (size, age, growth, etc.). Two thousand plaice have been tagged in different

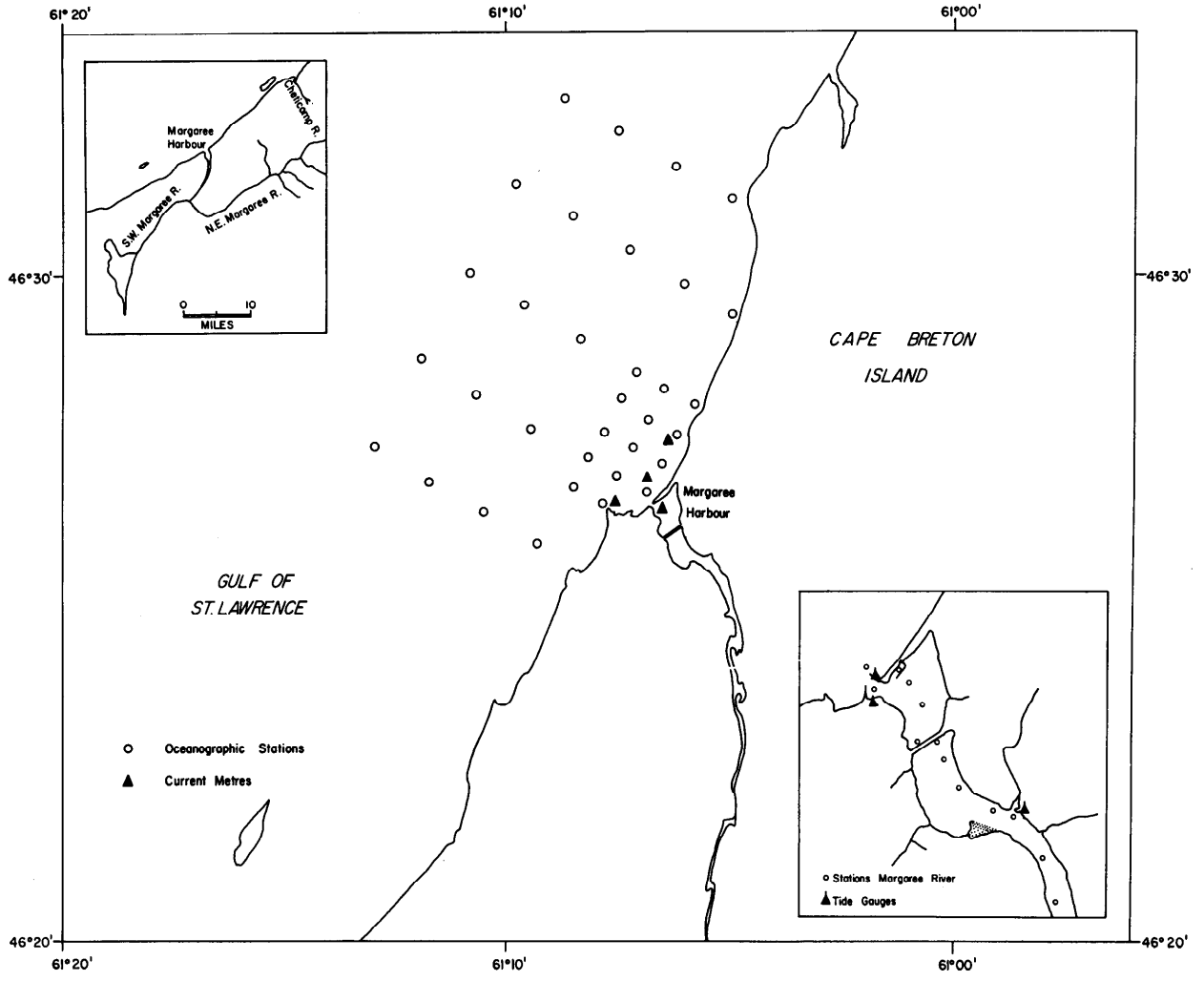


Fig. 23. Margaree Harbour and approaches.

parts of the bay (Fig. 19) in order to obtain data for estimation of the population size as well as indications of migrations.

Simultaneous studies carried out in the bay by other investigators will offer data on several environmental factors, such as fish food availability, physical and chemical properties of the water, and bottom characteristics. It is intended to examine their possible relation to the distribution patterns of the fish.

Erling Bakken

Fish Distributions and Fishing Success

Typically, the description of the success of a predator in its hunt for a prey or of a fishing vessel in its search for fish has assumed that the process of hunting or searching is similar to random sampling of a randomly distributed population. This leads to a Poisson frequency of catch, with the mean proportional to size of the exploited population. This has been the basis of models by Baranov (1918), Nicholson and Bailey (1935), Lotka (1925), Ricker (1940, 1944), etc. The probabilistic nature of the process has been considered by Neyman (1949), Koopman (1956), and Skellam (1958). Neyman extended the basic model by introducing a constant delay time for each successful catch made.

We have developed stochastic models of predator-prey relations allowing examination of the hunting or fishing success when the prey species is contagiously distributed. The contagious distributions considered include those which would result from direct clustering processes, or compound Poisson processes. In the case of clustering processes we have assumed that

cluster centres are randomly distributed but that the size and density of individuals in clusters varies.

In considering the catch from contagious distributions, explicit allowance has been made in the models for a number of variables, such as possible escape of prey and variable delay time due to the catching operation. The delay time may depend on the numbers of prey caught or the size of the cluster. The radius of perception of the predator may also be fixed or variable. The model thus allows many of the factors occurring in general predator-prey situations or in fishing operations to be studied either separately or in combination.

The distribution models considered have been two dimensional. This has permitted us to derive a relationship between the size and shape of the sample area and the frequency histogram of expected numbers caught. Thus for instance, theoretically, we can demonstrate why a negative binomial distribution graduates observation data at one sample size but not at another. Such models would also make it possible to infer from the sample, the spatial arrangements of prey in relation to their actual distribution.

The models clearly demonstrate the complexity of the prey-predator relationship. Only in the very simplest of situations would we expect to find the linear relationship between a catch and prey species abundance which has classically been assumed as typical. More commonly the catch to the predator will depend not only on its behaviour pattern but also on the distribution of prey. Depending on the interaction between the predator's behaviour and prey distribution, the schooling of prey can either increase or decrease the predator's catch or be advantageous or disadvantageous to the survival of prey. In the case of fisheries, schooling of fish is generally advantageous to the fisherman.

The theory suggests that maximum fishing efficiency of vessels will depend on the modification of fishing and searching strategy with given changes in the type of fish distributions. Practical application of the theory, however, requires better measures of fish distributions than are currently available.

J. E. Paloheimo

Instrumentation

During the past year the efforts of a newly formed Instrumentation Group have been devoted to acquiring and constructing essential specialized equipment, and developing a dialogue with other project groups so that effective use may be made of its technical resources and equipment.

The main project during the year has been the initial development of a Digital Echo-Counting system for fish population research. Although the group has also served as general consultant in electronics and acoustics problems. The usefulness of underwater television and specifications for transponder buoys are being investigated.

Digital echo-counting system.

A high-powered Echo-sounder with a narrow beam magneto-restrictive transducer has been purchased. This unit has been modified to give the higher resolution required for echo counting and fitted with special outputs for coupling into digital logic.

The transducer has been mounted in a towed body as it is becoming increasingly necessary, in view of the narrow acoustic beams being used, to stabilize its position in the water irrespective of the ships motion. The transducer can now be towed at a depth great enough to avoid the problem of air bubbles trapped under the ship in high seas. Using the Naval Research Establishment's Acoustic Barge, the transducer mounted in a towed body was acoustically calibrated. Directivity patterns were carried out in two planes, and source strength and receiving sensitivity were also measured. Preliminary towing trials have been carried out.

An important feature of the system for use with demersal fish species has been the design and incorporation of a bottom lock control and counter, constructed using digital modules and a passive delay line. The device uses the bottom echo as central reference, the echos then being counted from this reference point up to some predetermined height - generally the height of the net opening.

Two sea trials were carried out on board M/V *Cameron* this year. The first trial, on the

Scotian Shelf in June, was to check the digital bottom lock control unit and counter. During this trial, the ship's echo-sounder (with minor modifications) and ship's transducer were used. The second trial, in the Gulf of St. Lawrence in December, used our modified transmitter and receiver with the digital control unit, but also used the ship's transducer.

These trials consisted of simultaneous echo-counting and trawling. The fish caught in the net were later visually counted. Under satisfactory conditions - that is, with no air being trapped under the ship due to sea state and ship course, and with the trawl following the ship - good correlation was obtained between catch and count.

Oceanographic instrumentation for *in situ* salinity measurements

A program has been initiated to develop improved instruments for sensing and recording temperature and salinity *in situ*. The long-range objective is to develop self-contained recording packages that can be moored and left unattended for several weeks. The first phase of the program, however, is to concentrate on instruments for use on board ship. BIO has recently acquired a German Bathysonde unit which is currently undergoing field trials. Assistance with field evaluation was also given to the National Research Council, who have under development, a temperature-salinity-pressure recorder.

S. Paulowich
R. G. Dowd
J. P. Budlong

ToC

Studies in Physical Oceanography

Margaree Harbour

The physical oceanographic studies of Margaree Harbour and approaches begun in 1964 were continued in 1966. Field observations commenced in May and continued until the end of September. The two tide gauges operated in 1965 were re-established in 1966. A third gauge was installed just inside the breakwater. Braincon current meters and temperature recorders attached to aluminum quadrapods and positioned at four locations (Fig. 23) were established in May. It was hoped that these would be kept operational throughout the period, but, the program was severely interrupted in July when a brief intense storm carried away the three outside quadrapods with current meters and temperature recorders. After an extensive search, employing scuba divers, only part of the remains from one site were found. One current meter from this installation was recovered. The program was continued, emphasizing studies of the temperature-salinity distribution, but no attempt was made to re-establish the quadrapods. Over the period of survey approximately 300 meter-days of current records were obtained. This constitutes a 75% successful performance.

The 14-station network of observations established in 1965 was monitored throughout the 1966 period. In addition, two station grids (23 and 14 stations in each) were established in the approach area to the Harbour (Fig. 23). The larger grid was occupied only in May and September. The smaller grid was occupied intermittently throughout the period.

An EMF recorder was installed across the mouth of the river and was operated intermittently during the summer. Difficulty was experienced in obtaining good records, due to the polarization of the electrodes. Replacement of the electrodes provided only temporary improvement.

The Cheticamp Estuary was again surveyed, although most of the observations were carried out only in May and September. It had been observed in 1965 that the river mouth was sealed off as a result of storm action. This phenomenon was repeated in 1966. Temperature and salinity were measured at a grid of 16 stations off the mouth of the river on a number of occasions.

Rhodamine-B dye experiments were carried out near the mouth of both the Margaree and Cheticamp Estuaries, in May and September. In May, it was difficult to track the dye for more than a few hours, as the water moved quickly out of the area and dispersed rapidly. On most occasions the dye moved northeastward from the mouth of the estuaries. The pattern of flow appeared, generally speaking, similar during September, when fresh water discharge was at a relatively low level, but the bulk motion and the diffusion rate were considerably reduced from those observed in the spring period.

R. W. Trites

St. Margaret's Bay

Limited studies were initiated in St. Margaret's Bay in June and July, as background to

an anticipated large-scale multi-discipline study of marine production processes. The physical oceanographic program consisted primarily of current measurements near the mouth of the Bay (Fig. 19). Seven current meters were installed at five sites for approximately 29 days. A total of 161 meter-days of current records were obtained out of a possible maximum of 196. In July, 144 sea bed drifters were released at 48 stations. To date, only 3 have been returned. An RS-5 portable salinometer was used several times to measure temperature and salinity at 13 stations (Fig. 19). Tide gauges were established at three locations in June, but the record from two of these is of relatively poor quality.

In July, Dr E. R. Baylor from Woods Hole Oceanographic Institution carried out a 2-week program of studies that consisted primarily of towing a continuous plankton and temperature recorder. An attempt was made to relate the observed plankton and temperature patterns to the surface wind and water motions. Aerial photography from a helicopter, of smoke floats, aluminium powder, and Rhodamine--B dye, was employed to observe the wind and water motions. Fairly regular temperature fluctuations as much as 1° to 2°C over 5-10 m horizontal distances were observed at times.

From the preliminary observations taken in 1966 a more comprehensive program will be planned for 1967.

R. W. Trites

Cabot Strait

The study of circulation, dynamics, and distribution of properties in the Gulf of St. Lawrence was confined, in 1966, to the Cabot Strait area. Field studies, using two ships, were carried out in August and September. Nineteen Braincon and three Plessey current meters were installed at eight sites in the Strait. From the 22 meters recovered, a total of 440 meter-days of current records were obtained. Temperature and salinity were observed at a total of 95 stations. A section across the Strait was occupied six times; in addition two sections on parallel lines 30 miles to the east and west were occupied twice. Parachute drogues set at 6, 75, and 325 metres were also tracked through the Strait.

A more complete description of this survey is contained in the Applied Oceanographic Section of the MSB Annual Report (p. 34).

R. W. Trites

Sea Water Chemistry

Sea water is a concentrated electrolytic solution, and it is of interest to study how its behaviour differs from that of more ideal dilute solutions. A great many of the fundamental physico-chemical constants in sea water are either unknown or not known as accurately as desired. For example. the pressure and temperature coefficients of a specific volume are not known accurately enough for good sound velocity measurements even though the specific volume itself is quite accurately known. It is planned to measure several of these quantities in natural and artificial sea waters.

Vapor pressure measurements to determine activity coefficients in a simple synthetic sea water composed of 0.52 m NaCl + 0.05 m $MgSO_4$ are complete. The activity coefficients derived at 25° C for the three components are:

Component	Activity Coefficient
H_20	0.982
NaCl	0.66
$MgSO_4$	0.13

The system now under study (H_2O-NaCl-$MgS0_4$) is another ternary system containing the chemically interesting magnesium ion.

The partial molar volumes of the major salts in sea water have been determined. This information can be used by oceanographers to construct a density model for sea water, and it will lead to a better understanding of the physical chemistry of sea water. No information is available on the partial molar volume of certain non-conservative salts such as calcium carbonate, sodium silicate and calcium phosphate. A dilatometer is being constructed to make these measurements. The information from this study will be useful to the geologist as well as to the oceanographer, since he will be able to calculate the effect of pressure on water-mineral equilibrium constants.

A lower limit for transport processes in the oceans can be established if the diffusion coefficients of solutes in sea water can be measured. In addition, diffusion measurements give information about the basic behaviour of ions moving in the electrical field created by other ions. An apparatus has been set up and is now being calibrated to measure, by the porous-frit method, the diffusion of salts in sea water.

A survey has been started in conjunction with the marine production studies of St. Margaret's Bay to determine the largely unknown physical and chemical features of the water in the Bay. From 17 to 21 October 1966, a preliminary survey of the Bay was made. The following properties were determined: salinity, temperature, density, total alkalinity, pH, total carbon dioxide, and calcium carbonate saturation. The results of this survey are being analyzed.

R. F. Platford
I. W. Duedall

Geological and Geochemical Investigations of Marine Sediments in the Gulf of St. Lawrence

Geological investigations

The first part of the study of the sedimentology and submarine topography of the southern Gulf (Magdalen Shelf) has been completed and published. This investigation, which synthesized results from acoustical, underwater photographic and bottom sampling data, revealed that sandstone bedrock with an intermittent veneer of sediments occurs on the sea floor between PEI and the Magdalen Islands as well as to the north of the Magdalens. In contrast, the sea floor west and east of the Magdalens has an almost continuous sediment cover with only small exposures of bedrock. These sediments are considered to be mainly the erosional products of the bedrock locally intermixed with material foreign to the shelf area. It was also found that the major geomorphological features of the shelf are not related to present environmental conditions. Instead, the shelf shows the effects of extensive Pleistocene glaciation in the configuration of its submarine troughs, the occurrence of tunnel valleys, and in the composition of its sands and gravels.

Further detailed investigations were undertaken in 1966 on board CNAV *Sackville* and CSS *Kapuskasing* in the northwestern part of the shelf, along the edge of the Laurentian Channel, and in the Cape Breton trough. These cruises have provided us with bottom samples (~800), core samples (~50) up to 40 ft in length, and Sparker records (~300 nautical miles) of the subsurface structure in selected parts of the shelf. The data are being processed to further the study of the interrelationship between submarine topography, sediment distribution sources, present processes of deposition, and depositional history of the area. The Marine Geology Section of BIO lent us the deep coring apparatus and Sparker system for these operations.

Geochemical studies

Geochemical studies of marine sediments in the Gulf of St. Lawrence were continued in 1966. It was possible to expand the type and number of investigations this year by the use of atomic absorption techniques. The study of the distribution and significance of calcium carbonate ($CaCO_3$) in the Gulf sediments was completed and investigations were made of the contribution of the different particle-size fractions to the major element contents in sediments from the estuary, the geochemistry of sands from all over the Gulf, and the distribution and significance of "free iron" in sediments from selected areas. In addition, some short-term investigations on various materials were undertaken for the Nova Scotia Department of Mines and the Newfoundland Department of Fisheries.

Calcium Carbonate in Marine Sediments of the Gulf of St. Lawrence

Completion of carbonate analyses of over 400 samples provided a good picture of the distribution and significance of $CaCO_3$ in the marine sediments from the river and Gulf of St. Lawrence.

It was found that sediments in the river, estuary and southern Gulf contain less than 5% by weight $CaCO_3$ while sediments in the Laurentian Channel Jacques Cartier Passage and northeastern part of the Gulf contain between 5 and 30% carbonate. Sediments in the near-shore environs of Anticosti Island and at the southern end of the Strait of Belle Isle were found to have carbonate contents in excess of 30%. A study of these regional distribution patterns and the carbonate mineralogy shows that shell detritus is the main source of carbonate in sediments containing less than 5% $CaCO_3$, while those containing higher concentrations contain limestone detritus in addition to shell fragments and calcareous foraminifera. Limestone debris and detritus in the Gulf have been and are being derived from limestone bedrock on Anticostic Island, the Mingan Islands and the submerged reefs around these islands, as well as from the calcareous rocks on the sea floor between Labrador and Newfoundland. Since the calcareous material decreases in concentration away from these sources in a definite pattern, it has been possible to relate the patterns to the effects of present depositional conditions such as

ice-rafting and past environmental conditions such as glaciation in the Gulf. In addition, it has been possible to map the distribution of limestone bedrock on the sea floor around Anticosti Island and in the northeastern part of the Gulf from the results of carbonate content studies of the samples. This study has also shown that carbonate in the sediments is not related to the shell contents (fragments greater than 2 mm) of the sediment and that only two areas of the Gulf are prolific in calcareous foraminifera. Further study of these features of the carbonate distribution is contemplated.

Major element distribution in size fractions

The study of the distribution of major elements (Si, Al, Ca, Mg, Na, K, Mn, Fe, and P) in various size fractions of sediments from the estuary of the St. Lawrence provided definite confirmation of the constancy of the chemical mineralogical composition of each size fraction, and the chemical immaturity and crystalline source of these sediments. These results had been suggested from our previous study of the gross chemical mineralogical composition of sediments from this area.

Geochemistry of sands in the Gulf - Initial investigations of the chemical composition of sands from all over the Gulf shows that the distribution of the major elements can be used as a sensitive indicator of mineralogical variation within the Gulf sediments. At least four distinct chemical-mineralogical associations and their interrelationships have been identified so far in the Gulf sands with each association being diagnostic of its provenance and its past and present depositional history.

"Free" iron in Gulf sediments -- Investigations of "free iron", that is, amorphous iron compounds and secondary and primary iron oxides, in sediments from the Gulf were initiated as a basis for understanding the nature of physical-chemical exchanges at the sediment-water interface. Of immediate interest are the occurrence and formation of amorphous iron compounds and crystalline iron oxides associated with sediments at the sediment-water interface and the dissolution of iron oxide grain coatings in recently deposited sands.

So far it appears that selective chemical treatment results in the dissolution of amorphous and crystalline iron compounds and their associated trace elements to the extent of 5-10% of the sediment by weight, and that 20-70% of the total Fe and Mn in the sediments is contained in this fraction. The results also suggest an affinity with the extractable iron compounds of other metallic cations such as Cu, Co, Ni, Cr, and V. It seems from our preliminary work that the retention and mobilization of many of the metallic cations at the sediment-water interface is directly related to the formation and dissolution of these iron compounds under the present physical-chemical conditions. Further work is being done to evaluate these processes.

D. H. Loring