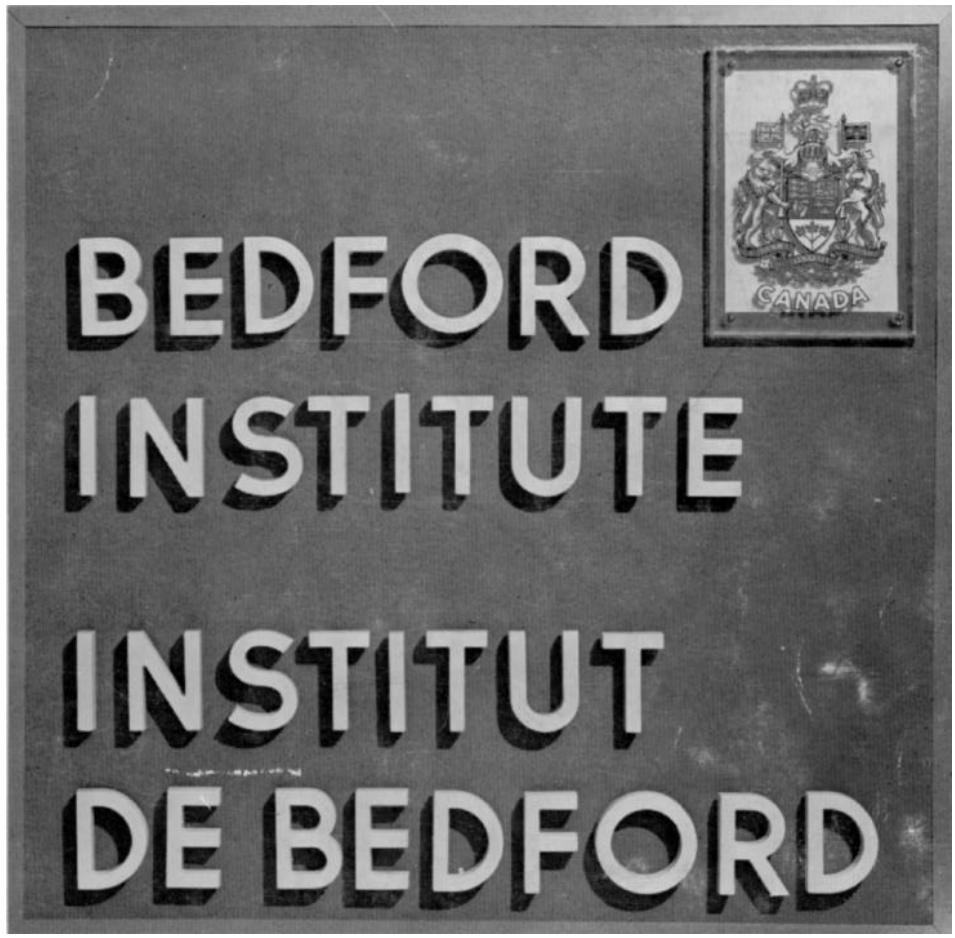


BIENNIAL REVIEW
1967 - 1968

BEDFORD INSTITUTE

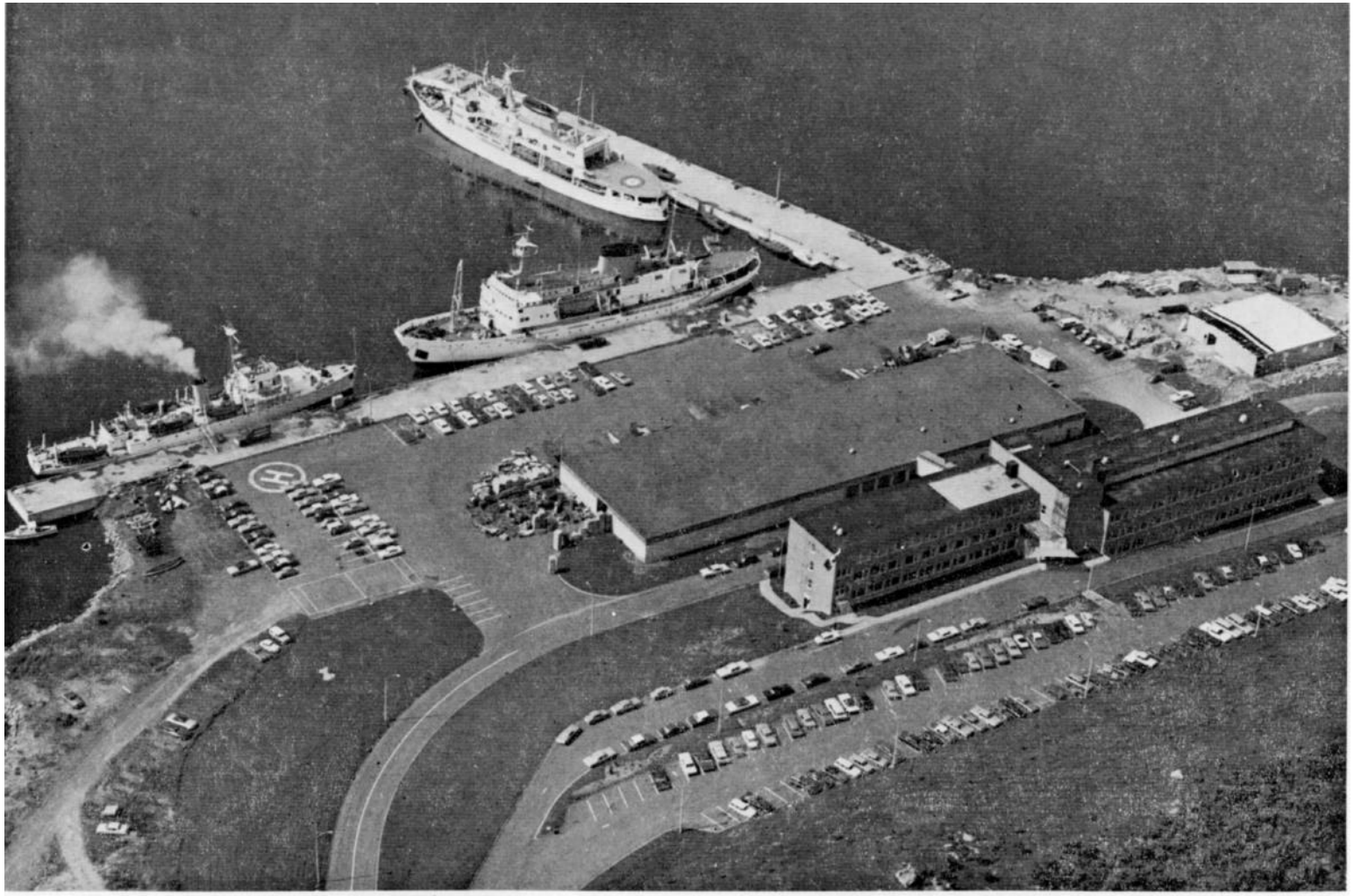
Dartmouth, N. S.

Biennial Review

1967 - 1968

Part A — Atlantic Oceanographic Laboratory,
Marine Sciences Branch,
Department of Energy, Mines and Resources

Part B — Marine Ecology Laboratory,
Fisheries Research Board of Canada



The Bedford Institute

Foreword

On February 1, 1968, the term Bedford Institute of Oceanography became simply Bedford Institute and two new titles were introduced to identify (unambiguously) the two major elements of the Institute.

The resulting formal organizational designations are :

Department of Energy, Mines & Resources
Marine Sciences Branch,
Atlantic Oceanographic Laboratory
Bedford Institute,
Dartmouth, N. S.

Fisheries Research Board of Canada,
Marine Ecology Laboratory
Bedford Institute,
Dartmouth, N. S.

The short forms are:

Atlantic Oceanographic Laboratory
Bedford Institute
Dartmouth, N. S. (AOL)

Marine Ecology Laboratory
Bedford Institute
Dartmouth, N. S. (MEL)

While the title "Bedford Institute of Oceanography" was originally the official designation of the Marine Sciences Branch, DEMR component only, it acquired over the years a national and international usage descriptive of the total activity of the Institute regardless of affiliations of the components. Everyone concerned agreed on the desirability of maintaining and strengthening the reputation implicit in this usage and further developing the concept of the Institute as an interdisciplinary, interagency centre of marine research. It is felt that the new name safeguards these objectives while eliminating the ambiguity resulting from the dual meaning of the old title.

From the inception of the Institute in 1962 up to and including 1966, it was the practice to issue a joint annual report. This is now replaced with a biennial review of progress of which the present document covering the years 1967 and 1968, is the first. A 2 year cycle is seen as being sufficiently frequent to provide a broad review of activities for general distribution. Specialized annual reports to meet specific agency requirements are also being produced as required.

In our 1966 report we commented on the rapidly developing need for additional accommodation to relieve overcrowding and to provide for certain specialized facilities. Since then considerable progress has been made toward meeting these needs. The Fisheries Research Board built a live fish-holding laboratory for MEL. It is a building of 5,000 sq ft serviced with a continuous flow of temperature-regulated fresh and sea water. This facility, completed early in 1968, has enabled those concerned with studies of the ecological physiology of fish to develop more effective research programs. MEL also took delivery of six 50 ft "trailers" outfitted as laboratories, five of which are in service at the Institute to relieve overcrowding in the main building. The sixth is in use as a laboratory at the field station established at St. Margaret's Bay, N. S. to support a continuing ecological study of the Bay. Also at this site a jetty was constructed to provide berthing for the small vessels employed on the study. Construction got underway early in 1968 on the first two phases of the AOL expansion program. One of these phases, the jetty extension, which was completed in August 1968, provides sheltered berthing for launches and small research vessels at the Institute. The second phase, the laboratory wing extension, is nearing completion; it will provide a much needed 50% addition to the present laboratory space in the Institute. These MEL and AOL construction projects involve a total capital expenditure of

$1,130,000. Planning for the third phase, expansion of the office wing, is well advanced and construction is expected to begin early next year.

The staff of the Institute has continued to grow at a reasonably healthy rate in overall numbers; some relevant statistics are given in the following table:

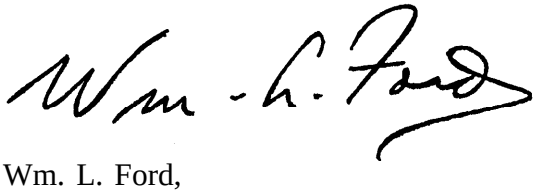
Growth of Staff in Bedford Institute

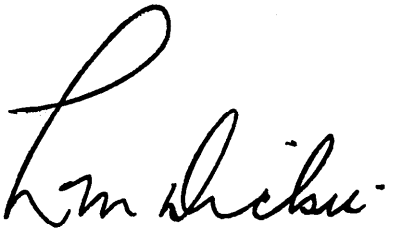
	AOL	MEL	ICNAF	Others*	Lab Total	AOL Shins	Grand Total	Remarks
Dec. 1962	94	15	-	3	112	237	349	Lab occupied in July '62.
Dec. 1963	134	15	6	5	160	300	460	*Hudson* commissioned.
Dec. 1964	158	15	6	8	187	300	487	
Dec. 1965	212	25	6	12	255	307	562	
Dec. 1966	239	37	6	14	296	314	610	
Dec. 1967	258	43	6	6	313	305	618	
Oct. 1968	287	52	6	7	352	334	686	*Dawson* commissioned.

* Comprising staff of purchasing agent and other EMR personnel.

During the past 2 years the Institute was host to many hundreds of visitors from the scientific community, the business world, the government and the general public. From among the many distinguished persons it was our privilege to host, it is possible to single out but a few. We were especially honoured by the visit of His Excellency The Right Honourable Roland Michener, Governor-General of Canada, on October 1, 1968. Other visitors included Dr O. M. Solandt, Chairman of the Science Council of Canada and 27 members of the Council, November 1967; Mr A. A. Ischkov, Minister of the USSR, and a pasty of 6 from the Ministry of Fisheries of the USSR, including Dr A. S. Bogdanov, Director, All-Union Research Institute of Marine Fisheries and Oceanography (VNIRO) and Dr S. A. Studenetsky, Director, Atlantic Research Institute of Marine Fisheries and Oceanography (Atlant-NIRO), accompanied by Mr E. G. Young representing the Minister of Fisheries for Canada, and a party of other representatives of the Department, September 1967; The Honourable Jean-Luc Pepin, then Minister of Energy, Mines and Resources and the Honourable Robert L. Stanfield, then Premier of Nova Scotia, April 1967; Dr Hely G. Neuymin of the Marine Hydrophysical Institute of the Ukrainian Academy of Sciences, Sevastapol and some 40 scientific staff from *RN Lomonosov* in July 1968, when this noted Russian research ship paid a, visit to Halifax.

The Institute, while only now in its sixth year, has made real progress toward achieving the goal of being a strong and productive centre for oceanographic research. We believe it is thus contributing, along with our sister organizations in the area, to the development of a regional community of excellence in the marine sciences. The following reports provide details of progress in the main programs of the Institute during 1967 and 1968.





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

L. M. Dickie,
Director, MEL,
Fisheries Research Board of Canada.

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

Part B-Marine Ecology Laboratory, Fisheries Research Board of Canada

Part A

The Biennial Review for 1967 and 1968
of the Atlantic Region,
Marine Sciences Branch,
Department of Energy, Mines and Resources

In Memoriam

It is with sorrow that we report the sudden and untimely death from heart failure of Captain W. N. Kettle on April 6, 1969. Captain Kettle was born in 1918 in Newfoundland and his love for, and understanding of, the sea was outstanding even for a native of that province. His career at sea started when he was 14, and by the time he was 20 he was Captain of a fishing vessel. During the war he served with distinction in the RCN, returning to the Canadian Merchant Marine at the end of hostilities. He joined the Department in 1949, initially as First Officer on *CSS Acadia* ; he served for 5 years as Master of the *Acadia*, and was appointed Master of *CSS Baffin* in 1958. Since 1966 he has been Master of *CSS Hudson.*

Captain Kettle will be sorely missed by us all. His was a career of which to be proud and which commanded respect and admiration. He made very great contributions to the work of the Canadian Hydrographic Service and latterly to oceanographic research in general. Not only did he command his ship with great ability and act as a firm but kindly father to all aboard, but he could handle a ship superbly and was always on hand when any particularly difficult operation was taking place. He was always extremely interested in the scientific or survey work being carried out from his ship and his enthusiasm infected the rest of the ship's company, creating an atmosphere which was noted with envy by many visiting scientists who took part in cruises with him.

The traditions which he established in the fleet will endure for many years to come, and these perhaps form his finest memorial; he will forever be remembered as an outstanding Captain.

Part A

The Biennial Review for 1967 and 1968 of the Atlantic Region, Marine Sciences Branch, Department of Energy, Mines and Resources

Director's Remarks

Two years ago, by an Act of Parliament, the Department of Energy, Mines and Resources was given its present name and was assigned several functions related to natural resources, chief among these being in the realms of water and energy. In addition, its terms of reference were restated to clarify ambiguities and to place on a firmer base the functions carried over from the old organization. The following excerpts from the Act are relevant here; "Subject to . . . matters . . . over which the Parliament of Canada has jurisdiction, the Minister (of Energy, Mines and Resources) shall be responsible for coordinating, promoting and recommending national policies and programs with respect to energy, mines and minerals, water and other resources, and in carrying out his responsibilities under this section the Minister may conduct applied and basic research programs and investigations and economic studies in relation to such resources, and for that purpose maintain and operate research institutes, laboratories, observatories and other facilities for exploration and research related to the source, origin, properties, development or use of such resources."

Passage of the new Act was accompanied by a major reorganization of the Department, by which the various branches, old and new, were grouped into four functionally distinct sectors. One of these is the Water Sector, which has broad responsibilities in the realms of inland waters and marine environment. The latter is, of course, the concern of the Marine Sciences Branch (MSB) and hence of the Atlantic Oceanographic Laboratory, Bedford Institute (AOL).

Under the federal government's responsibility to provide essential and common services to marine transportation and to explore and describe the mineral resources of the Canadian continental shelves, MSB is charged with providing navigational charts, tidal information, and with carrying out marine resource research and surveys. It is also responsible for undertaking research in physical and chemical oceanography and for providing oceanographic information to those agencies whose responsibilities involve and are influenced by marine conditions - including defence, fisheries, transportation, and coastal engineering. These services are provided under the coordinating aegis of the Canadian Committee on Oceanography, upon which are represented all federal agencies (eight) concerned with the field and four university institutes of oceanography. In this cooperative system MSB provides the use of its research vessels by personnel of other agencies, and itself makes use of specialized vessels of other agencies as opportunity permits.

AOL, as the most fully developed of the three regional units of MSB, is engaged in a spectrum of activities representative of almost every element of the MSB program. These activities are discussed in the investigators' reports which form the body of the Review. As a means of presenting something of a cross-sectional view of the scope, direction, and accomplishments of AOL a few activities have been selected for discussion here.

It is a truism to say that major advances in the quantitative description of the physical processes involved in all forms of energy exchange through the air-sea interface would be of great importance to progress in both physical oceanography and meteorology. An air-sea interaction project was begun some years ago in AOL with the selection of one particular aspect of the field, i.e. the precise determination of momentum flux by the measurement of the horizontal and vertical fluctuations of the wind over the open sea. By late 1966 the basis of an experimental system, including a stable platform, had been developed and tested in relatively sheltered locations. However, the experiment requires

that observations be made in a location exposed to the open ocean. The stable platform was placed in such a location in 1967, some 2 miles offshore near the approaches to Halifax Harbour. It performed as designed and withstood the elements for a full year. Wind stress measurements began in April 1968 and continued as wind conditions dictated until mid-October, when the platform had to be removed to avoid interference with seasonal fishery. Excellent data were obtained over the range of wind speeds experienced, but unfortunately the latter did not exceed 20 mph from a seaward direction during the entire period. With the re-installation of the platform at another location in the near future, it is hoped to attain the primary objective of comprehensive wind stress data at wind speeds up to storm force. At the same time measurements of heat flux will be initiated.

The formidable character and quantities of sea ice in eastern and northern Canadian waters is a. fact of life for the national economy which is demanding increasing attention. Basic to progress on the problem is an improved understanding of the behaviour and properties of this ice. The Frozen Sea Research Group of AOL is studying the physics of the growth and decay of polar sea ice and the related processes in the sea water beneath. The 1968 winter field operation at Cambridge Bay was considered particularly successful. Among the accomplishments the detailed examination of a 6-ton section extracted from the Bay ice was especially rewarding in providing new data on the pattern of brine drainage channels and on the process of salt rejection. These observations provide a basis for a new look at the little understood dynamics of brine-induced convection in the water column beneath the ice.

The investigation of fundamental physical processes occurring in the sea, the central concern of the ocean circulation group, has strengthened and broadened considerably in the past 2 years. While the synoptic approach to problems such as the current system in the St. Lawrence estuary or the mechanism of formation and rate of production of the deep waters of the North Atlantic continues to occupy much of the effort of the group, an increasing amount of attention is being paid to time-dependent processes, that is to say, the problems of variability in the ocean. These are the subjects of theoretical and numerical model studies, laboratory scale experiments, and full scale observations in the sea by moored buoy systems. The conviction is growing that the key to the quantitative description of important physical processes in the sea not presently understood lies in the development of practical methods of observing and analyzing time-dependent processes guided by meaningful theoretical models. Sound progress has been made in several facets of this broad program and is summarized in the main text.

Nearly 3 years ago the Applied Oceanography Section was established as a joint undertaking of AOL and MEL in which personnel and resources from both organizations were pooled under single leadership. The experiment has worked well -the Section has about doubled in size and the demands on its services have grown even faster. Its activities are reported upon in both parts of this Biennial Review depending upon whether the projects in question are sponsored by AOL or MEL. It has become the central authority in the Institute for the development and evaluation of moored oceanographic buoy systems and is one of the primary users of buoys for the maintenance of standard oceanographic stations and the direct measurement of currents in the coastal and shelf waters of the eastern seaboard of Canada. Increased effort has been devoted to applied research projects undertaken to solve specific problems raised by other agencies of government and by industry. Two of these are pollution problems; one in Pictou Harbour arising from the construction of a causeway and a large pulp mill at that site, the other in the Canso area of Cape Breton Island where again a causeway together with the impact of a pulp mill, an oil refinery, a heavy water plant, and a thermal powered electricity generating station has raised the question of water pollution control.

The program of the hydrographers of the Canadian Hydrographic Service in AOL encompassed a large number of projects, big and small, ranging from the charting of Lake Kejimkujik in the newly-established national park of that name located in southwestern Nova Scotia, through major surveys on the Grand Banks and in the Gulf of St. Lawrence, to the reconnaissance of uncharted inlets along the east coast of Baffin Island. A sampling of survey statistics for the 2 years show 58,300 nautical miles of soundings resulting in an area surveyed of 56,000 sq. nautical miles; 5,318

shoals examined and 4,539 bottom samples recovered. The latter are analyzed by marine geologists and contribute significantly to the geological exploration of the continental shelf. Special surveys in support of industrial or commercial developments have been a feature of the work over the years; in 1967 and 1968 12 such projects were undertaken, similar to the number completed in the previous 2 years. An important development in this review period is the progress made in the integration of hydrographic and geophysical surveys of offshore areas to obtain the economies of operation resulting from the one ship performing the two functions simultaneously; it is likely that geophysical surveys, as distinct from research, will eventually be incorporated in the functions of the Hydrographic Service. The CSS *Baffin*, our major offshore hydrographic survey ship, was outfitted in 1967 with a gravity meter, towed magnetometer and the data monitoring and on-line processing system Geodal, and performed a joint hydrographic/geophysical cruise in which 33,000 sq nautical miles of the Grand Banks was surveyed. This was followed in 1968 by a similar undertaking in the Gulf of St. Lawrence where the gravity and magnetic anomalies and bathymetry in an area of 14,000 sq nautical miles were mapped.

The Geophysics group has collected, in the past 2 years, an immense amount of geophysical data as well as having made strides in the development of equipment and data handling systems. The main field efforts were centered on the Gulf of St. Lawrence, the Grand Banks, and Flemish Cap, in continuation of the program of geophysical exploration and mapping of the continental shelf and margin of eastern Canada. These are the surveys mentioned above undertaken jointly with the hydrographers. From among the geophysical features delineated thus far, attention is drawn to the marked contrasts between the gravity and magnetic maps for the Gulf region and the Grand Banks. The group also organized and conducted a major cruise in 1968, the third in a long term continuing project, Hudson Geotraverse, to study the structure beneath the Atlantic Ocean in a one-degree wide strip, 45° to 46°N, from Cape Breton Island, across the Tail of the Banks to the eastern flank of the Mid-Atlantic Ridge. The traverse crosses most of the major oceanic provinces and it is believed that systematic interdisciplinary investigation of it by the most advanced techniques available is a practical and promising way of attaining the ultimate objectives of the project - to understand the deep-seated processes presently active under the mid-oceanic ridge system, the formation of the deep ocean floor, and the interaction of the oceanic and continental crust at the margin.

Of all the disciplines represented in the program of AOL, that of marine geology is probably presented the greatest challenge and opportunity by the Arctic and Atlantic continental shelves of Canada. This immense area, of about 1 million sq. miles, is as yet only superficially investigated but undoubtedly contains resources of great potential value. For the past several years reconnaissance investigations involving the techniques of physical geology, micropaleontology, and geochemistry have ranged far and wide over the entire region. With these studies as a basis upon which to build and with more enquiries coming from industry for information about specific areas, there has been a shift to more intensive investigation of particular regions such as the Scotian Shelf and the Grand Banks. The recent upsurge of interest in oil exploration in the Arctic and the continuing interest in Hudson Bay and along the Labrador coast as well as in the structures off eastern Canada, suggests that the demand for geological data about the continental shelves will soon exceed the capacity of centres such as AOL to meet it, if indeed, such is not already the case.

These brief comments on selected aspects of AOL's activities taken together with the more comprehensive coverage in the following investigators' reports, present a program the central focus of which is applied research and survey, backed-up by the innovation and stimulus of vigorous research, instrument development and evaluation.

Wm. L. Ford,
Director.

Oceanographic Research

The Oceanographic Research Section consists of five groups who carry out research in a number of fields and study the properties of the ocean and its boundaries. The Ocean Circulation, Marine Geophysics, Air-Sea Interaction, Chemistry and Radiochemistry groups are located at the Bedford Institute, while the Frozen Sea Research Group operates from Esquimalt, B. C., where it shares some specialized facilities with the Arctic Acoustics Group of the Defence Research Establishment Pacific.

During the period covered by this report, two research scientists left the Section for duties with other units of the Department. Dr L. A. E. Doe accepted a position as scientific advisor to the Assistant Deputy Minister (Mines and Geosciences) and Dr R. R. Weiler joined the staff of the Canada Centre for Inland Waters. Two members of the staff completed requirements for the Ph.D degree: W. D. Forrester from the Department of Oceanography, Johns Hopkins University; and Charles Quon from the Department of Applied Mathematics and Theoretical Physics, Cambridge University.

Five research scientists and three scientific officers have joined the staff. Dr D. M. Garner from New Zealand, Dr E. M. Levy from the Defence Research Establishment Atlantic, and Dr E. R. Walker from the Meteorological Branch have had considerable post-doctoral research experience. Dr J. M. Bewers joined the staff here after completing his Ph.D. at Exeter University, and Dr R. T. Haworth joined after completing his Ph.D. at Cambridge University. R. A. Lake, J. M. Woodside and G. J. Pearson joined after completing M.Sc. requirements at University of Washington, Massachusetts Institute of Technology, and Queen's University, respectively. An additional research scientist will join the staff after he has completed his Ph.D. requirements.

The major projects of the individual research groups are described in the following reports.

C. D. Maunsell

Air-Sea Interaction

R. G. Stevens

G. E. Awalt
J. A. Dimmers[2]
L. A. E. Doe[2]
W. W. Hall
D. L. Hendsbee
R. H. Loucks
S. D. Smith
R. G. Tippett[2]
B. Trudel

The period covered by this report has been marked by a number of personnel changes. L. A. E. Doe resumed active leadership of the group in the autumn of 1966 and relinquished it again in the autumn of 1967 to accept an assignment in Ottawa. Since that time R. G. Stevens has been acting as Head of the Air-Sea Interaction Group. During the summer of 1967 R. G. Tippett left the group and the Institute to return to university. In September W. W. Hall joined the group as an instrument machinist. In October 1967 D. L. Hendsbee joined the group as a replacement for Mr Tippett. Later that month J. A. Dimmers left to accept employment with R.C.A. in Montreal.

The sole important source of energy which makes life possible on earth is, of course, the sun. Of the radiant energy reaching the top of the atmosphere, part is reflected back into space and part is absorbed directly by the atmosphere: but the larger part is absorbed in the form of heat at the earth's surface. Eventually all but a tiny fraction of this incoming energy will be lost into space in the form of long wave infra red radiation. In the meantime, however, the energy goes through several complex transformations producing, in the process, wind, rain and snow, ocean waves and currents; all of the interesting dynamical processes which we study in oceanography and meterology. Although many of these processes are extremely subtle and not well understood, it is evident that water plays a central role in maintaining the world's climate and weather. First, the water in the oceans acts as a vast heat reservoir tending to stabilize climate. Furthermore, evaporation and condensation of water is the major source of energy within the atmosphere. And of course life itself is sustained on the land because of the precip-

[2] Left AOL

itation of water. Since the ocean is the primary source of water vapor this fact alone would compel the study of interaction between the air and the sea but other processes such as the interchange of sensible heat, momentum and gases are also of importance.

Because of the complexity and vast amount of observational data required for the study of air-sea interaction, it has only been during the 20th century that a serious attempt has been made to explore the subject. Although the work of the past few decades has contributed significant insights into the global workings of the complex thermodynamic machine constituted by the ocean and the atmosphere, it has only been during the last few years that the technology necessary to conduct a detailed study into the energy exchange processes between the two media has been available.

The approach adopted by the Air-Sea Interaction Group is to apply these technological advances to the experimental determination of how much and by what means energy is transferred between the air and the sea. The processes of major concern are the exchange of heat - in its sensible form and as the latent heat of evaporation, primarily from the ocean to the atmosphere - and the transfer of mechanical energy from the wind to the sea surface. Since the wind plays a dominant role in the transfer of heat and water vapor as well as being the source of mechanical energy which generates waves and drives currents in the sea, the first experiments deal directly with the measurement of wind. In future the technique and instruments developed for these experiments can be applied directly to the measurement of heat and water vapor exchange.

It can be confidently expected that the results of these experiments will have important implications for meteorology as well as oceanography. Their direct application includes the determination of important parameters necessary for improved and longer range weather forcasting, the prediction of ocean waves, and the forecasting of ice formation and movement in enclosed bodies of water.

Several factors combine to make the experimental investigation of air-sea interaction processes an unusually difficult one. To begin with, the surface of the sea is never still, and the oceans are very deep. Thus it is no easy matter to place instruments, fixed in space, near the air-sea boundary. This problem is further compounded by the fact that any solid obstruction which interferes with the flow of air or circulation of the water can seriously affect the measurement of energy exchange processes. Secondly, the relevant quantities to be measured are small fluctuations of wind speed, temperature and so on which require the use of precise and delicate instruments in an environment which may become extremely violent.

One of the most stringent technical requirements for air-sea interaction studies is that several time-dependent variables must be measured simultaneously. Some of the quantities to be studied are vectors or tensors - the wind, for example, is a three component vector. Some experiments require that differences over spatial intervals be observed, such as the gradient of temperature. In other cases the correlation between two or more distinctly different quantities must be observed. Finally, the actual quantities of physical interest almost invariably require that two or more of the observed quantities be combined and their time averages calculated.

The first task of the Air-Sea Interaction Group, then, has been to develop the necessary equipment for the acquisition, reduction and analysis of data appropriate to a broad class of air-sea interaction problems. By the end of 1968 such an integrated system had been developed, tested and used to obtain experimental results on a routine basis.

Research projects

Open Sea Energy Exchange. The most ambitious and longest established research project of the Air-Sea Interaction Group was initiated by Dr L. A. E. Doe in 1963 and has for its objective the definitive measurement of energy exchange between air and water under open sea conditions. This project has three major parts. First, a detailed measurement of the turbulent momentum transfer will be made. This study will produce not only an accurate determination of the force exerted on the sea surface by the wind, but also will provide details about the turbulent structure of the wind. It is hoped that this latter information can be used to simplify the design of instrumentation for later stages of the

project. In the second phase of the project instruments will be devised for the measurement of heat and water vapor flux measurements. Observations of all the energy fluxes will be made under a wide variety of climatic conditions in order to determine their range of variability. At this point sufficient information should be available to contribute to the solutions of some important problems. The final stage of the project will consist of establishing specifications for instrumentation suitable for use in broad synoptic studies such as the Global Atmospheric Research Project (GARP) or other programs requiring routine reporting of air-sea energy exchange.

Measurements of the wind stress were begun in April 1968 and continued through mid-October. It was necessary to discontinue them because the observing platform was located in an area which caused interference with seasonal mackerel fishing. Because of this interruption it was not possible to make observations during the high winds prevailing during the autumn of the year, but every effort is being made to relocate the platform in time to make additional observations during the winter storms of 1968-69. The limited results obtained so far are encouraging, however, inasmuch as the measurements show a high degree of consistency. The level of consistency is sufficient to bestow confidence in the measuring instruments.

The conduct of this scientific program has been the primary responsibility of S. D. Smith during the past 2 years, although the concept and development of the thrust anemometers, as well as the design and erection of the stable platform are due to L. A. E. Doe.

Microscale Mechanisms. In the summer of 1967 some exploratory experimental observations were made in a shallow pond on the processes of wind wave generation and propagation. In one experiment wave length and speed were measured by a technique using coloured motion pictures. The results indicated that at least for very short fetch, the actual wave crest speed is some 50% higher than the theoretical speed calculated for waves of the observed wave length. In another experiment it was observed that the effect of oil slicks on the process of wave generation and growth appeared to be substantially greater than can be explained by present theoretical models. As a result of these and other related observations, discussed in Internal Note BI 67-24-I a project has recently been initiated to study the microscale processes of energy transfer between air and water in which the immediate objectives will be to make quantitative observations on: the modification of the wind field during transition from land to water, the velocity of currents generated in the very top layer of the water by the wind, the relationship between these currents and wave generation, the effect of surface contaminants on the process of air/water momentum transfer, and the variability of wind fields over water.

Research facilities

Stable Platform. The major research facility of the Air-Sea Interaction group is the stable platform (Fig. 1) moored in open water near Halifax Harbour entrance. The platform was designed and installed under the direction of L. A. E. Doe and was successfully moored in August 1967. The structure is supported by buoyant tanks, fully submerged, and very heavily restrained by wire cables attached to thirteen 25-ton anchor blocks so that it is practically motionless even in very heavy sea conditions. The structure provides a working platform about 20 ft above sea level, atop which a radio antenna mast extends 50 ft into the air. A variety of instruments may be mounted on the structure in order to make precise measurements of the exchange of heat, water vapor and momentum between atmosphere and the ocean under open sea conditions and in high winds.

Since the platform is inaccessible except in relatively calm weather, provisions have been made to power the instruments from a large battery supply located on board the platform, to control the operating functions of the instruments by a radio command system and to transmit the signals from the instruments to the shore by radio telemetry for recording. The control and recording equipment is located in a trailer parked on the shore in line of sight of the platform.

The stable platform has been on site since late summer of 1967, and has thus proved its ability to weather winter storms. The radio command and telemetry system has only been operational since April 1968, but it has performed its functions satisfactorily. However, the system is difficult to operate, and it is

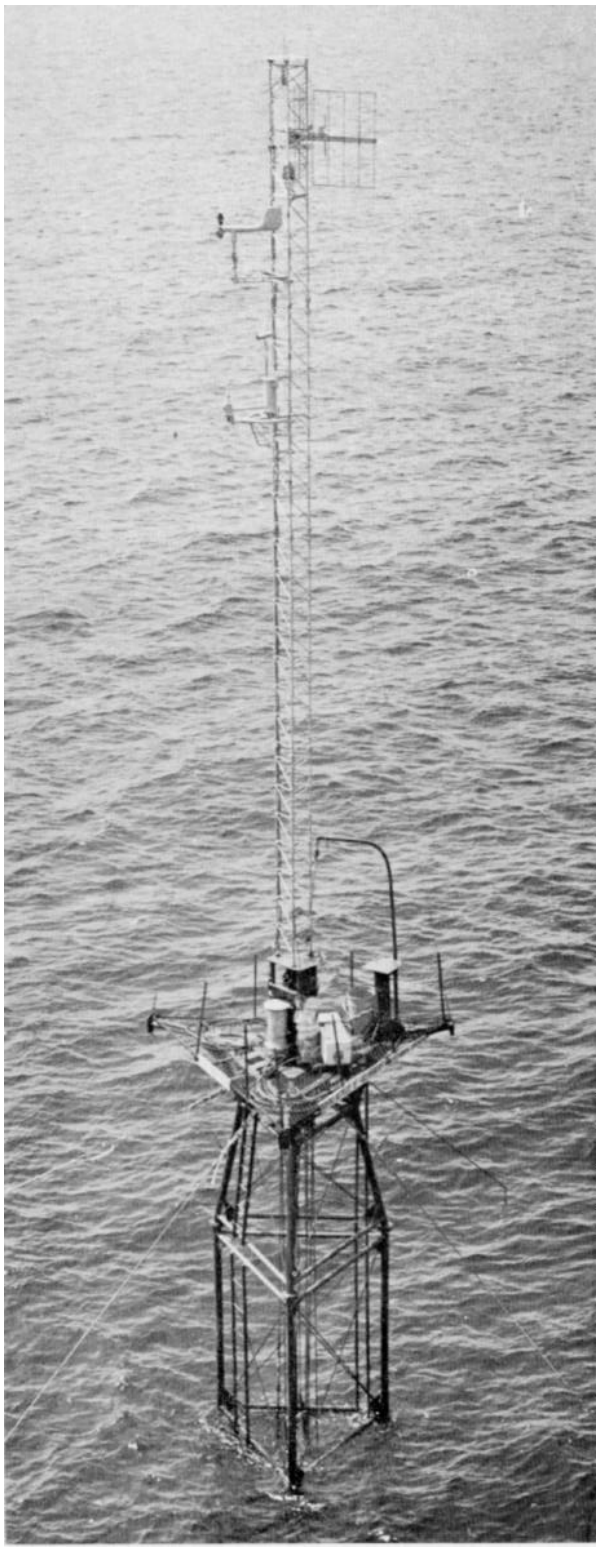


Fig. 1. The stable platform moored off Chebucto Head at the entrance to Halifax Harbour. The thrust anemometer and aerovane are mounted on the mast along with the radio antennas. Cannisters on the platform contain instrument electronics.

not readily expandable to include other sensing devices.

The platform has been the cause of serious objections by local inshore fishermen since it causes some obstruction to the mackerel fishery. Accordingly, it is being relocated. This opportunity is being taken to replace the radio telemetry and command system in order to provide more extensive and flexible control of the greater number of instruments to be placed in service on the platform. These include, for the present, a three component sonic anemometer, an apparatus to measure the slight tilt or bending of the structure which occurs at high wind speeds, and a wave sensing system for use by the Applied Oceanography Section. The opportunity is also being taken to simplify the mooring arrangement of the platform. It is planned to have the revamped system installed and operational by early 1969.

This project is under the general direction of R.G. Stevens with G.E. Awalt responsible for design and production of electronic equipment. Platform redesign and relocation is under the direction of Gibb, Albery, Pullerits, and Dickson, Consulting Engineers.

Microscale Field Laboratory. In order to support the field operations of the project on microscale mechanism discussed earlier, a mobile laboratory is being assembled. The outfitting includes an electrical generating plant and a data acquisition and monitoring system identical to that used on the stable platform. Since studies will be conducted in small, relatively shallow bodies of water, there is no need for radio telemetry and control equipment ; sensors will be connected by direct wire to the recording console. The assembly is designed to be transportable in a vehicle such as a Travelall plus a utility trailer for the power plant.

The development is under the general direction of R. G. Stevens and B. Trudel is technician-in-charge. Engineering design and testing is performed under contract with the Atlantic Industrial Research Institute of Nova Scotia Technical College by Drs O. K. Gashus and D. Winter.

Calibration. In the development, evaluation or calibration of anemometers used in the air-sea interaction project an essential facility is the low turbulence wind-tunnel which was installed early in the program. With space at a premium in the laboratory, this bulky piece of equipment was moved to a nearby storage

building and the opportunity was taken to upgrade the control system. As a result it is now possible for one operator to carry out calibrations in one day that formerly required two men three days to accomplish.

The development is under the supervision of S.D. Smith with W.W. Hall serving as technician-in-charge and B. Trudel responsible for electronics. Engineering consultations were provided by O.K. Gashus D.Sc.

Data Reduction and Analysis System. Early in 1967 specifications were established for a central data reduction and analysis facility to service all of the data acquisition systems. The data reduction function converts the raw data into physically meaningful quantities. It includes calibration, compensation for instrument non-linearities, and correction for undesirable sensor response to temperature, etc. Data analysis may require the combination and manipulation of two or more variables, calculation of average properties, frequency transformation and so on. It also includes summarization of results of several experiments and the preparation of tables and graphs.

It is reasonably simple and economical to convert several continuous electrical signals into the form of frequency modulated subcarriers and superimpose the several signals on a single tape recording. However, digital computers offer the most effective means for combining and manipulating variables and have the additional advantage of permitting processed data to be retrieved for further analysis and summarization. Consequently, in the autumn of 1967 equipment was acquired which operates in conjunction with the CDC 3100 computer to sample the continuous data recordings and convert them into digital form suitable for analysis by the computer. At the same time, development of a complete programming system was undertaken to provide a simplified means for accomplishing data reduction and analysis. The integrated programming system and sampling equipment has been in routine use since mid 1968 but is still undergoing intensive development.

This project has been a major concern of R. G. Stevens. D. H. Herman of the Computing Services Group has carried out much of the detailed programming and R. C. Richards, Head of that group, has provided invaluable advice and assistance.

R. G. Stevens

Frozen Sea Research Group

E. L. Lewis

A. A. Armstrong[1]
J. D. Bradbury
J. A. Elliott
R. A. Lake[1]
A. E. Moody[1]
S. W. Moorhouse
W. C. Parsons[1,2]
R. B. Sudar
E. R, Walker[1]
H. G. Wells

The Frozen Sea Research Group is engaged in studying 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. Laboratory experiments and preparation for field work are made at Victoria, B. C. Field investigations have been carried out at Cambridge Bay, N.W.T., and further work is planned for Greely Fjord, N.W.T.

The emphasis is slowly shifting from ice physics as described in the papers by Lewis (1967), and by Lewis and Lake (in press) to the effects of ice cover on the formation of water structure in northern oceans. During the period covered by this report, the group spent much of its time attempting to develop a system which would facilitate scientific operations in the Arctic winter.

Arctic research system

The Arctic research system consists of two large tracked driving units with a fibreglass insulated body mounted on each. One of these units is fitted as a laboratory, the other as living quarters for four scientists. Each unit can tow two large sleds. One sled is fitted out as a complete workshop and is enclosed so that both mechanical and scientific work can be carried out in all weather. For example, a hole provides access to the ice so

[1] Joined AOL.
[2] Left AOL.

that bathymetric soundings can be made. The other sleds are used to carry supplies and fuel.

The system is completely self-contained for travelling, for living, and for scientific operations. Floatability, demonstrated during lake trials in June 1968, ensures survival in case a unit breaks through thin ice. The extensive navigation system which includes Astronav, RDF, radar and gyro compass is flexible enough to overcome the lack of magnetic guidance available in the northern archipelago. Enough electricity is generated to supply all the anticipated instrumentation requirements. The complete system has been designed to operate in temperatures as low as -6O°F. The main units have been shipped to Greely Fjord, 80°36' N, 79°35' W, where winter trials will be made in March and April 1969.

Field season 1968

A successful 2 month field trip to Cambridge Bay, N.W.T., was carried out in February and March 1968, where temperature on arrival was -50°F. The ice-water interface was studied with very small thermistors, in order to enlarge on the findings of earlier field work in this area. A search was made for dense salt-rich streamers in the water below the ice sheet. The temperature distribution in the water column was studied from below the ice to below the thermohalocline at about 30 m.

Three chains each of six thermistors in hypodermic needles outside diam. 0.032 inches were constructed to measure temperature variations at the ice-water interface. A photograph of one of these chains from the bottom of the 160 cm thick ice is included as Fig. 2. The voluminous output from the new and stable Vidar data logger, which recorded temperatures with an accuracy of ± .00l°C (relative) and ± .002°C (absolute), is currently being analysed. Regular pulses appear in the interface temperature suggesting bursts of

Fig. 2. Underwater photograph shows hypodermic thermistor chain projecting from the bottom of ice sheet. Cambridge Bay, North West Territories, Februray, 1968.

fluid motion. Horizontal scanning of temperature just below the ice was done by a thermistor in a hypodermic needle attached to a device constructed by S. W. Moorhouse. After being lowered through the ice, an arm could be pivoted and driven sideways through several metres and at various speeds.

To examine the under side of the ice shelf and the instrumentation mounted near the interface, a periscope 14 ft long and 3 inches in diameter was constructed. By means of this periscope with its underwater camera and light case, photographs such as Fig. 2 were taken.

To measure temperature fluctuations at greater depths, a chain of less sensitive thermistors extended over depths from 10 to 40 m. Additional thermistors suspended from two small winches were used to check these chains and to attempt to follow internal waves.

A shadowgraph, based on a device which was initiated in the 1966 field season, was used to search for streamers of dense saline water leaving the ice sheets. No indications of streamers were recorded, again suggesting that the salt intermittently leaves the ice in particular locations.

In order to study the physical structure of the ice a 12,000 lb. cube was cut from the ice sheet and examined thoroughly. The bottom centimeters of the block showed many vertical tubes 0.5 mm in diam. A less dense network of larger tubes filled with ice crystals extended 90 cm into the block. A letter submitted to *Nature* by Lewis and Lake, discusses these observations as well as temperature fluctuations at the interface. There appears to be intermittent convective overturn of sea water in the tubes as the upper end becomes cooled and freezing occurs there.

Plans

Extensive scientific work on problems concerned with the ice-water interface such as those discussed above is planned. Both laboratory and theoretical work are presently underway. This should contribute to an understanding of the solidification of aqueous solutions. The path of the rejected salt in the water near the interface is still uncertain. The field data of water structure in deeper layers and the time series of mean temperature and salinity at Cambridge Bay is being examined closely for evidence of convective mechanisms. Concurrently a theoretical model of cell or plume convection is being developed. A continuing observational program will be needed to delineate the convective mechanisms. Plans for the coming season include the application of optical and dye tracer techniques, as well as salinity measurements. Chemical analysis using deuterium or tritium tracers are also to be undertaken this coming year. The convective mechanism is of wide general interest as elucidation of convection below the ice might lead to significant results in explaining the formation of deep, cold waters in the ocean.

To support our planned scientific program, instrumentation development will continue at a high level. A Dauphinee type Temperature, Depth and Salinity Recorder has been purchased and will be tested in the Arctic in the spring of 1969. It is hoped this instrument will provide some of the much needed high quality salinity measurements. The in *situ* measurement of micro-scale salinity in the laboratory is also on our list of instrument development programs. Schlieren techniques are expected to be very important in our laboratory investigations over the next year or so. In the field improved optical techniques will be used with visible tracers in an effort to identify convective mechanisms below the ice. If early trials are successful, chemical tracers will be used over the next year or so.

In order to have convenient access to a wide variety of Arctic oceanographic environments, the Group has established a small base at Greely Fjord. Two huts were set up during the summer 1968, and the base is expected to be ready for the shakedown trials of the Arctic research units in the spring of 1969. With this Arctic research base in full operation, we expect to be able to study the waters of Greely Fjord and Nansen Sound thoroughly in the colder seasons.

E. L. Lewis

Ocean Circulation Group

C. R. Mann

B. D. Carson
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J. R. Lazier
G. T. Needler
C. Quon
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R. L. Russell[1]
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A. Lee
J. Warner } Ph.D Students (Dalhousie)

The Ocean Circulation Group is engaged in studies of fundamental physical processes occurring in the oceans and the major current systems. Until 1966, the studies had been limited to synoptic observations of current systems, such as the Gulf Stream, and to some theoretical work. During the last 2 years the program has expanded considerably to include studies of internal wave motions, time dependent motions and numerical models. Some indication of the past and present interests of the group may be found in the publications and reports by C. R. Mann, W. D. Forrester, G. T. Needler, and R. Reiniger and C. K. Ross that are listed in Appendix A-l.

Collaboration with university groups has also increased. Besides the fluid mechanics course given at Dalhousie by C. R. Mann, a course in Advanced Dynamic Oceanography is given by G. T. Needler and H. Sandstrom who have been appointed as Research Associates with Dalhousie Institute of Oceanography. Three members of the group, C. K. Ross, B. D. Carson, and H. Sandstrom worked with a group from McGill University in the Caribbean. Professor P. LeBlond from the Institute of Oceanography, University of British Columbia, spent the summer of 1968 at AOL working on internal wave problems.

Field operations ranged from the coastal waters of eastern Canada to the Denmark Strait and the Caribbean. Projects of the group are described below.

North Atlantic deep water

It is generally understood that there are three sources of cold deep water moving into the western basin of the Atlantic Ocean from the north. Two of these are overflows from the Norwegian Sea, one through the Denmark Strait between Greenland and Iceland, the other over the Iceland-Faroe Rise and Wyville Thomson Ridge between Iceland and Scotland. The third source is the sinking of cold water in the Labrador Sea in winter.

The heaviest water is the Denmark Strait Overflow which sinks to the bottom. Next heaviest is the Iceland-Scotland overflow which spreads on top of the water from the Denmark Strait. On top of this lies the Labrador Sea water. The waters from these three sources move south, mixing as they flow into the North American Basin below the warm waters of the Gulf Stream system moving north.

The problem with the Labrador Sea source is that there is no clear understanding of the way the water is cooled at the surface and 'sinks. A very detailed set of data was obtained with *Labrador* in 1965 and *Hudson* in 1966 in the Labrador Sea. A study of this data and oceanographic data from weather station Bravo* from 1964 to 1967 has improved our understanding of the process. As the circulation of the Labrador Sea is cyclonic, isopycnal surfaces which lie at a depth of about 1,000 m at the edges of the sea rise to the surface at the centre. Sinking of the cooled water could occur along these surfaces each year and carry water to depths of 1,000 m. The data did not lead to a clear understanding of the way that water at depths greater than 1,000 m is renewed. There was no evidence of deep convective mixing in the data from the *Labrador* or *Hudson* cruises of 1965 and 1966. However, a study of the Bravo data shows that conditions in the winter of 1964 were much different from other years and deep convective mixing may have occurred. It could be that this happens only rarely but that large volumes of water are formed. To reach a better understanding of this important aspect of the circulation of the North Atlantic, several fixed stations in the Labrador Sea are required to operate through several winters

[1] Joined AOL.
[3] Transferred within AOL.
* Kindly provided by the Oceanographic Unit, United States Coast Guard.

with a ship available to determine the extent of the deep convective mixing when it appears.

From January to April 1967 a cruise was made by CSS *Hudson* to investigate the overflow through the Denmark Strait, and to determine the extent to which Labrador Sea water flows into the basin between Greenland and the Reykjanes Ridge. A network of stations, where observations were made and measurements taken of temperature, salinity, oxygen content, and dissolved silica, was run through this basin and the Denmark Strait, with extensive sampling near the bottom in the overflow. These data established that two layers of water in the Strait contribute to the overflow: a bottom layer containing water from the Greenland Sea, and a shallower layer of lower salinity containing Polar water. It was possible to trace the influence of these two layers down the west side of the basin and to delineate two mixing processes. As the overflow comes through the Strait, considerable turbulent mixing occurs over the rough bottom, and as the overflow moves south along the continental slope of East Greenland, it mixes with water from the Iceland-Scotland overflow which lies above it. The data also established the presence of a considerable layer of water from the Labrador Sea and showed it to be lying above the water from the Iceland-Scotland overflow. A paper on some aspects of this work has been submitted for publication. Scientists from Woods Hole Oceanographic Institution (WHOI) headed by L. V. Worthington, and Dr J. C. Swallow of the National Institute of Oceanography (UK) took part in the cruise. The WHOI group laid six moorings across the Strait for 6 weeks, equipped with current meters and temperature sensors. While only two moorings were recovered, they showed considerable pulsations of the cold overflow water and current velocities up to 3 knots.

The northern overflow waters have much less reactive silica than the deep waters moving north into the Atlantic from the Antarctic (about seven compared with 15Oμg - At/l). Because of this difference, it may be possible to distinguish between the remnants of these deep flows using silicate observations when it is difficult to do so using temperature and salinity. A considerable number of silicate measurements have been made during AOL cruises to the northern areas of the Atlantic. Silicate data from both North and South Atlantic have been acquired from data centers to augment the AOL collection and the complete set processed by machine and plotted into charts of silicate distribution for the whole Atlantic. The charts are now under study to determine the usefulness of the silicate data as a tracer of water masses.

J. R. N. Lazier
C. R. Mann
D. Garner

Gulf of St. Lawrence

This project has been concerned with the usefulness of the geostrophic approximation in assessing the circulation in coastal channels, in general, and in the Gulf of St. Lawrence in particular. In an experiment in 1965, the velocity field was measured with a set of eighteen current meters across the channel at Pointe au Père. The density field was determined at different stages of the tide by a set of water bottles and reversing thermometers set on moorings and tripped simultaneously by a timing mechanism. Analysis of the data, completed in 1967 (AOL Report 67-5), shows that the response of the density field to the tidal oscillations produces an oscillating shear in the geostrophic current of opposite phase to that of the share in the true axial current. The instantaneous geostrophic current is not then a good representation of the true current. If, however, sufficient observations are obtained over several tidal periods and averaged, then the mean geostrophic current does represent the residual flow quite accurately. The Gulf in this area can be considered as a two-layer system and the response of the density field can be explained in terms of cross-channel internal oscillations. It also seems that a standing internal wave motion occurs along the channel. A second series of measurements were begun in the channel in summer 1968 to study this phenomenon.

W. D. Forrester

Caribbean and Gulf Stream

In January 1968 opportunity was taken of a passage of *CSS Hudson* to the Caribbean to study the flow of Atlantic water into the Venezuelan Basin through the Anegada Passage, the passage through which the deep water of this basin should be supplied. Studies of existing measurements of potential temperatures at the bottom of the basin by L. V.

Worthington *(Deep Sea Research,* p. 731-739, 1966) showed that the bottom waters originated in the Atlantic. The isotherms did not, however, rise to sill depth at the Anegada Passage and no connection was evident between the deep water of the basin and water of similar potential temperature in the Atlantic. This indicates that renewal of deep water in the basin is not taking place at present. Our measurements were more definitive than previous ones but only confirmed previous results. Water of potential temperature 3.76° C was traced through the passage from the Atlantic and was found on top of the sill (depth = 1,950 m), but could not be found 2 miles further on into the Caribbean at depths of 2,500 m. Dynamic calculations showed unrealistic shears of 5 knots. Beside the problem of the deep water not cascading over the sill, there also appears to be an interesting dynamic problem in the passage.

From 1963 to 1966, studies by the group of the Gulf Stream southeast of the Grand Banks of Newfoundland resulted in a description of the current system in this area. These studies were reactivated in 1968. Mass transports were calculated for a line of stations run in 1966 between the Grand Banks and Azores. These did not prove satisfactory as a suitable level of no motion could not be established. Further work will have to be supported by current meter measurements.

C. R. Mann
C. K. Ross

Scotian Shelf and Slope

During 1967 and 1968 a series of measurements of the variability of currents and temperatures of the waters of the Scotian Shelf and Slope were made in collaboration with Applied Oceanography. The measurements, which aimed at an understanding of the time dependent motions in the ocean, were carried out with continuously recording current meters and temperature sensors suspended at several depths from surface to bottom with moored buoys.

Throughout 1967 instrumented buoys were maintained at four positions on the Scotian Shelf. Although the series was not completed because of losses, a great deal of new and useful information was obtained. Analysis of the current meter records has shown the existence of inertial motions, and that tidal ellipses associated with tidal motion are of different shapes at different places on the shelf. An extensive grid of oceanographic stations was run several times in August to provide synoptic temperature and salinity data for use with the current meter data in the study of residual currents.

The 1968 program was curtailed during the first 6 months due to "shakedown" difficulties with *CSS Dawson* assigned to service the moorings, and only a few short period records were obtained. A set of eight moorings was laid in early September and recovered in mid-October with 100% success. Five of these moorings were on the Shelf and three in 1,000 m deep water along its edge. The latter were installed to study the complex mixing of waters from the Labrador Current and Gulf Stream which occurs in this area.

J. Warner
A. Lee

Time-dependent motions

It has long been recognized that time-dependent processes play an important part in the dynamics of an ocean; for example, time-dependent motions are associated with most of the mechanisms by which energy is added to or removed from the ocean. Although in certain cases the free modes of oscillation of the ocean are relatively well understood, in general the theory of wave motions in the ocean is not well developed and many opportunities for research are available.

Of particular interest to oceanographers are wave motions near to, and lower than, the local inertial frequency and with wave lengths longer than the depth of the ocean. In an effort to obtain a reasonably rigorous and general theory for such wave motions, a perturbation equation for the pressure has been obtained. Although, for the purpose of obtaining this equation the momentum and continuity equations have been linearized and the effects of friction neglected, no approximations based on scaling have been made. In the summer of 1968 an analysis of the solutions of this equation was started (in collaboration with Professor P. LeBlond of the Institute of Oceanography, U.B.C.). It is hoped that it will be possible to obtain valid local wave solutions for a wide range of frequencies (for such waves) and to systematically obtain some understanding about the relative importance

of the earth's curvature, the horizontal component of rotation, the ocean's depth and the depth of the stratification. Among the initial conclusions which may be drawn is that waves, such as Rosby waves, which have an east-west asymmetry are only possible if the fluid is stratified.

In accounting for the energy balances in the ocean, it is necessary to explain the highly uneven spatial distribution of energy as well as temporal variations. Such spatial variations occur not only because of localized external forces (e.g. hurricanes) but also because the ocean is nonhomogeneous and the shape of the ocean basins influences some types of motion more than others. In the vicinity of highly variable topography the usual procedure of analyzing the motion in terms of normal modes cannot be carried out. In such cases, wave motions can be studied with the aid of ray theory and this approach has been used to study some special problems. Although it remains the ultimate aim, analytical models at present cannot be tested in the real environment. Model experiments can however be devised to aid in further theoretical development. For this purpose two wave tanks, one to simulate an infinite two-dimensional medium and the other a more conventional flume, have been constructed and some preliminary experiments have been carried out.

The serial oceanographic data from Weather Station Papa in the Northeast Pacific has been examined to determine its usefulness as a time series. Since the data was obtained for alternate 6 week periods, it presents special problems in power spectrum analysis. If the data is averaged over the 6 week intervals, the resulting power spectrum may be highly aliased at low frequencies (see the paper by C. R. Mann and G. T. Needler-Appendix A-l p. 87). Ways of analyzing the spectrum without averaging are being investigated with the aim of obtaining an estimate of the increased variances of the spectral estimates which result from the gaps in the data.

C. Quon returned from the University of Cambridge in October 1967, after completing his Ph.D on problems of thermal convection in rotating fluids which he studied using numerical techniques. Consideration is being given to using numerical techniques in the solution of large-scale problems such as the thermohaline circulation of the ocean.

G. T. Needler
H. Sandstrom
C. Quon

Data processing and instrumentation

The work on interpolation of serial oceanographic data that has been carried on for several years has been completed and the results incorporated in a new computer program to process temperature data, etc. The system has been taken over by the computing section. All AOL cruises in the North Atlantic from 1965 to 1967 have been processed using the new system. Programs have been written so that the data can be automatically presented by a plotter either in the form of a parameter as a function of depth or as a section. The sections run from 1965 to 1967 are being compiled in atlas form for publication.

R. Reiniger
C. K. Ross
A. Grant

The development of a competent technical staff in the group has enabled us to undertake the design and construction of new experimental equipment. A water sampler for use with salinity-temperature-depth recorders is under construction. The device consists of a set of water bottles which can be closed on command by an electrical signal, mounted in a frame suspended below the STD recorder. Water samples may be collected at selected depths and used for determination of dissolved oxygen, silicates, etc. Determination of salinity using the samples will provide a calibration of the STD recorder at sea on each cast.

Ice point apparatus has been built for calibration of reversing thermometers. A considerable amount of time is being spent in calibration in AOL of the STD recorder, salinometers, and other electronic devices now in use. These checks and calibrations must be done very carefully if the potential of these new devices is to be realized.

Chemistry and Radiochemistry

A. R. Coote

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R. S. Hiltz
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J. G. Pearson'
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W. Young

The Chemistry and Radiochemistry Group is engaged in two projects, The first, and the one that has occupied the major part of the group's time over the past 2 years, is the development of an instrumental method of chemical analysis, based on gamma ray spectrometry, for the determination of trace elements in sea water. The second project, which involves the service function of the group, is a study of quality control procedures which are required for the collection and determination of those hydrochemical parameters customarily used by the oceanographer. Of the approximately 13 man-years of work available to the group during 1967 and 1968, about 11½ man-years have gone into the trace element project, and 1½ man-years have gone into the service function.

Dr T. Kuwamoto, a National Research Council Post Doctoral fellow from the University of Kyoto, was with the group in 1966 and 1967 doing research on the chemical separation processes involved in the trace element project.

A. R. Coote

Trace element project

A better knowledge of the behaviour of the ocean's trace elements and of its natural and artificial radionuclides will contribute significantly to understanding the chemical, biological, and physical processes that take place within it and through its boundaries. Because the trace elements and radionuclides are present at very low concentration, the sampling and analytical problems involved in their measurement have limited the study of their behaviour in the ocean.

Instrumental neutron activation analysis using single or coincident gamma ray spectrometry has great sensitivity for many elements. In addition, recent developments in electronics have improved instrumental activation analysis to the point that chemical processing of sea water samples can be simplified or eliminated. The single method involves the interaction of individual gamma quanta with a single detector to produce a gamma ray spectrum from the sample. The coincidence method utilises simultaneous interactions of two quanta, each with a detector, to obtain the spectrum of coincident gamma rays originating from a source. The coincidence method greatly increases the selectivity of gamma ray spectrometry for the many radioisotopes which emit sequential gamma rays in their decay. The sensitivity of this method may be increased by the use of anticoincidence devices and shielding to suppress the effects of unwanted interactions.

We believe that substantial advances in the study of the occurrence and behaviour of trace elements in the sea would result from the use of a more powerful, but operationally much simpler, analytical tool than presently exists. Therefore, an objective has been the development of coincidence spectrometry for analysis to provide the necessary selectivity and sensitivity through the use of lithium drifted germanium detectors of an order of magnitude larger than those commercially available. It became apparent that this development would be a long term project dependent upon the construction of larger detectors.

Suitable large detectors have not been commercially available although germanium crystals for detector fabrication can be obtained at a cost estimated to be 10% of the cost of a completed detector. We gained expertise in technique by successfully restoring the detector characteristics of smaller units which had been damaged in shipment. The procedures involved correspond to the most critical stages in detector manufacture. By using methods outlined in the literature 10cc-20cc annular "U" drift detectors with desirable characteristics have been made. Larger units of this type, requiring refinements in fabrication technique are being produced for assembly into multicomponent detectors for coincidence spectrometry. In the short term more effort has been applied to analysis by singles spectrometry, which has less selectivity and whose sensitivity is less dependent on detector size. This approach requires rather large volume sea water samples and chemistry to remove interferences from some major constituents of sea

[1] Joined AOL.
[2] Left AOL.

water, principally sodium. Prior to irradiation, the separated trace elements must be placed in a container, which is itself uncontaminated by trace or interfering elements. The gamma ray spectrum obtained from the induced radioisotopes should then be analyzed mathematically for its individual components, and the analysis must be handled by computer if the results are to be obtained quickly and easily. (For a discussion of the computer aspects of the project see Computing Services, p. 82.)

Three different types of trace element separation technique have been tried and compared: (1) adsorption on the hydrous oxide precipitates of aluminium and titanium; (2) evaporation of the sea water followed by the extraction into chloroform of the metal chelates formed by the trace elements with oxine, diethyldithio carbamic acid, and thenoyltrifluoroacetic acid; (3) absorption of the transition elements onto a chelating ion-exchange resin. Initially, a method using a chelex-100 ion exchange resin has been chosen. It has an advantage because it is highly selective for transition and rare earth metals, discriminates against the absorption of uranium and is easily adapted to shipboard sampling, making the storage of large sea water samples unnecessary. All three features are desirable for a trace element program based on singles spectrometry.

We have investigated the use of commercially produced purified graphite containers for sample irradiation. The supplier machines the container, purifies it by a high temperature technique and ships it to AOL inside a larger graphite container. The inner container is filled with the sample under clean room conditions and replaced in the protective container. The complete assembly is shipped to Chalk River for irradiation and then returned to AOL. The outer protective container bearing any impurities that may have collected during shipping is discarded, and the inner capsule containing the irradiated sample material is presented to the spectrometer for analysis. Since the inner capsule is low in impurities, sample handling both before and after irradiation is simplified.

The results of these experiments have been set out in a set of internal notes by Pagden and Coote, see Appendix A-l.

I. M. H. Pagden
A. R. Coote
J. M. Bewers

Chemical services

The advent of in *situ* instruments for recording salinity profiles and the acquisition of portable salinometers for sea use has reduced the number of salinity samples processed at the Institute. It is likely that the in *situ* instruments will receive increased use and further reduce the processing of individual samples. Nevertheless, there is a continuing need for highly accurate salinity observations and interagency calibration. The group is therefore investigating quality control procedures that are required for stated levels of precision and accuracy. It will extend similar procedures to other chemical observations where quality control is of importance also. The chemistry group is continuing to carry out all types of salinity determinations for outside agencies.

E. M. Levy

Marine Geophysics

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W. W. Power[1,2]
D. D. Prentiss[1]
D. I. Ross
R. Sparkes
S. P. Srivastava
G. F. Stewart[1]
J. M. Woodside

The Marine Geophysics Group is primarily concerned with the investigation of the properties of the earth beneath the sea in order to understand the processes which have formed the continental margins and the ocean basins. The studies can be subdivided into surveys of continental shelf areas, such as Grand Banks and Gulf of St. Lawrence, to provide information about potential resources; research in regions where active formation of ocean bottom may be occurring, such as the Mid-Atlantic Ridge; and the design, assembly, and evaluation of new methods to be used in gathering, processing, and interpreting data.

[1] Joined AOL,
[2] Left AOL.

The statistics for major projects during the past 6 years are shown in the following table:

	1963	1964	1965	1966	1967	1968	Total
1. End-of-year staff	5	4	9	10	14	18	
2. Man-days at sea	210	273	573	653	674	1,425	3,808
3. Days-at-sea per staff member (2:l)	42	68	64	65	48	79	63.5
4. Ship gravimeter (km)	4,600	13,900	41,800	21,000	30,500	40,300	152,100
5. Ship magnetometer (km)	11,100	17,600	74,600	53,000	41,900	67,900	266,100
6. Gravimeter km/man-day at sea (4:2)	22	52	74	33	44	28	40.0
7. Magnetometer km/man-day at sea (5:2)	52	65	129	81	63	48	69.9
8. Ratio of magnetometer to gravimeter track (5:4)	2.39	1.27	1.78	2.52	1.37	1.68	1.75

As might be expected in the early stages of development of a small group, the level of field activity fluctuated by a factor of two or more over the past 6 years. In spite of the staff increase in 1967, the days at sea remained almost the same as in the previous year. This was a result of a deliberate effort to develop techniques for handling the backlog of data awaiting reduction and interpretation. Productivity remained at the high level due to the efficient use of the GEOphysical DAta Logger on the hydrographic survey of Grand Banks.

During 1968, several major operations were undertaken, resulting in a record 1,425 man-days spent at sea. Although the instrumentation has now reached such a high level of sophistication and reliability that it could be left permanently on board ship, ready to be used on any cruise, the group at its present size cannot support such a demand.

The 1968 Gulf of St. Lawrence Survey was the culmination of a 5 year effort to upgrade the standard offshore hydrographic surveys by increasing the quality and quantity of parameters recorded along survey tracks. During the Gulf Survey which lasted 5 months, one staff geophysicist and one instrument technician were the only Geophysics Group personnel on board CSS *Baffin.* In addition, three operators, hired as general personnel by the Hydrographic Service, kept routine watches on equipment. This group continually collected and processed, through a shipboard computer, gravity and magnetic data whenever the ship was on a survey line. The high professional standard of this operation surpassed the initial objectives. The development over the next 5 years will concentrate on further streamlining of the digital data processing techniques with the ultimate objective to produce a finished machine-contoured chart, ready for printers by the time the ship returns to home port. This will require larger computers on board our ships.

The group continued as custodians of the shipboard computer installation. Each installation was expanded by the addition of three Dectape transports. Several experimental interfaces were built and tested at various times. An oscilloscope display and a radar fix thumbwheel have been interfaced with the *Hudson's* computer installation. Also, a disk pack data storage system was temporarily added to the *Baffin's* computer installation and operated satisfactorily. The total computer running time on two ships is now 11,250 hr. The addition of satellite navigation has increased the demands on computer time and a second (a PDP-8s) computer was carried on board *CSS Hudson* during most of 1968. The need for higher accuracy of computations has accelerated considerations for conversion to larger and more powerful shipboard computers.

Professional training was pursued through formal courses of instruction whenever possible. A special consultant, Professor Doreen Heaps, was engaged in 1967 to establish an information retrieval system for charts originating within the group. During this project she conducted a series of discussions, instructing the group in coordinate indexing and modern trends in Information Retrieval. Another consultant, Professor A. Bowen, was

engaged to review the requirements for Senior Shipboard Operators. During a S-week period he conducted an intensive training exercise on board *Baffin*. A professional programmer, Mr Patrick Hoyt, from Digital Equipment Corp., Maynard, Mass., spent various periods in 1968 on both *Hudson* and *Baffin* instructing staff in the use of latest software developments.

The group continued to acquire experience on ships outside of the Institute fleet. Members Barrett, Loncarevic, Manchester, and Srivastava participated in five expeditions : three originated from Scripps one from Woods Hole and one from AOL, ESSA. Members of the group have now taken part in cruises on 42 research vessels from five nations.

The number of visitors has grown too large to be listed. The largest single group was composed of over 60 professional geophysicists from oil companies (more than half from Calgary), government agencies and University laboratories from Canada and abroad, who attended the first Bedford Institute Symposium on Marine Subbottom Exploration Methods which was organized by the Subcommittee on Exploration Geophysics of the Associate Committee on Geodesy and Geophysics, NRC. Included in the 3 day symposium were 2 days of lectures and discussions at the Institute and a 1 day demonstration cruise on board *Hudson.*

Individual scientists as well as groups also visited the Institute. Dr F. J. Vine from Princeton University spent 6 weeks here during the summer of 1967. He studied the lineations (or the absence thereof) in the North Western Atlantic and documented several computer routines. In March 1968, Dr A. S. Richardson, Imperial College, London, joined the Institute for 6 months to study numerical methods for geophysical interpretation of systematic oceanic surveys. He also produced machine-contoured bathymetric and magnetic charts of the Mid-Atlantic Ridge survey areas. Dr. W. N. Li and Mr C. G. Williams, Imperial College, London, spent 2 months at the Institute in October 1968, working on a joint project to evaluate new instrumentation for magnetotelluric measurements at sea. The equipment was successfully moored and recovered after 3 weeks on the Continental Shelf about 80 miles south of Halifax.

As a part of the scientific exchange of ideas and information, several members participated in National and International Scientific meetings. Of special interest were the meetings of the VII World Petroleum Congress, Mexico City (Ewing) ; American Geophysical Union, Washington (Manchester, Ross, Woodside); Canadian Association of Physicists, Toronto, (Loncarevic, Srivastava, Woodside) ; and International Union of Geodesy and Geophysics, Switzerland (Haworth, Loncarevic, Ross, Srivastava). Dr. Loncarevic continued to serve as a member of the Commission on Continental Margins and Island Arcs, UMP and was elected a member of a newly formed Commission on Marine Geophysics, IAPSO.

Dissemination of information was continued through publications. The group distributed 265 reprints, by mail. In addition, two new regular publications were instituted within the Data Report Series. Since July 1967, regular monthly bulletins of the diurnal magnetic activity (at 10 min intervals) are mailed to 30 addressees. The gravity and magnetic observations along ship's tracks are issued as data reports in standard format as established by Admiralty Marine Sciences Publication No. 4, London, 1963. The distribution at present is 125.

Instrumentation

Three major advances in instrumentation have been made in the past year. These are the development of equipment for seismic experiments, the conversion of existing shipboard geophysical equipment to a form compatible with the new BIODAL shipboard data acquisition system developed by the Metrology Section, and the acquisition of satellite navigation equipment by the Institute.

In developing seismic equipment, considerable time and effort has been spent in designing a quiet receiving and recording system. This has involved work in the design of the hydrophone array and the electronic equipment on the receiving ship. Experiments have also been carried out with different sound sources. In particular, it has been found that the new air-guns available commercially can provide a very efficient and convenient sound source for refraction as well as reflection work.

In the process of modifying existing geophysical equipment for use with BIODAL, considerable thought has been given to improving the design of the equipment involved.

Minor modifications have been made to the gravimeter and VLF systems to improve their reliability. A new prototype shipboard magnetometer, developed in conjunction with the Metrology Section, has given extremely good results.

During this summer's Mid-Atlantic Ridge survey, the precision echo sounding system developed as part of BIODAL has proved successful. The use of a transducer mounted on a retractable ram in the oceanographic well has enabled excellent sounding records to be obtained while surveying at full speed, regardless of sea conditions. (See report of Engineering Services for details.)

D. L. Barrett
D. I. Ross

Continental Shelf

Grand Banks. As part of the continuing program of geophysical exploration of the continental shelf and margin of eastern Canada, shipborne gravity and magnetic measurements were made during 1967 over the Grand Banks of Newfoundland. The geophysical survey was conducted in conjunction with a continuing hydrographic survey of that region. The area covered lies approximately between long 53°W and 44°W and lat 45°N and 48°N.

The use of a PDP-8 computer onboard ship enabled the observed data to be processed and the results plotted within 24 hr of the data acquisition. The rapidity with which the data was processed, plotted and contoured made it possible to recommend changes in the program to ensure detailed study of anomalous features, to check instrument repeatability and to correct processing and/or navigational errors.

Computed values of the free air gravity anomaly and the magnetic anomaly were plotted on 1:250,000 charts at 5 min intervals along 16,500 nautical miles of ship's tracks, i.e. approximately every nautical mile. In addition, the observed values of bathymetry and total magnetic field were plotted at the same interval. A chart showing the ship's track was updated on a daily basis.

Fixed magnetometer stations were installed at the Decca Slave sites adjacent to the survey area. Data from these stations and the station at the Institute is being used to reduce diurnal and magnetic storm effects from the total field magnetic data recorded at sea.

The preliminary total field magnetic charts show that the magnetic field has a well defined but gentle regional dip to the southeast. There are a few low amplitude magnetic anomalies on the Banks proper and some very intense magnetic anomalies over the Flemish Cap area.

The most interesting features of the gravity charts reveal : (1) very steep horizontal gradients; (2) a large "low" near the central portion of the survey area ; (3) a very extensive "high" in north central portion of the survey area; (4) a positive zone associated with the Flemish Cap; (5) a belt of circular positive features lying within and parallel to the 100 and 1,000 fathom contour lines. These features are readily identified in Fig. 3.

The top of the Grand Banks, especially within the 50 fathom contour, is remarkably flat; therefore the steep gradients of the gravity field are due to major variations in the density distribution and/or structure of the subsurface rocks. This, coupled with the fact that the magnetic field in the same area is very smooth, indicates that the density variations are due to changes in structure within the sedimentary rock section. The gravity "lows" that are relatively small in area1 extent are believed to be due to salt structures, while the large low in the central portion of the survey area is believed to be a basinal type feature with a total sedimentary rock thickness probably in excess of 6 km. Structures such as are indicated here are very favourable to the accumulation of hydrocarbons.

In June 1968 *CSS Hudson*, accompanied by *MV Theta*, returned to the Grand Banks for 2½ weeks. The purpose of this short cruise was to obtain geophysical measurements in a previously unsurveyed area lying between the 1966 and 1967 survey areas and to carry out seismic refraction measurements. A Magnavox satellite navigation system was used to provide navigational control for the survey and a single slave Hi-Fix system was used for determining shot to receiver distance during the seismic refraction experiment.

Two short (30 nautical miles) and one long (150 nautical miles) refraction seismic lines were shot using a large 2,000 cu. inch air-gun and conventional explosives. Six distinct refraction layers were mapped with the

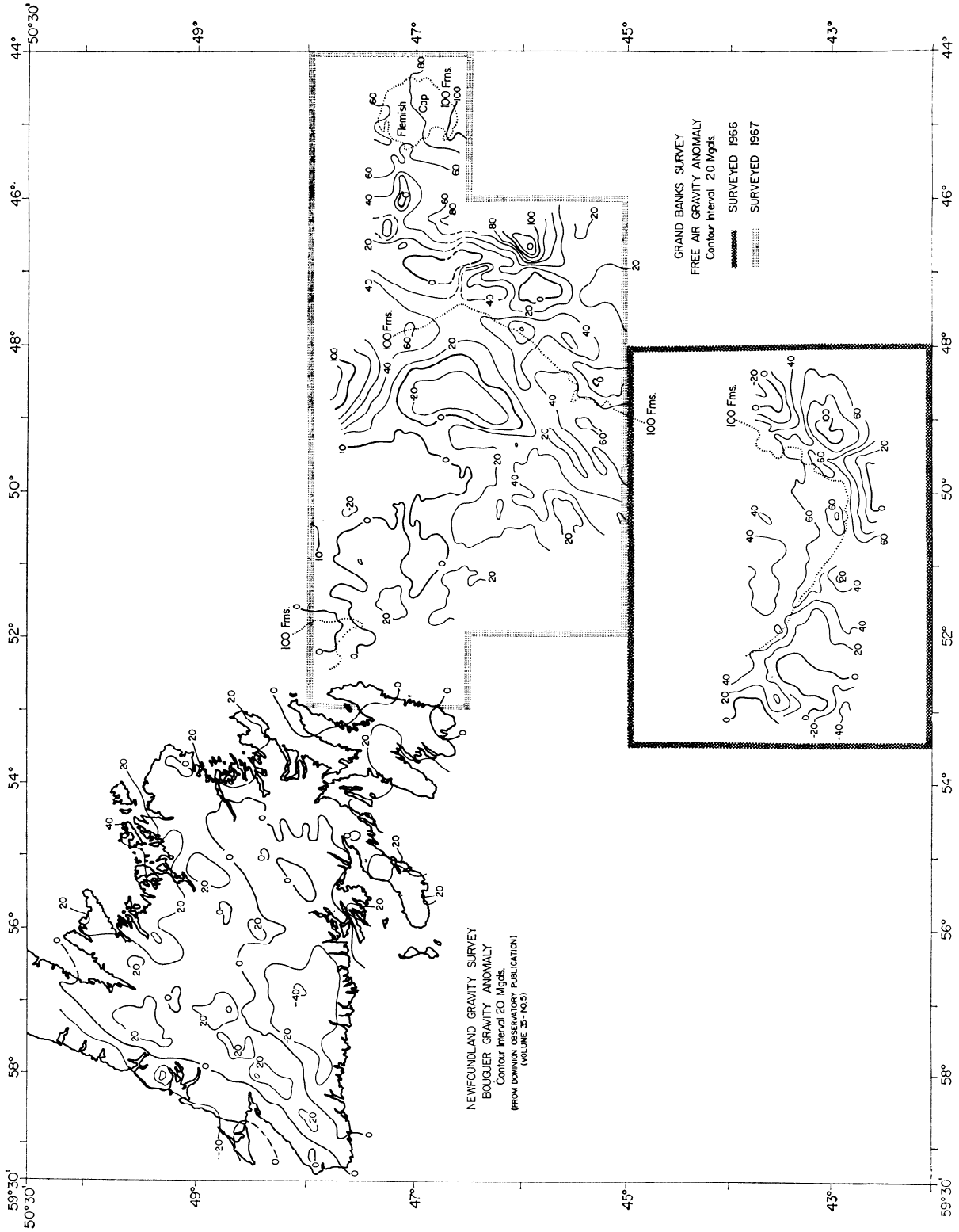

Fig. 3. Grand Banks Survey Free Air Gravity Anomaly.

following velocities: 1.67, 1.84, 2.69, 4.59, 5.40, and 6.03 km/see. The highest velocity probably identifies crystalline basement rock in this area. As expected from previous investigations, a thickness of sedimentary rock in excess of 3 km was found in the vicinity of the long profile near 45°N and 49°W.

Gulf of St. Lawrence. During the summer of 1968, gravity and magnetic measurements were recorded in the northeast portion of the Gulf of St. Lawrence. As in the Grand Banks survey, the data was processed and plotted at sea and preliminary contour charts were produced.

The Gulf gravity maps covering parts of the western flank of the Canadian Appalachians are featureless when compared with the gravity maps of the Grand Banks which comprise part of the eastern flank. Maps of the total magnetic field in the Gulf, however, show several large amplitude anomalies generally trending in a northeast-southwest direction. The magnetic anomalies are most intense along an elongated shoal area just south of the Labrador coast line.

The sedimentary rocks underlying the survey area are probably of Ordovician, Silurian, and Cambrian ages, and have a total thickness of from 1 to 2 km. The intense magnetic anomalies indicate areas of very thin or nonexistent sedimentary rock cover over the pre-Cambrian basement rocks. There is evidently very little density contrast between the pre-Cambrian basement rocks and the overlying early Paleozoic sedimentary rocks.

G. N. Ewing

Mid-Atlantic Ridge Survey

Hudson Geotraverse is a cooperative project organized by the group to study a one degree wide strip of the Atlantic Ocean between the latitudes of 45°N and 46°N and longitudes 25°W and 6O°W. The 300,000 sq km area (comparable in size to the UK) stretches from Cape Breton across Grand Banks of Newfoundland to the eastern flank of the Mid Atlantic Ridge. This geotraverse crosses most of the major oceanic provinces recognized so far. The ultimate objective is to understand the deep seated processes presently active under the mid oceanic ridge system, the formation of the deep ocean floor, and the interaction of the oceanic and continental crust at the margin.

In 1968 the third Institute expedition to the Mid-Atlantic Ridge continued the comprehensive geophysical survey of the area between lat 45° N and 46° N which began with the voyage of *RRS Discovery II* in 1960. Two ships, *CSS Hudson* and *MV Theta* were involved full time on the expedition which included accurately controlled lines across the western Atlantic to the main survey area. The two major advances over previous surveys were the use of a second ship for tending the radar transponder buoys during the survey portion of the cruise and as a shooting ship during the seismic phase, and the use of satellite navigation for the absolute positioning of the survey and the lines to and from the survey area.

A total of 34 radar transponder buoys were moored to provide accurate navigation for the survey lines being run. The absolute position of the buoys was determined from measurements on 297 selected NNSS satellite passes made with a Magnavox 702CA satellite navigation receiver. The frequency of satellite fixes enabled the surface movement of the buoys to be monitored while on survey.

A total of 5,600 miles of bathymetric, magnetic, and gravity measurements were made at a line spacing of less than 2 miles to complete the detailed survey of the western flank of the ridge between 45° N and 46° N. In addition, some 1,600 miles of surveying was completed on the eastern flank between 45° 15’N and 45°45’N.

Two seismic experiments were carried out in conjunction with Cambridge and Dalhousie Universities. In these experiments, *Hudson* acted as the receiving station in the centre of a square pattern of sonobuoys while *Theta* dropped charges. Two further split profiles were recorded using the seismic cable and hydrophones as a receiver and a 2,000 cubic inch air-gun as a sound source.

Ninety-eight stations were completed. These included 8 camera stations, 8 core stations, 8 velocimeter stations, 10 hydrographic stations, and 69 plankton hauls for groups within the Institute, and 38 dredge stations for Geological Survey of Canada. Sixty-three of the plankton tows were taken in conjunction with other station work.

The crest of the Mid Atlantic Ridge at this latitude is located between long 27°

20'W and 28°3O'W. High, rugged, and steep volcanic peaks rise within 700 m of the sea surface. The direct dating and inference from underwater photographs, absence of sediment cover and relatively thin manganese coating on the dredged samples indicate that these are young mountains. The Median Valley with a strike of 020° is the most prominent feature of the crestal region. The average width is 11 km and the depth ranges from over 3,500 m in a few deep holes to less than 2,600 m in the region of a blockage where outpourings from two volcanoes have partially filled the valley.

The crestal region is bounded on the western side by the 2,600 m contour. To the west of this contour the relief is gentler, the seamounts are more distinctive, and are separated by ponds filled with recent sediments. Cores up to 20 m long have been obtained in these basins. Seismic profiling (by M. J. Keen of Dalhousie University) indicates a sedimentary layer thickness of up to 1,000 m. There is an asymmetry in the physiography of the Crestal Region, Median Valley being closer to the eastern than the western boundary; the slopes of seamounts are steeper, and individual echo sounding profiles suggest extensive block faulting. The level of sediment ponds east of the crestal region is on the average 200 m deeper than the level of ponds to the west. Other geophysical evidence also suggests that there is a difference in the structure between the eastern and western flanks. Further analysis of the collected data is necessary before speculations can be made on the significance of this Ridge asymmetry.

The topography of the Upper Flank gives an impression of an older geological province which has been exposed to erosional and tectonic deformations. The existence and thickness of sediments also is an indication of this province's age. The confirmation of the increasing age of seamounts away from the axis of the ridge was reported by Dr F. Aumento of the Geological Survey of Canada. Fission track and isotope ratio age determinations showed that the samples from the Median Valley floor are 13,000 years old, those from the Confederation Peak (19 km distance from the M.A.R. axis) are 740,000 years old and samples from Bald Mountain (62 km) are 7 million years old.

The most prominent magnetic anomaly is the strong positive one over the Median Valley, with an amplitude which is twice that of the next largest anomaly. This positive anomaly, and the fact that it is flanked by two negative anomalies, suggests that the extrusion of the valley walls occurred during the last reversal of earth's magnetic field (about one million years ago). Beyond the magnetic anomalies associated with the Median Valley, the lineation of magnetic pattern is not outstanding. The process of ocean floor spreading and generation of magnetic anomalies by periodic reversals of the earth's field, if it occurs, is complicated in the study area.

The Geological Survey of Canada party under Dr F. Aumento collected bottom rock samples of 28 successful dredge stations in 1968. A total of 440 numbered specimens were collected. In addition to the ever-present basalts and tuffs, three noteworthy rock types were recovered in the area.

(A) Serpentinites and serpentinized basic volcanics and intrusive rocks appear to be widespread over the whole area, except in the Median Valley and on its immediate sharp slopes. Surprisingly, serpentinite is not restricted to elongated, presumably block faulted seamounts, but is also common on the slopes of shield volcanoes. This may indicate that serpentinization did not require any great depth of burial or heating of the parent basic rocks.

(B) The steep eastern inner walls of the Median Valley have yielded basalts and diabases showing the preliminary stages of low grade regional metamorphism of the Greenschist species. Original igneous characteristics are still predominant, but there is an abundance of chlorite, and in places albite, epidote and calcite. This mineral assemblage indicates that these basic igneous rocks must have been buried at approximately 2 km and were subjected to temperatures within the range of 200° to 400°C for metamorphism to have taken place. Hence, the inner slopes of the Median Valley must be fault scarps along which a vertical throw of some 2 km must have taken place quite recently for these rocks to be exposed and to appear so fresh.

(C) Restricted along the fault scarps of elongated seamounts and farther away from the Median Valley, there appear higher grade metamorphic rocks of the Almandine-Amphibolite species of regional metamorphism. These are the cummingtonite amphibolites,

which represent considerably greater depths of burial (4,000 - 8,000 bars, 400° to 600°C) of basic rocks as compared with the Greenschist species of rocks in the Median Valley. Hence, additional block faulting and uplift of the seamounts must have taken place well away from the Median Valley.

B. D. Loncarevic
D. I. Ross
K. S. Manchester

Information retrieval

In January 1967, Professor D. M. Heaps was engaged as a consultant to instruct the group in the principles of information retrieval and to set up a chart storage and retrieval system. This system uses the coordinate indexing method of retrieval and has been developed so that members of the group can rapidly retrieve material for reference or use, and stow new charts in an orderly fashion.

Chart material has been classified under three basic headings: (I) Raw-material that has not been correlated or interpreted in any manner; (2) Compiled-material that has been correlated or interpreted ; (3) Storge-material used as an information source or as a base for plotting new work. Some 300 keywords have been used to describe the documents in the system. These include some 20 common scales in use on documents. A Marsden Square numbering system has been developed to indicate geographical area. The accession number under which the documents are filed is composed of a combination of letters and numbers. The first group of numbers indicates the sequential filing order of the document. This is followed by a letter which denotes the type of document as Raw, Compiled, or Storage. The final group of digits indicates the cruise number. In this way considerable information is conveyed to the searcher before the actual document is retrieved.

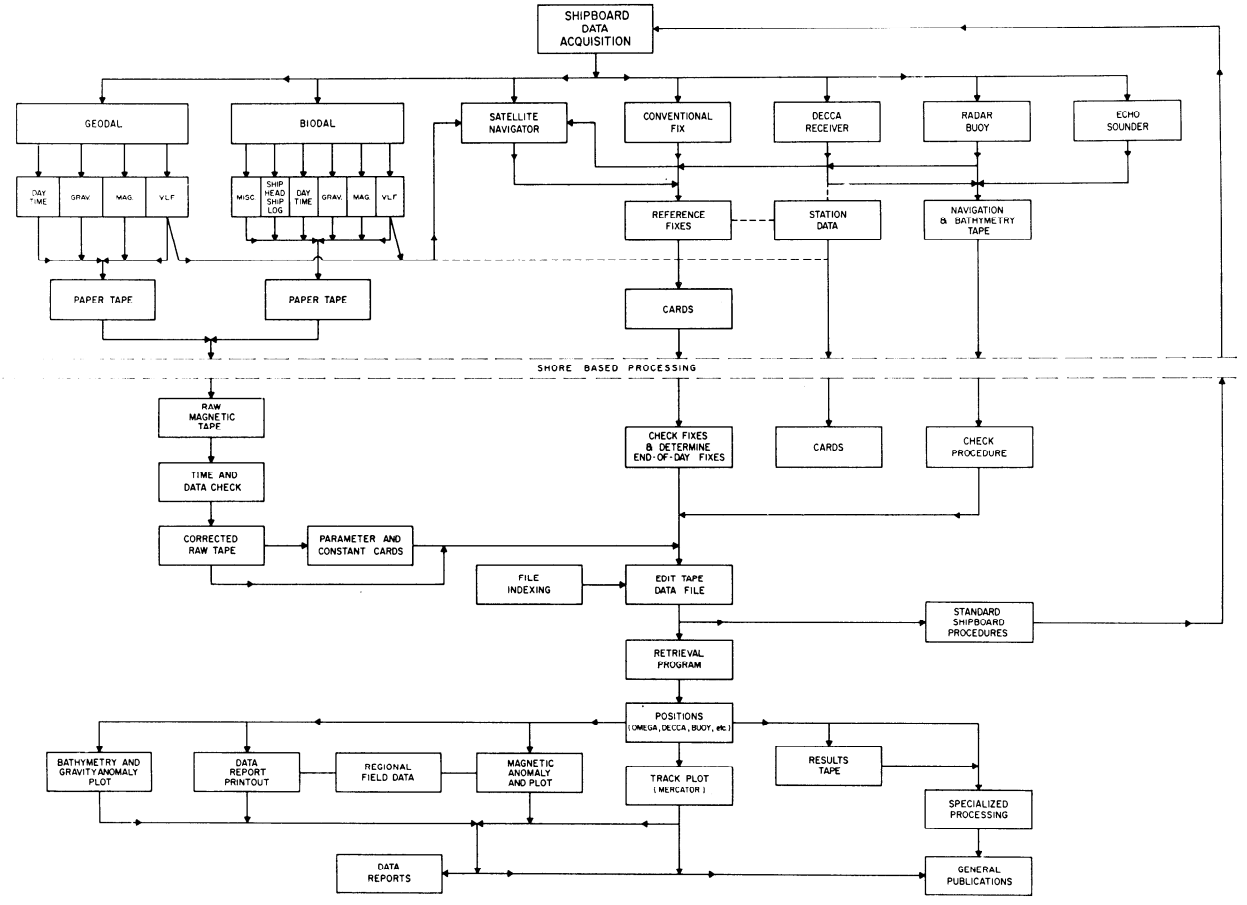

Fig. 4. Data handling procedures developed for the shore-based Data Storage and Retrieval System. (This diagram does not include the shipboard data analysis procedures with which all preliminary analysis is carried out.)

At present, 594 charts are included in the system. Some reprints (1,208) have also been keyworded and included in the retrieval system.

A system that enables the recorded data of an underwater camera station and the geological and biological data interpreted from the resulting photographs to be coded, digitized and stored with a diazo copy of the original negative on IBM cards has been developed. The system enables the data from a large number of underwater photographs from different stations to be used to its full scientific potential. A total of 5,000 photographs have so far been incorporated into the system.

A data storage and retrieval system has been developed for geophysical data collected at sea to complement the shipboard processing procedures presently available. Standard procedures have been developed to prepare the data from a cruise and to merge all available data on a single "edited data" tape. The system is versatile and can be expanded easily to handle extra data which may be obtained in the near future, while still providing easy and rapid access to any particular parameter recorded at any geographical location.

With the establishment of standard procedures for data acquisition tailored to the requirements of the data filing system, data can now be processed and filed immediately after a cruise returns from sea. Facilities are therefore available for the final processing of data for publication within a short time of the completion of a project, thus allowing the early revision of preliminary shipboard charts produced with the aid of shipboard computing facilities. An additional feature of the retrieval system is the facility of producing a standard format data report for distribution to other Institutions. Three such reports have been issued since the system became operational early in 1968.

Figure 4 illustrates data handling procedures that have been developed. The shore based processing consists of two separate procedures: (1) the editing and filing of data; (2) the retrieval and processing of data for publication. In the actual files, data is indexed by time but a card control system is used to provide access by geographical location (Marsden Square Number) thus enabling direct retrieval of small sections of data by geographical location if it should be required. Software development is being continued in order to increase the efficiency of retrieval and the range of processing that can be accomplished during the retrieval of data.

G. N. Ewing
B. D. Loncarevic
D. I. Ross

Electromagnetic studies

In order to supplement our knowledge of the composition of, and temperature distribution in, deeper parts of the earth below the ocean, it is desirable to make other geophysical measurements at sea in addition to gravity and magnetics. One of the ways to achieve this is by making electromagnetic measurements on the sea floor. In order to investigate the problem inherent in making these measurements, an experiment was carried out in 1966 in which magnetic and electric measurements were made at Fredericton, N. B., Halifax, N. S., and Sable Island. The data from the stations have been analysed by using power spectral techniques to obtain a conductivity profile across the eastern coast of Canada and to study the effect of the coast on the magnetic and electric variations. The results indicate an anomalous behaviour in the intensity of the vertical component of the magnetic field at Halifax for periods between 30 - 35 min and a gradual increase in its intensity for longer periods from Sable Island to Fredericton. The electric and magnetic fields at each station do not show any marked direction of polarization.

The magnetic field was further analysed by using Parkinson's technique to study the pattern of current distribution below each station. Except for 30 min periods at Halifax, no definite current pattern was recorded at any of the stations.

It was concluded that the enhancement in the vertical component ("z") for 30 min periods at Halifax, in comparison with the other stations, is due to the conductivity contrast between the land and the adjacent shallow sea. The decrease in amplitude of "z" variations at Sable Island compared with the other stations, and the absence of any definite current pattern for periods up to 120 min, indicates the absence of deep ocean effect at this station.

The z/H values obtained at each of the stations were then interpreted in terms of

different conductivity distribution beneath each station. The model which best fitted the observed data indicates a gradual decrease in the depth to the high conductivity mantle from land toward the deep ocean. This interpretation is compatible with seismic and gravity interpretations for this area.

To understand the mechanism of the coastal effect on the magnetic and electric field variations, it is desirable to make simultaneous electromagnetic measurements on land and at sea in areas where large anomalies have been reported. One of these places, Trivandrum, lying on the west coast of India near the magnetic equator, is an ideal place to carry out such measurements. A detailed geophysical investigation was carried out by the Scripps Institute of Oceanography near Trivandrum during May and June 1968, and this provided an excellent opportunity to carry out an electromagnetic experiment in that area. Hence, a joint electromagnetic experiment was planned and carried out in the Indian Ocean by Dr. Srivastava, representing the Institute, and a team headed by Professor C. S. Cox from the Scripps Institute of Oceanography. The experiment involved setting up three land stations at Trivandrum (8°29'N, 76°7'E), and Cochin (10°N, 76°E), in India, and Colombo (7°N, 80°E) in Ceylon, to record fluctuations in the magnetic and electric field of the earth. Similar measurements also were made simultaneously at sea aboard Scripps' *RV Argo 50*, 125 km off the west coast of India along the geomagnetic dip equator (lat 8°), by towing electrodes and magnetometer sensor behind the ship in a fixed pattern. Concurrently, an attempt was made to measure the electric field at the sea floor by moored instruments. The main purpose of these measurements was to investigate the possible causes of the enhancement in the fluctuations of the vertical component of the magnetic field at Trivandrum as compared with those at other magnetic observatories in India. The preliminary analysis of these measurements indicates that the enhancement at Trivandrum could be due to the upwelling of the highly conductive material below the ocean, close to the coast.

S. P. Srivastava

Applied Oceanography

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The Applied Oceanography Section which is jointly supported and manned by both MSB and FRB carries out request surveys, studies and analysis to meet physical oceanographic requirements in fisheries, defence, coastal engineering, navigation, pollution, and basic research. At the time of formation, the Section was comprised of 10 MSB and 4 FRB staff members. At present, the staff numbers 27, with 22 from AOL and 5 from MEL. Mr. H. J. A. Neu, a hydraulics engineer from the National Research Council, joined the staff in 1967 and is engaged in nearshore oceanographic and coastal engineering studies. Mr T. M. Hallett, a recent graduate in electronics engineering, also joined the Institute in 1967 and has been devoting much of his attention to the development of acoustic systems for recovering our moorings.

The nature of the Section's responsibilities necessitates extensive field studies. In turn, this requires that we have adequate facilities for specialized instrument servicing and calibration, as well as for data reduction and analysis. The projects undertaken by the Section range from taking deep ocean current measurements to explore variability in the ocean, to studying the way energy propagates into a harbour. A summary of the Section's activities follows.

[1] Joined AOL.
[4] FRB staff.

Coastal Studies and Deep Ocean Surveys

Cabot Strait

A knowledge of currents and circulation patterns in the Gulf of St. Lawrence is required for a variety of applications, e.g. navigation and ice movements, fisheries and marine production. One part of the physical oceanographic study involves detailed examination of the boundary conditions. In 1966, field studies utilizing two ships were concentrated in the Cabot Strait area. Details of the survey itself have been discussed in the 1966 Bedford Institute Annual Report. The oceanographic data have been computer-plotted but are still being analysed. The current meter data have been extensively analyzed and have been used to draw up new amplitude and phase charts for the cross section. The residual flow through the Strait was found to fluctuate markedly from day to day. Correlations with meteorological conditions over the Gulf have been attempted, but have not yet revealed any simple consistent relationships.

These surveys, for the first time, have provided a comprehensive picture of the currents through a deep strait over a 30-day period and have provided a longer data record for harmonic analysis of tidal currents than had been previously available. As a result, the tidal analysis programs have had to be re-examined for possible revision. It seems evident the program must analyze for more of the minor tidal constituents. Particularly in the shorter 15-day analysis, this requires the assumption of fixed or "regional" relationships between the minor constituents and their associated principal constituents. The questions of whether these relationships should come from longer current meter records from the same area, or from more extensive tidal height data, and whether regional relationships are valid at all when dealing with currents have yet to be resolved.

In 1967 two current meters were placed at one of the 1966 sites. One of these operated successfully for 84 days. It is hoped that this lengthy record will provide a basis for improving our tidal analysis program.

D. J. Lawrence

Physical oceanography of the southern Gulf of St. Lawrence.

In 1964 and 1965 a program was initiated to measure non-tidal currents in the southern Gulf of St. Lawrence by the use of parachute drogues and transponding drift buoys. Relative geostrophic flow was calculated from a network of oceanographic stations occupied during the surveys. The results obtained by the two methods were highly similar. From these surveys there was evidence that gyres 10 - 20 miles in diam were present and moving through the system. These gyres, which appear to form locally and move along with the general flow, have a very significant effect on the thermocline beneath them. Because of this, the moving gyres represent a potential mechanism for producing large fluctuations in the bottom temperatures of nearshore areas. It is conceivable that the centre of an anticlockwise gyre may be a region of increased biological activity because such a gyre brings deeper water nearer to the surface. Greatest activity would be expected for stationary or slowly moving gyres.

In June 1968 a joint 'program with MEL was undertaken to survey the southwestern Gulf of St. Lawrence north of the area covered in 1964 and 1965, and to resurvey part of the area previously studied (Fig. 5). Two ships were employed and plankton, fish eggs, and larval samplings were taken, and physical oceanographic measurements were made. The plan of the survey was to follow and to take samples inside and outside of a gyre, should one be located. More than 200 physical oceanographic stations were occupied at 98 sites, using principally a salinity-temperature-depth recorder recently developed by NRC. Some stations were occupied only once, some twice, and others three times. Ten parachute drogues were released at a depth of 6 m and five drogues at 40 m.

As a survey tool, a running plot of temperature at 20 m depth was maintained. The thermocline, which was normally very sharp (several degrees/meter) was usually found at about 20 m. Thus, it was thought that the 20 m temperature plot would provide a sensitive indicator of gyres. It was further assumed that flow was along the isotherms, with warm water to the right. From this pattern it was concluded that there was a dominant flow from northeast to south-southwest, a smaller area where water was moving to the northeast and a zone between these two flows where the motion was feeble and very weak gyres were present. The movement of drogues coincided with the southerly flow, and also with the apparently weak gyre in the western area, but they gave no indication of other gyres or of the northeast flow. However, when the relative geostrophic flow pattern was computed, it agreed remarkably well with the drogue patterns, and indicated that there was just one, well-established clockwise gyre present. It was unfortunate that a running plot of dynamic heights was not possible as our measurements would have been focused immediately in the vicinity of the gyre. Instead, we continued to expand our area of survey in the hope of locating an intense gyre.

To date, three cruises all have revealed the presence of gyres, but there is still insufficient knowledge of their formation and their persistence. It is, however, essential to have shipboard computer facilities in order to properly assess the flow pattern at the time of the survey. In carrying out this kind of work, speed is always important, thus the use of in *situ* STD's is essential to provide a maximum amount of data in minimum time. Similarly, rapid, automatic biological measurements are required if the more subtle biological-physical relationships are to be established.

R. W. Trites

Deep ocean current measurements

In 1964 a program was initiated to measure currents in deep water south of the Scotian Shelf in order to provide information about the characteristics of the motion of deep water north of the Gulf Stream. An analysis of the currents at one station indicated the presence of a clockwise rotary movement at 180 m depth with a period equal to the local inertial period of 17.8 hr. The progressive vector plot shows this quite well (Fig. 6). A second mooring at the same site indicated the motion persisted for at least 15 days, but did not exist at the 1,370 m depth.

In contrast, a mooring placed in 1965, northwest of the previous site, revealed mainly tidal motions at 240 and 730 m depths. Power spectrum analyses indicated that the period of the predominant coherent movement was semi-diurnal at 240 m and diurnal at 730 m. The

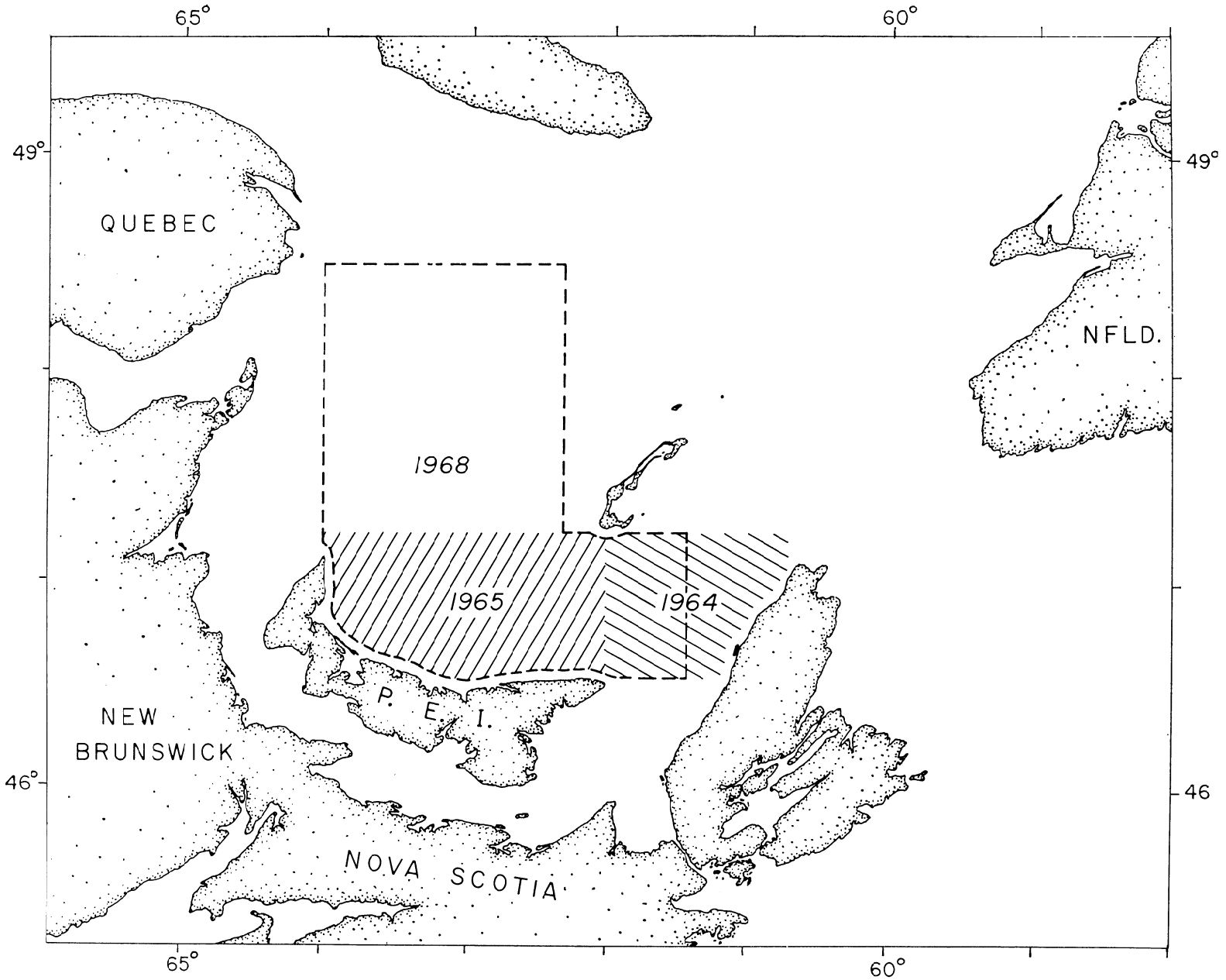

Fig. 5. Areas surveyed in 1964, 1965, 1968 with a 10 mile grid of oceanographic stations.

background noise was slightly lower with increasing depth. Harmonic analysis of the 240 m data gave values for a mean current of 19.7 cm/see flowing towards 229°T and for a semi-diurnal current of RMS amplitude 5.2 cm/sec. At 730 m, the results were a mean current of 4.6 cm/sec towards 096°T and a diurnal current of RMS amplitude of 5.7 cm/sec.

Unsuccessful attempts to recover moorings placed in deep water southwest of the Grand Banks in 1966, together with only moderate successes during the 2 previous years, temporarily terminated the program until an improved mooring system could be developed at the Institute for deep water installations.

D. J. Lawrence

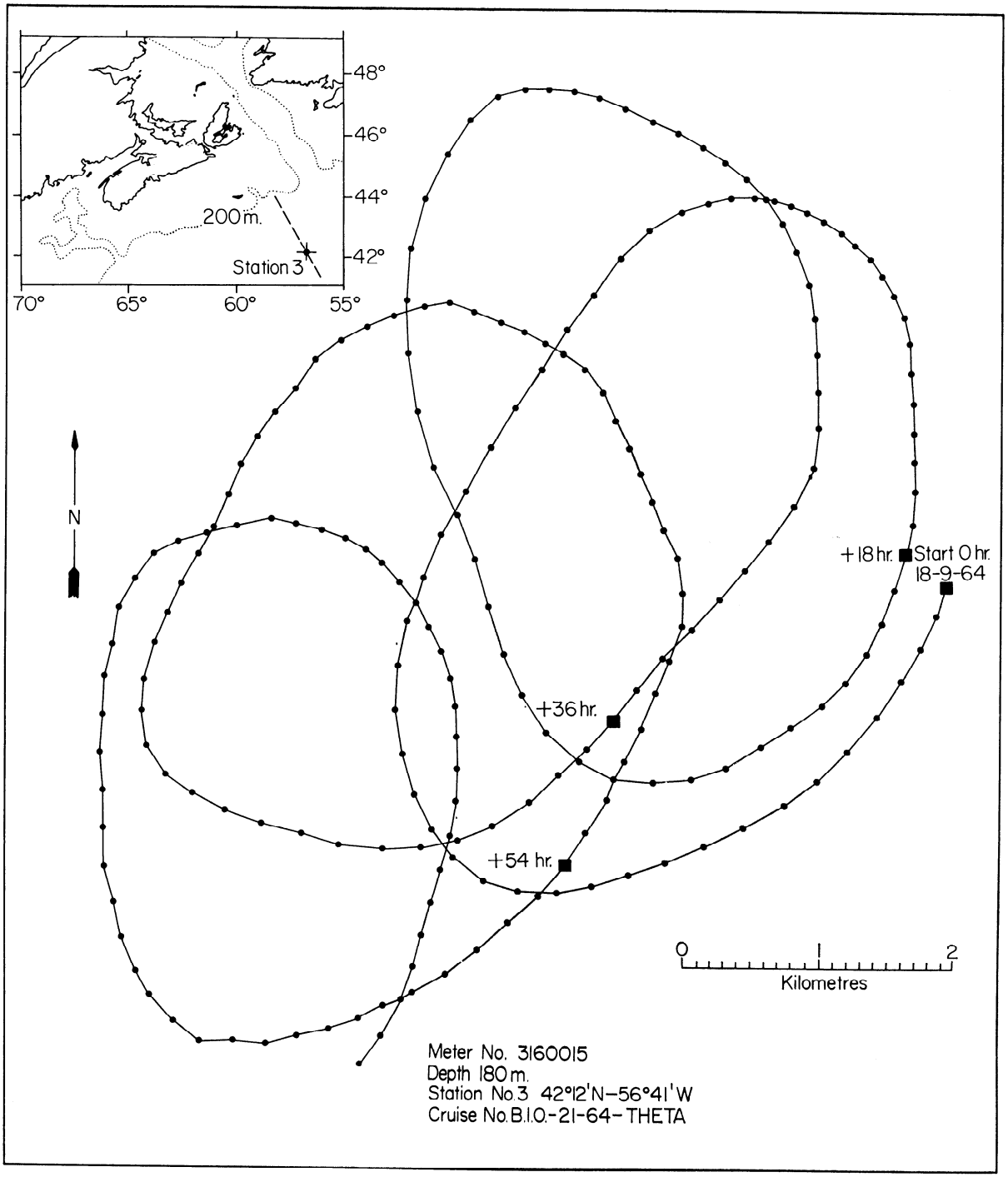

Fig. 6. Progressive vector diagram of the current at 180 m depth as measured with a current meter moored in deep water southeast of Sable Island.

Nearshore Studies

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 the development of marine production studies has greatly emphasized the need for oceanographic information to answer problems arising in fisheries, pollution, and coastal engineering.

The major activity in the nearshore area has been in St. Marga,ret's Bay and its approaches. Limited studies were indicated in 1966 and expanded in 1967 and 1968. The project, aimed at studying the processes underlying marine production, has several investigators engaged in different but related facets of the problem. The Applied Oceanography Section has assumed responsibility for carrying out the physical oceanographic facet of the program, while the biological studies are being undertaken by MEL. Both physical and biological results are reported more fully in the FRB section of this Biennial Review.

A brief physical oceanographic survey was carried out in the Pictou area to complement the work done earlier (1965) in order to determine the flushing characteristics and to predict conditions which might prevail after a causeway was constructed and Boat Harbour was made into a holding pond for effluent from the pulp mill at Abercrombie Point. The 1968 work consisted of releasing dye with the effluent discharging from Boat Harbour for a period of 48 hr and measuring the dye concentration and distribution in the area.

Limited physical oceanographic studies were initiated in the Strait of Canso area in 1968, as background for an anticipated detailed study to be undertaken in 1969. The program consisted of temperature and salinity measurements in the Strait south of the Causeway, the establishment of a Plessey meteorological recording station during the period of survey, and a number of dye experiments. Preliminary results from the survey suggest that the flushing is strongly dependent on the prevailing wind patterns.

Halifax Harbour study

Coastal engineering is a field which has become increasingly prominent in recent years. This has been caused by the failure of various marine structures, and by the need for improved protection of harbours and coastlines as well as the development of off-shore installations. Oceanographic surveys and studies are therefore required in order to provide advice and assistance to those engaged in marine engineering projects.

In response to a request for assistance from the National Harbours Board, the Institute initiated an investigation of swell and wave propagation into Halifax Harbour, where for several weeks of each year, waves from the ocean disturb the loading and unloading of ships. Since feasible proposals were required without delay and since no field observations were available, the problem was subjected to a preliminary analysis in which systematic interpretations based on theoretical principles were applied. The results are reported in AOL Report 68-3. It was concluded that the disturbances of ships in the harbour are primarily caused by ocean waves with periods of 5-10 sec. As shown on Figs. 7 and 8, for a wave train with a 10 sec period, the waves spread as arc-shaped curves over the harbour and approach the wharves of the eastside directly and those of the westside obliquely. Since the natural period of oscillation of a wide range of ships is similar to that of the predominant ocean wave, resonant or near resonant motion of the ships occur. This response is probably the main cause of ship motion in the harbour.

Several proposals were submitted, one of them suggesting that one or two breakwaters be constructed at the entrance to the harbour. The exact location of the breakwaters and the quantitative reduction they would create on the wave height at the wharves, should be studied through a wave model of the harbour.

As restrictive structures of this nature interfere with the natural flow of water into and out of the inlet system, flushing will be reduced and, in turn, the concentration of pollutants in the harbour and basin may increase. Moreover, with reduced water exchanges ice formation could increase. It is anticipated that these factors will be considered as studies develop.

H. J. A. Neu

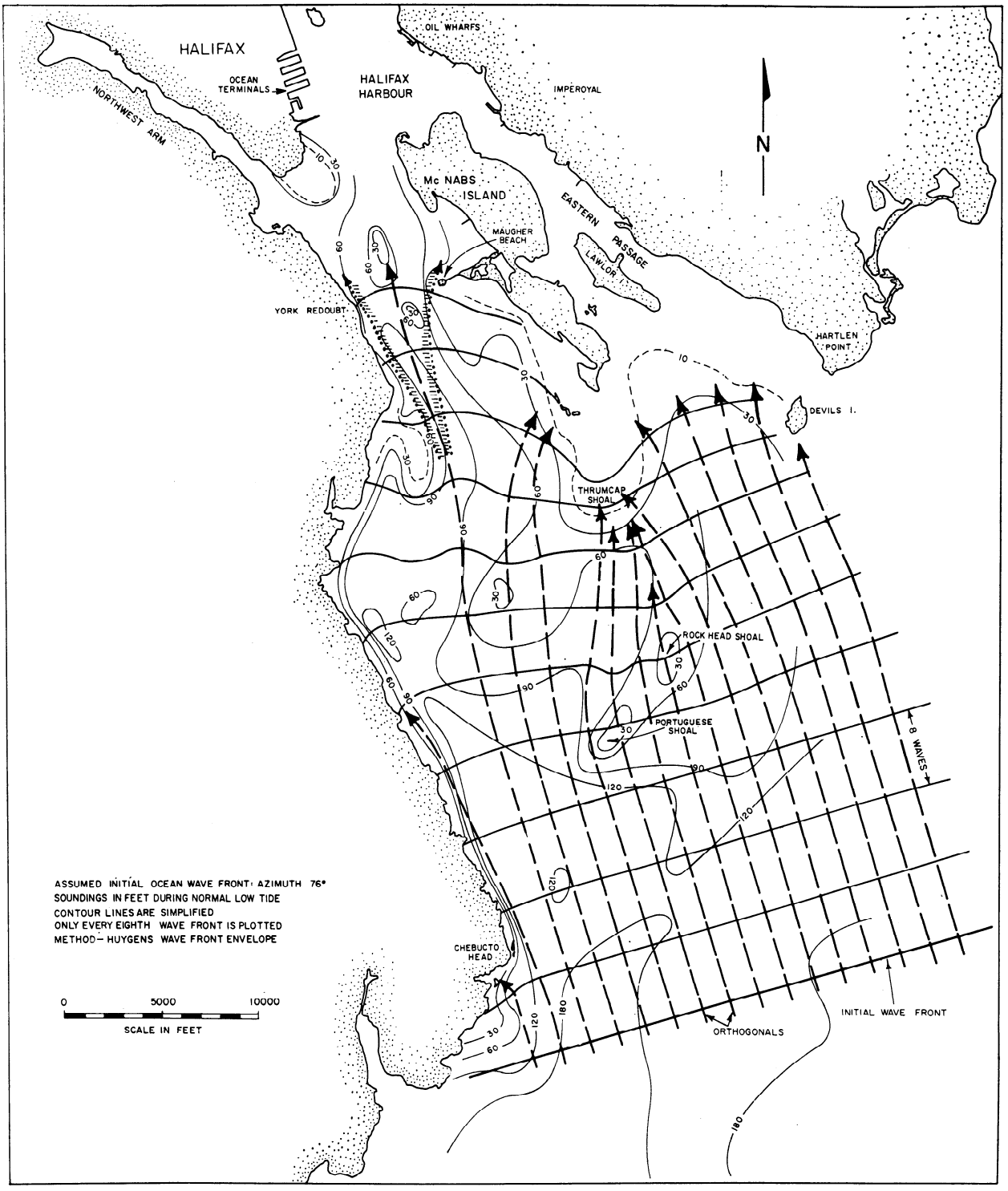

Fig. 7. Wave refraction diagram of a 10-second wave train in the approach area of Halifax Harbour.

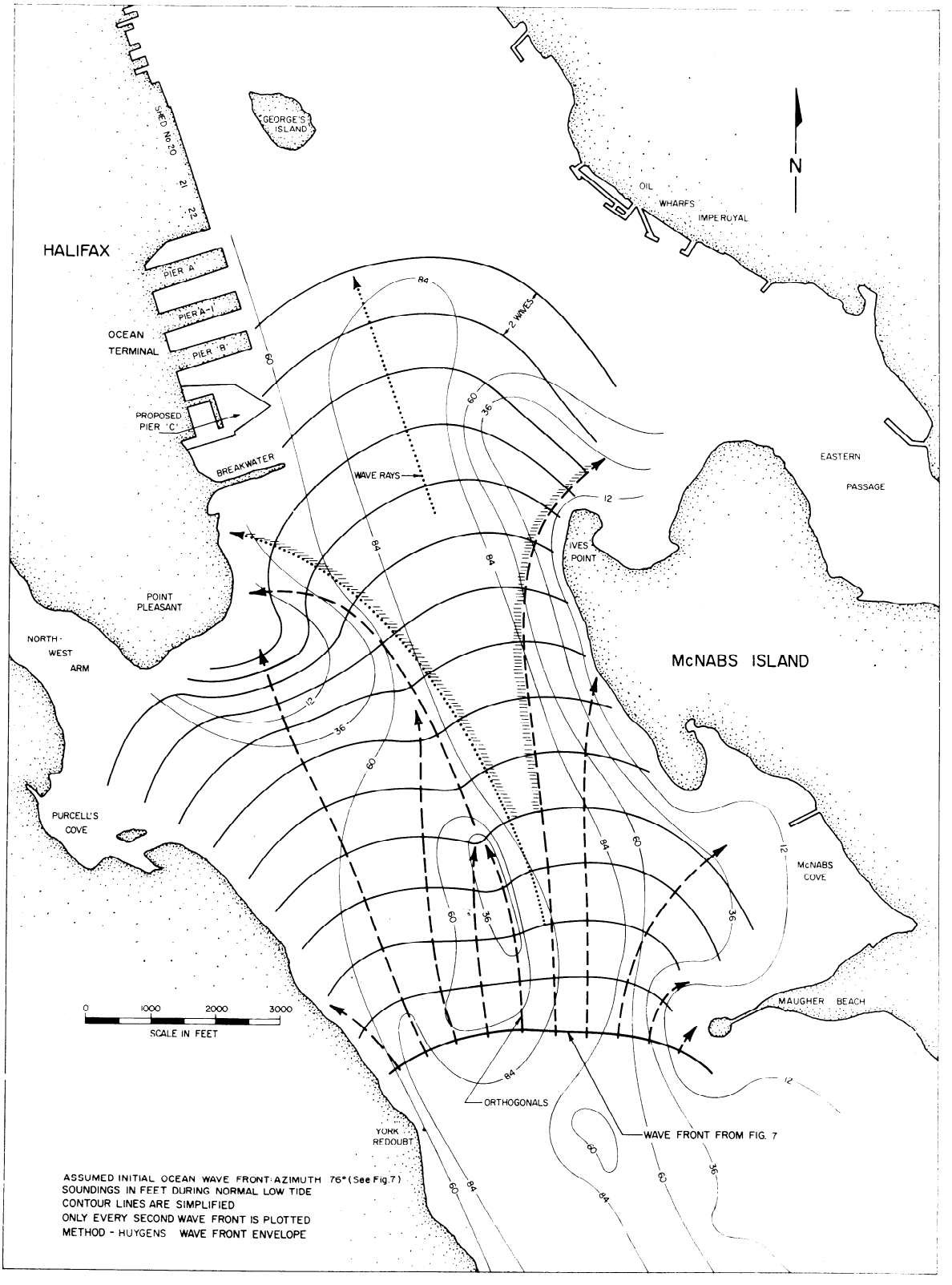

Fig. 8. Wave refraction diagram of a IO-second wave train in Halifax Harbour.

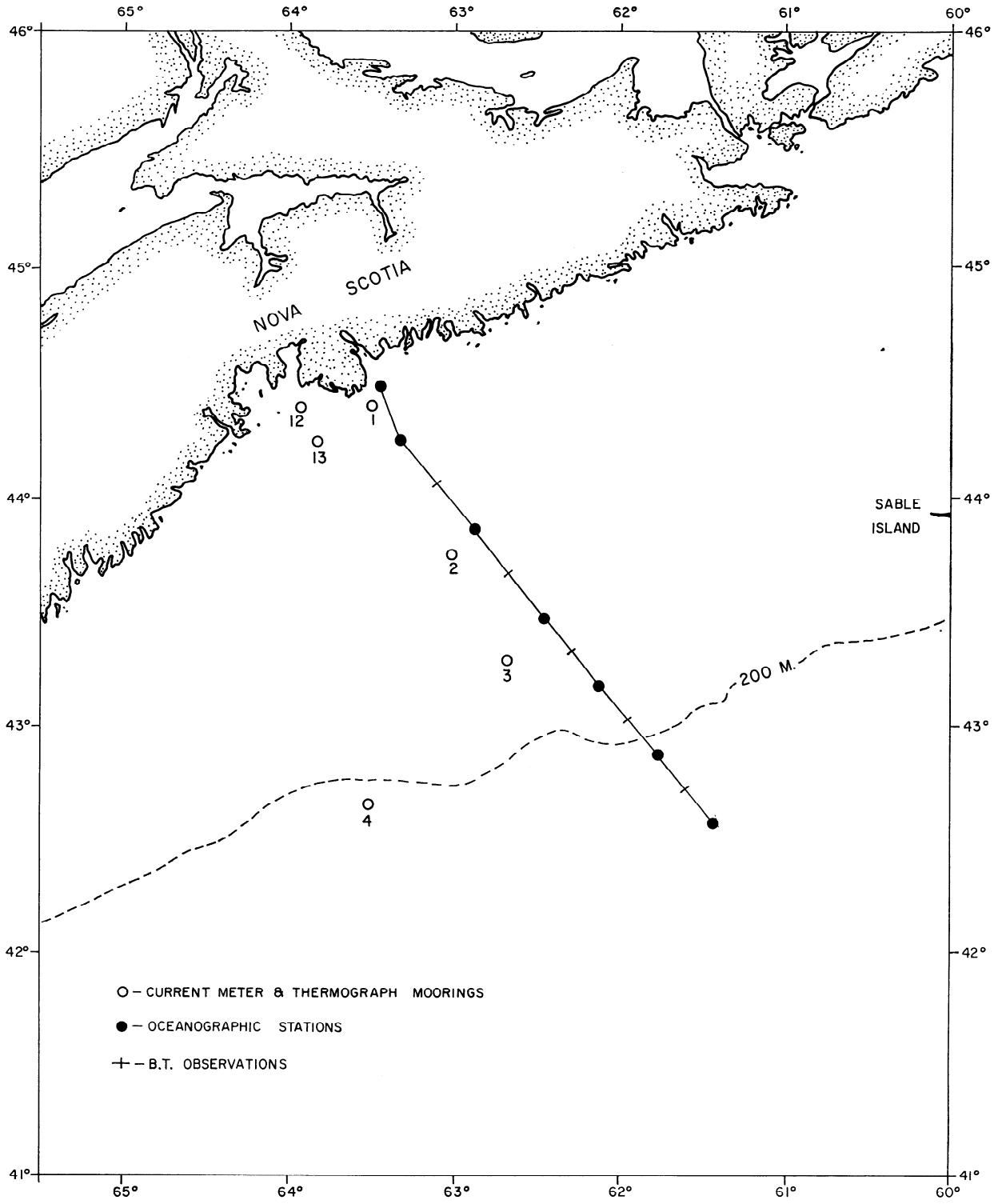

Fig. 9. Location of the Halifax Section oceanographic stations and the current meter and thermograph mooring sites.

Synopsis, Monitoring, Forecasting

A significant proportion of the Section's activities is devoted to providing synoptic physical oceanographic information, which is required by a number of agencies with widely differing needs. There is a requirement for oceanographic information of a climatological nature, for a picture of present conditions and for forecasts of anticipated conditions. The Oceanographic Services for Defence (OSD) Unit, located within Maritime Command Headquarters in HMC Dockyard, Halifax, is jointly staffed by the Institute and the Services. The provisions of synoptic oceanographic charts is mainly the responsibility of this unit. In addition to OSD, a major moored buoy project on the Scotian Shelf was initiated in 1967 to measure variability and to monitor currents and temperature throughout the year. The Gulf of St. Lawrence ice forecast survey is undertaken each November for the Department of Transport, and the Halifax Section continues to be monitored for fisheries purposes.

Scotian Shelf - moored buoy project

In 1950 a network of 30 oceanographic stations on the Scotian Shelf was established by FRB. An attempt was made to occupy these stations seasonally for several years in order to provide evironmental information for fisheries. In the late 1950's, the network was reduced to eight stations located along a line running seaward off Halifax Harbour. This has become known as the "Halifax Section" and, to date, has been occupied approximately 50 times, which has provided a valuable time series of data. The frequency of occupation has varied from one to ten times per year. Although certain features reproduce themselves annually and are detectable from the existing data, there were other fluctuations present about which little could be discerned. Knowledge of currents on the Shelf was very scanty and circulation patterns were inferred mainly from the mass field.

In order to gain needed information about variability in the ocean and the Scotian Shelf in particular, a moored buoy project was initiated in January, 1967, jointly with the Ocean Circulation Group. Four sites were established on the Shelf (Fig.9). Three of these are located relatively near to the Halifax Section and the fourth was sited on the slope in an area where it was thought it would be a sensitive indicator of deep water replacement in Emerald and LaHave Basins. The sites have been instrumented with a total of 11 current meters and 12 temperature recorders.

Despite the difficulties experienced with ship scheduling, as well as corrosion and interference with moorings by fishing activities which have resulted in significant losses, the data obtained have been very valuable. Over the 2-year period, records of more than 70 meter-months of current meter data and of more than 100 meter-months of temperature data have been obtained. Further discussions of the results are outlined in the Ocean Circulation Group's report (p. 15).

R. W. Trites

Oceanographic services for defence

Maritime Command, because of the nature of its military role, is vitally concerned with many aspects of oceanography. Therefore, an operational Military Oceanographic Section was set up in Maritime Command Headquarters. The oceanographic activities of the Command are carried out principally by a Staff Officer Oceanography and his staff. While the activities in oceanography involve research, development, and training, the foremost activity is in the field of synoptic oceanography and forecasting. Data are received as daily radio reports both from ships and aircraft travelling in the western North Atlantic and from fixed locations such as moored buoys, ocean station vessels, light vessels, and ferries.

During 1967, over 100,000 sea surface temperatures and 16,600 bathythermograph reports were received and analysed. There were marked increases in data receipts during 1968 due to the more extensive reporting of sea surface temperature by both ships and aircraft. The analysed data are broadcast daily as charts of sea surface temperature, layer depth, and selected bathythermograms. An additional part of this program is the synoptic wave data charts that are prepared and broadcast on radio facsimile twice daily by the Maritime Command Weather Office. These charts are in demand by civilian sources in the Atlantic Region and are used by fishery, weather, and oceanographic interests. To meet this demand, ozalid copies are dispatched by mail 3 days each week. A review of the addresses had indicated a shift of interest from research to fisheries use, resulting in a reduction in the number of charts mailed from

16,000 in 1966 to 12,000 in 1967. A marked increase in the use of oceanographic charts by commercial fishing interests has resulted in the 1968 rate of production of charts for this source alone equaling the total 1967 production.

A second Canada-United States co-operative oceanographic survey was undertaken in October, utilizing two oceanographic research ships and an aircraft equipped with an airborne radiation thermometer for a survey in the eastern Atlantic. The *Canus* co-operative oceanographic survey was one of the most encompassing of military oceanographic surveys and involved not only survey forces but also numbers of operational vessels.

Techniques and procedures for data collection, handling, interpretation, dissemination, and usage have received considerable attention on both the national and international levels. The staff of OSD have contributed to the establishment of the procedures to be used.

W. B. Bailey

ToC

Instrumentation and Systems Development

Mooring systems

As oceanographic parameters vary both in time and space, the physical oceanographer must acquire oceanographic data over fairly wide areas as nearly synoptically as possible and also at selected locations for extended periods of time. The only practical way of acquiring this information is by means of moored instruments. At the present time, self-recording packages are moored for periods of about 2 months. It would be more desirable to have a system that would be able to remain intact and record for at least 6 months. To do this satisfactorily requires, in addition to having suitable instruments, a high probability of success in positioning, maintenance, and recovery of the moorings.

To date, the Institute has done most of its moorings on the Continental Shelf with some mooring sites out to about 1,000 fathoms. Attempts to moor in deep ocean waters have been less successful. Basically the same mooring methods for shallow water sites have been used for a number of years although the equipment has been improved. All moorings are of the sub-surface taut-wire type with instruments suspended in the taut-wire. A surface marker buoy is anchored to mark the site and connected by a ground line to the instrument anchor; no semi-taut or slack wire moorings are used.

Acoustic command releases are being used on some shallow site moorings. They are inserted at the bottom of the taut-wire above the main anchor to allow the wire and subsurface float to remain tethered to the marker buoy anchor after release.

This method is moderately reliable because there are three means of recovery. Normally, if everything is in place at the site, the subsurface float is brought to the surface by means of the acoustic release. The mooring is then brought onboard, subsurface float first, then instrument line, ground line, marker buoy anchor, marker buoy line and marker buoy last. If the acoustic release fails, the mooring is recovered by bringing the marker buoy aboard first and the subsurface float last. If the marker buoy is not at the site and the acoustic release fails, the mooring is recovered by dragging.

Despite the precautions taken, moorings are lost. Most failures seem to be caused by one of the following: corrosion of the terminations allowing the taut-wire to part and drift away with subsurface float; fishing trawlers dragging through the site and destroying the mooring or moving it out of the area; ground line failure during recovery by dragging; inability to find the mooring due to a navigational error either in placing the mooring or in returning to the correct site. Recovery failure caused by corrosion should be reduced in the future by using stainless steel hardware. Cathodic protection is being tried to help cut down the corrosion of the copper “Nicopress” sleeves.

The growing need to extend our moorings over longer periods and into deeper water necessitates that increased attention be given to development of our mooring techniques. In the latter part of 1968, a new program was initiated jointly with Metrology to study and improve our mooring systems.

D. Dobson
T. R. Foote
R. W. Trites

Acoustics location and release devices

In order to improve the reliability of the recovery of moored oceanographic instruments, a program was implemented in 1967 to

develop a system utilizing acoustic equipment. The objectives of the project were to evaluate commercially available equipment, to carry out a testing program, and to develop a feasible system and begin acquisition of the recovery units. The acoustic equipment which was investigated included location devices and release devices.

In August 1967 environmental testing was carried out off the Nova Scotia coast. A total of six engineering test moorings were laid and recovered by an acoustic command release system. Test moorings were placed in water depths ranging from 50 to 1,500 fathoms and releases were effected from two to 15 mile ranges.

In 1968 five moorings have been successfully recovered by using acoustic release mechanisms, and only one has been lost to date. However, the fact that the mooring was left in place longer than the expected battery-life of the release device may explain why it did not release on command. Since the mooring parted during dragging operations and the complete instrument package was lost, it was not possible to verify this conclusion.

Because of errors in electronic navigation systems in certain areas, acoustic transponders are deemed necessary for locating moorings before effecting release. Moreover, as it is possible to trigger a release up to 15 miles from the site, a mooring may be released and never located unless it is fitted with a locating or homing device. A transponder-identification-ranging system composed of modified off-the-shelf items has recently been obtained, but has not yet undergone sea trials.

As a result of the trials described above, it is hoped that a single taut-wire mooring can be used without the necessity for the groundline and marker buoy section, thereby reducing lost equipment costs as well as the chances of having the mooring fouled by ships and fishing activities. Since a single deep sea mooring represents an investment that may exceed $30,000, only a modest increase in reliability of recovery is required to justify the added cost of acoustic equipment.

T. M. Hallett

Instrument shop

An instrument maintenance, calibration, and evaluation shop is operated by this section to handle a selected group of specialized equipment in common use by the section and to a lesser extent by others in the Institute. The major responsibility of the shop is for current meters (Braincon, Hydrowerkstatten, Plessey, Geodyne, Kelvin Hughes, Ott, Hydro Products); temperature recorders (Braincon, Plessey); pressure recorders (Braincon) ; release devices; and buoy lights ; plus additional equipment such as dynamometers; strain gauges; portable meteorological stations; fluorometers; etc. Until mid-1967, the shop had the responsibility for servicing tide gauges, but with the change in responsibility, this function and a staff member were transferred to the Inland Waters Branch of the Department.

Each time equipment is used in the field, it requires servicing before it can be reused. Over the 2-year period, more than 600 service operations were carried out on current meter and temperature recorders alone.

A great deal of time was spent on the Hydrowerkstatten current meters to solve the' film transport failures which first became a major problem in 1967. This has been largely overcome and the instruments are now performing at about the 90% level. Braincon meters are also performing at about this level. We continue to experience difficulties with the Plessey meters because of clock failure and transducer leakage (which in salt water means almost complete destruction of the instrument).

A hydrophone receiver for the Plessey current meters was developed which enables a daily check to be made on the meters and thus immediate recovery if they become defective. The system also permits recording the data, received via the acoustic link, onto a strip chart recorder while the instruments are moored. This is a convenient monitoring arrangement for instruments moored very near shore.

The past 2 years have been a transition period in which the duration of instrument moorings has increased from 15 days to 60 - 70 days. The longer periods of time have created new problems. One of them, corrosion, has been extremely severe, particularly with the temperature recorders, and thus more attention needs to be given to the use of materials and to cathodic protection. The Physical Metallurgy Division of the Mines Branch of the Department has very kindly provided advice and assistance with this problem.

F. Barteaux

Numerical Analysis and Data Processing

In the Data Analysis Group films and magnetic tapes from current meters are developed and processed for tidal, residual, and other functions of currents. A variety of meters are in use: Geodyne (USA), Braincon (USA), Plessey (UK), Hydrowerkstatten (Germany), and Neyrpic (France). Films from the Hydrowerkstatten and Braincon meters are usually developed at AOL and the data on each frame read out by hand. Punch cards are then prepared for computer analysis. Films from the Geodyne and Neyrpic meters and magnetic tape spools from the Plessey meters are processed by outside contract and the Group receives standard computer magnetic tape and paper tape as data records from these meters. The work load per year is approximately as follows: Geodyne 10 films, Hydrowerkstatten 60 films, Braincon 100 films, Plessey 20 tapes, Neyrpic 30 films. Each film or tape represents the immersion of one current meter for a period of about 60 days. The total number of data points processed during the 2-year period has exceed two million.

While individual stages of the data analysis may take a number of days or weeks, the total elapsed time between recovery of the meter to final computer output of analyzed data may take many months. The processing time for poor data varies widely. Routine checking, time-interpolations (where internal clock time does not agree with actual elapsed immersion time) and diagnosis of meter faults are often time-consuming.

Depending upon the length of a current meter record, a 15 or 29 day harmonic analysis is carried out routinely, to provide the phase and strength of the harmonic constituents of the tidal streams, the residual current, and the daily means of resolved components. In addition, a number of other plots such as frequency distribution of speed and direction are provided.

A computer program has been developed for converting the analog output of the Bathysonde, which is in non-linear units of conductivity, into temperature in degrees Celsius, salinity in parts per thousand, and pressure in decibars. The analog graphical signal from the Bathysonde is presently digitized by hand, but a curve-follower that is now under development will soon be able to output paper tape for the computer program. Several programs have been written for handling Plessey thermistor data and also a new version of the OCDA-31-26 mixing program (combines the chemical parameters with the temperature data) has been incorporated into the library of standard oceanographic programs. A power spectrum program has been developed for handling temperature and current meter data, and has been used extensively on the Scotian Shelf records.

F. Keyte

Marine Geology

B. R. Pelletier

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D. F. Clark[1]
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G. Drapeau[1]
C. A. Godden
M. E. Gorveatt[1]
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H. Josenhans[1]
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K. M. Kranck
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R. M. McMullen[3]
M. A. Rashid
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The continental shelves of Canada have an extent of 1.4 million sq miles. This immense area, located mostly in the Arctic and the Atlantic sea-board, as yet only superficially known and representing a tremendous potential of future resources, presents a great task and challenge for marine geology. This is the continuing focus of the Institute's program. This program consists of a spectrum of projects involving the subdivisions of physical geology, geochemistry, and micropaleontology, mostly in Canadian waters (Fig. 10).

Areas in which marine geological studies were carried out include parts of the Arctic Ocean and adjacent continental shelf waters in the Arctic Archipelago, Hudson Bay, the continental shelf and slope off Labrador and Newfoundland, Northumberland Strait and the Strait of Belle Isle, the continental shelf and parts of the continental slope off Nova Scotia, various inshore areas around the Atlantic Provinces and New England, the Bay of Fundy, parts of the eastern Caribbean Sea and Windward Islands, the western North Atlantic Ocean, and the Mid-Atlantic Ridge. In addition, fossil collections were made at type localities and other out-crops in Europe, the West Indies, Venezuela, and Costa Rica.

To carry out the major objective of aiding resources development programs on the marine areas adjacent to Canada, it was expedient to follow a course of fundamental scientific research and instrumental design, together with applications of conventional principles and techniques. This program has resulted in determining subbottom geological structures as well as the distribution of surficial sediments over a large portion of our continental shelves. Other highlights of the program include elucidation of certain principles of sedimentation in Arctic waters, defining physiographic and hydro-dynamic environments of sedimentation in Hudson Bay, new relationships of tidal cycles to sedimentational phenomena in the Gulf of St. Lawrence, the surficial mapping of the Scotian Shelf, a stratigraphic description of the important oil-potential Tertiary rocks on the Atlantic continental shelf and slope, defining new northern limits to ancient ocean circulation in the North Atlantic through the study of microfauna, the discovery of important geological structures on the Labrador Shelf and adjacent northeastern Newfoundland, the potential application of studies in inorganic chemistry to those of chemical pollutants in marine waters, and the continuing long term comparative study of foraminiferal ecology in various latitudes and marine environments of the North Atlantic Ocean.

Many special projects have originated at the Institute which involve instrumental and equipment design. A remotely controlled, submarine rock-coring drill that will be capable of operating at a depth of 1,200 ft has been designed and completed. This drill is designed to recover short core samples of rock and to penetrate unconsolidated cover up to several feet in thickness. An electron microscope has also been acquired and will be used extensively in micropaleontological investigations of various types.

An underwater television system was also acquired and is being adapted for use with other underwater research tools. Equipment designed to assist underwater ecological studies has been further modified and includes such apparatus as samplers, recorders, and in situ sensors or probes. A laboratory experiment has been devised to study living Foraminifera

[1] Joined AOL.
[2] Left AOL.
[3] Transferred within AOL.
[4] NRC post-doctoral fellow.

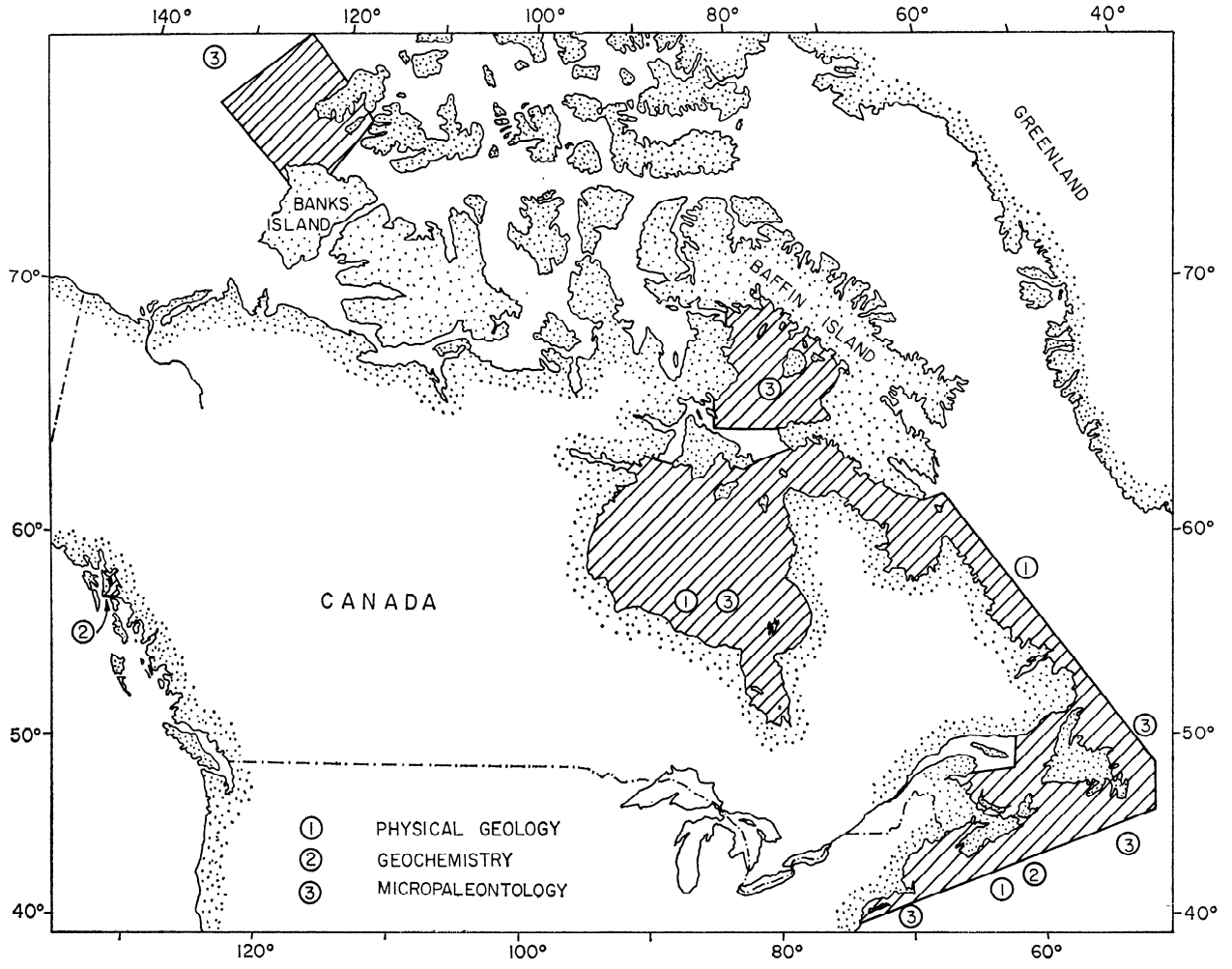

Fig. 10. Projects of the Marine Geology Section in Canadian waters.

and to observe the effects of varying ecological factors under controlled conditions. A series of dives were made at various depths to 1,520 ft in the submersible PISCES-l in Canadian Arctic waters to determine the feaisibility of this vessel to carry out underwater research, exploration, and survey.

The Marine Geology section palrticipated in a display by the Institute at Expo '67, in Montreal. Exhibits and demonstrations illustrating marine geological studies were placed aboard *CSS Hudson* and were attended at Expo by several members of the Marine Geology staff.

A. C. Grant has been on part-time educational leave and is carrying out studies toward a Ph.D. degree at Dalhousie University. D. E. Buckley has completed his studies at the University of Alaska and has returned to the Institute. During 1967 and 1968, five new staff members joined the marine geology section. C. T. Schafer, who arrived from New York University, is carrying on studies in the ecology of Foraminifera and G. Drapeau, from Dalhousie University, is working on sedimentological studies. D. F. Clark, M. E. Gorveatt, and D. A. Clattenburg joined the staff as technicians and are working in the Physical Geology, Micropaleontology, and Sedimentology groups, respectively.

A number of researchers in universities have been assisted in their field work and report compilation. These include G. Drapeau, of Dalhousie University (now with the Institute), J. M. Shearer of Memorial University of Newfoundland, Mrs John Henderson (formerly Penny Wise) of Johns Hopkins University, Sandra Tapley, Jill McRoberts and C.

Yorath of Queen's University, I. M. Harris of the University of Edinburgh, J. D. Macdougall of McMaster University, Professor K. Hooper of Carleton University, J. Iqbal of Dalhousie University, T. Hoffmann of Heidelberg University, and J. Adshead of the University of Missouri. In addition, J. L. Usher, R. Greggs, and L. Smith, of Queen's University, received logistical support for research that they carried out in conjunction with a program of the Institute's project in the eastern Ca,ribbean Sea.

B. R. Pelletier

Physical Geology

The Physical Geology Group carries out investigations in stratigraphy structure, sedimentology, and geomorphology in marine areas. Field information is gathered by means of mechanical samplers and seismic equipment. These geological data, the environmental dynamic data and the results from the laboratory are collected in order to obtain an interpretation of both ancient and modern environments, as well as to assemble the geological and physiographic history of the marine areas under investigation.

J. I. Marlowe

Arctic and Sub-Artic

Arctic Ocean and Adjacent Channels of the Queen Elizabeth Islands. For the past several years a continuing program of bottom sampling and geomorphic analyses of the sea floor comprising the Arctic continental shelf and the adjacent channels of the Queen Elizabeth Islands has been underway. Early results of the study showed the existence of an ancient, submerged fluvial system that underwent modification by the action of valley glaciers that originated in the highlands, and whose remnants exist as modern, local ice caps. In the past 8,700 years the land has risen relative to sea level and more than 1,000 ft of elevation has been restored due to the combined action of adjustment following a period of ice unloading, and to incompletely understood vertical and warping movements in the earth's crust.

Many environments of deposition in Arctic waters have been examined, namely: river, lake, delta, channel, and open ocean. Principles of sedimentation have been established such as the exponential decrease in size of particles over linear distances in a down-current direction. Patterns of sediment distribution have been defined for areas undergoing uplift and these results have been applied to the ancient sediments in the geological column. Other analyses were made on organic carbon content to show that such values are somewhat lower than world values except for the open ocean which appears to be consistent. Clay minerals were identified and related directly to parental bedrocks in the source area thereby establishing the detrital nature of these minerals.

B. R. Pelletier

Hecla and Griper Bay Area, Queen Elizabeth Islands, District of Franklin. Examination and analyses of the bottom samples collected from Hecla and Griper Bay (48 grab samples and 8 samples from two short cores) during the summer of 1966 was completed during the period under review. The laboratory study consisted of textural, heavy mineral, and clay mineral (by x-ray diffraction) analyses. More than 50% of the material in most samples was finer than sand size, although several samples were predominantly sand size and coarser. In cases where the sand size and coarser material makes up about 15% or less of the sample, it is probable that the coarser material has been ice-rafted. The heavy mineral suite is fairly complex, with garnet, amphibole, pyroxene, and zircon being the dominant minerals. A notable mineral occurrence is fluorite; it appears in small quantities (<2%) in many samples but does go up to over 10% in one. The x-ray diffraction results have not as yet been fully interpreted.

R. M. McMullen

Hudson Bay. Models of sediment transport have been devised from an analysis of bottom sediments and their relation to the bottom morphology of Hudson Bay. Three fundamental physiographic zones have been discerned, consisting of the shallow shelf zone which extends from shore to the 80-m bathymetric contour, the intermediate slope zone which lies between 80 and 160 m below sea level, and the deep zone which extends below 160 m to the bottom of the Bay at approximately 240 m. Generally coarsest sediments occur in the shelf zone and the finest in the deeps. However, very coarse as well as very fine, ice-rafted sediments are found in all zones. By removing the coarse ice-rafted material

from the analyses, and by removing proportionate amounts of assumed ice-rafted sediments in the finer fractions, a model of sediment transport was constructed. This model showed that the distribution of sedimentary textures was related partly to physiographic zones and partly to areas of varying hydrodynamic vigour. Thus the nearshore, shallow-water sediments of the shelf zone are coarse because of their proximity to wave action, while the deep-water sediments are fine because they are deposited in quieter waters.

B. R. Pelletier

Atlantic seaboard

Labrador Shelf. From July 12 to August 31 1967, approximately 550 nautical miles of continuous seismic profiler coverage was obtained on the Labrador Shelf from 15 locations between Hudson Strait and the Strait of Belle Isle. A number of dredge and core samples of the unconsolidated bottom sediment were also collected. This work was done on board the *MV Fredrick L. Blair,* which at that time was under charter to Tenneco Oil and Minerals, Ltd.

The seismic profiler results confirm the "marginal channel" along the Labrador coast as marking the approximate contact between Precambrian crystalline rocks and layered rocks occuring on the outer shelf. A number of large-scale structural features were outlined, and several interesting contacts within the layered rocks were traversed. The analysis of these data is in progress. Further work on the Labrador Shelf was carried out in the autumn of 1968 from the *CCGS d'lberville.* Tenneco Oil and Minerals, Ltd. conducted a marine seismic survey within their permit area on the Labrador Shelf during the summer of 1968.

A. C. Grant

Shelf and Slope Northeast of Newfoundland. An interpretation of approximately 875 nautical miles of continuous seismic profiling from the continental margin northeast of Newfoundland has been completed, and the results are discussed in the B. I. Contribution No. 125. The data were collected in June and July 1966, in conjunction with a Dalhousie University Institute of Oceanography cruise on board the *MV Theta.*

On the continental shelf, the seismic profiler recordings show an accumulation of unconsolidated sediments ranging in thickness from 30 to 150 m, unconformably overlying bedrock that dips gently eastward toward the continental slope. The distribution of these unconsolidated sediments indicate that the banks that compose the "shelf-edge rise" are not primarily composed of morainal material, but consist rather of areas of positive relief on the bedrock surface. Anomalous strike-dip relationships associated with these bank areas suggest that they may also have structural significance. The underlying bedrock layers are truncated by the continental slope, and there is reversal in the dip of these layers from eastward to westward beneath the slope. The axial zone of the resulting fold apparently coincides very nearly with the axis of a large magnetic anomaly that extends along the continental margin in this region. Within the continental rise an area of irregular bottom topography is considered to be due to the accumulation of large masses of sediment by slumping. Sub-bottom reflectors at depths beyond the continental rise show crumpling, which is assumed to be further evidence of mass-movement due to gravity. Superficially, the continental margin northeast of Newfoundland appears similar to parts of the continental margin to the south of the flank of the Applachian structural complex.

A. C. Grant

Grand Banks. In addition to samples collected in 1964 and 1966, a further 484 underway and grab samples were collected by *CSS Baffin* during her hydrographic survey in 1967 and 70 more by Dr B. K. Sen Gupta in the same summer. All of these samples have been texturally analyzed and statistical parameters, such as standard deviation, mean, etc., have been calculated using a computer program developed at the Institute. The heavy mineral analysis of the samples is not yet complete, although about 200 samples have been studied. On the basis of the textural analyses, a number of different sedimentary types (sand, gravelly sand, silty sand, etc.) have been identified and their areal distribution on the Grand Banks has been mapped. In general, this shows that a predominantly gravel facies covers the central western part of the Grand Banks, a mixed sand and gravel facies covers the central and northern areas, while a predominantly sand facies covers the remainder, except for a linear band (about 100 miles by 25 miles) of fine sediment parallel to the southwestern edge of the Tail

of the Banks. Some of the results of this study will be published in a joint paper with Dr B. K. Sen Gupta.

R. M. McMullen

Strait of Belle Isle. An investigation of the nature of the bottom in the Strait of Belle Isle was undertaken in co-operation with the Newfoundland and Labrador Power Commission in order to examine the feasibility of laying power cables across the strait. This investigation was carried out on the chartered *MV Fairmorse.* Fifteen hours of video tape were recorded with an underwater television unit, 167 bottom samples were collected, and 100 miles of echo-sounder profiles were recorded.

Bottom sediment in the strait was found to be composed of gravel and shell detritus. Underwater television was used most successfully to obtain information on this sediment.

G. Drapeau

Northumberland Strait The study of bottom sediment distribution in Northumberland Strait is close to completion. A map showing bottom-sediment composition of the strait has been compiled on a scale of 1:150,000. Grain size analysis of the samples was completed and grain size parameters calculated. This data was examined in relation to source area, depth, bottom configuration, and currents. The results indicate source area and depth to be negligible factors, while currents and bottom configuration exert a major and minor influence respectively on the distribution. Extensive current data available for the strait including maps of the areal distribution of tidal current amplitudes show that the large scale distributional features are controlled by the maximum tidal current amplitudes. Distinct tidal current regimes in the western part of the strait have caused a two-fold sediment distribution pattern to develop. West of Abegweit Passage, as well as in the narrow passages south of Woodbland, average tidal current speeds above 0.5 knots prevent the deposition of mud, and restrict the bottom material to sand and gravel.

In the central and western part of the strait where currents are less than 0.5 knots, a mud deposit covers most of the bottom. Bottom configuration becomes a distributional factor only near the shores and on shoals where an earlier bottom surface protrudes through the mud. A direct linear relationship exists between maximum tidal current speeds and the grain size of sediments for material with median diameters above 4ø (.062 mm). Material finer than this appears to settle out without further sorting by currents. This is believed to be due to the fluctuating properties of particles below this size or the action of "settling lag" or "scour lag" processes. Further examination of the material will attempt to determine what portions of the grain size curves or which grain size parameters are most sensitive to current amplitude differences.

K. M. Kranck

Sediment Transport by Tidal Currents. An investigation of the mechanisms of transport of suspended sediments by tidal currents was initiated in 1967. During two cruises to Northumberland Strait 840 suspended sediment samples were collected using a U.S. Corps of Engineers suspended sediment sampler, modified for use in salt water. The suspended sediment was sampled every 24 hr at two or four different depths, and undisturbed bottom samples were obtained by diving. During the period of sampling, current speed and direction were also monitored. At selected stations continuously recording current meters were installed for 28 days or more. The samples are presently being analyzed to determine concentration and grain size of the suspended material. The vertical, horizontal and temporal variations in these factors are related to the current velocities during sampling as well as to the long term averages for the station. Tentative preliminary results indicate a direct relationship between current velocity and concentration for particles larger than 9ø (.002 mm). Material below this size does not settle appreciably during slack tide but remains in suspension irrespective of current conditions.

K. M. Kranck

George *Bay.* A study of the bedrock and structure of George Bay and the surrounding land is being carried out jointly with the Geological Survey of Canada. From continuous seismic (Sparker) lines a preliminary structural map of the bay has been produced. This is being examined in relationship to the geology of the neighbouring shores mapped by conventional survey methods. Outcrops in the bay itself have been discovered and located through extensive Scuba diving on selected shoals.

K. M. Kranck

Bay of Fundy. This study deals with a compilation of geological and oceanographic data obtained on cruises carried out by Dalhousie University and the Institute. Sounding charts have been produced by the Canadian Hydrographic Service who also carried out a bottom-sampling program while the sounding operations were underway. These samples were texturally analyzed at the Institute and the results were related to the bottom topography and the distribution of the tidal and oceanographic currents. With aid of a ternary diagram in which the apices consist of 100% gravel, 100% sand, and 100% mud respectively, the gravel/sand/mud ratios were plotted for each sample. Two distributional patterns emerged: (1) sediments that occurred in areas of extreme hydrodynamic vigour belonged to the gravel-sand field of the ternary plot; (2) sediments that occurred in areas of less hydrodynamic vigour belonged less to the gravel-sand field and more to the sand-mud field. This is to be expected and thus it is possible to outline areas of varying hydrodynamic vigour based on results obtained from a textural analysis of the bottom sediments.

Dr. D. J. P. Swift and A. Cok, formerly of Dalhousie University, carried out seismic investigations in the bay and, over several seasons, Swift made numerous geological studies on land surrounding the bay. His interpretation shows that the Bay of Fundy is ancient, presumably formed during a period of subaerial erosion in Mesozoic time. However, the evidence of modification by glacial scour is strong; a flat striated pavement borders the bay, and glacial drift is common. Both longitudinal and transverse troughs occur; the former in the early stages when ice advance was controlled by topography, the latter when the ice sheet was thick enough to follow the regional gradient of eastern North America.

B. R. Pelletier
D. J. P. Swift, Old Dominion College, Norfolk, Virginia

Halifax Harbour. In October 1966, a detailed seismic profiler survey was made of a one-half mile strip across Halifax Harbour, immediately to the north of George's Island. The survey was undertaken at the request of the Port of Halifax Commission as a contribution to a feasibility study of a Halifax Dartmouth tunnel at this site, and was carried out in conjunction with a hydrographic survey by Messrs. A. L. Adams and E. J. Comeau of the Canadian Hydrographic Service.

The maximum depth of water in the centre of the harbour at this location is 95 ft, and the seismic profiler results indicate that the apparent thickness of the underlying unconsolidated sediments is between 50 and 60 ft. The harbour appears to occupy a bedrock channel that was glacially cut, or at least scoured, and infilled with till. Within the area surveyed the till was removed along a stream channel approximately 1,000 ft wide, and the stream channel was subsequently infilled with stream-borne sand and silt. The harbour bottom is blanketed by foul black mud, in places exceeding 15 ft in thickness, that is presumed to be of modern accumulation.

A. C. Grant

Southwestern Scotian Shelf. This project was undertaken to complement studies of the areal geology of other parts of the Scotian Shelf carried out by L. H. King, utilizing the interpretation of echo-sounder records to delineate sediment patterns on the bottom. The project also served as a subject for a Ph.D. thesis that will be submitted to Dalhousie University.

The study made use of echo-sounding records taken along traverses spaced one-half mile apart, and bottom samples collected at intervals to verify conclusions as to bottom type that were interpreted from the records. Two hundred forty-two samples were obtained during the cruise over the area on the CSS *Kapuskasing.*

The results obtained by this method are very accurate and were used to assess the value of a conventional bottom sampling survey done previously over the same area. Statistical models based on trend and factor analysis were computed using data from the earlier survey and were compared with the sedimentary facies delineated by the present technique. The analysis based on the echo-sounder technique was found to be more accurate and complete.

G. Drapeau

Continental Slope off Nova Scotia. Beginning in 1963, investigations were made into the geological nature of the continental slope near Sable Island. These investigations, which were concentrated in a large submarine canyon ("The Gully"), were concluded in 1967 and a

summary was made of the stratigraphy of the area. Data obtained by dredge sampling and geophysical surveys in The Gully were combined with information from the continental shelf, in part obtained by L. H. King, to form a regional synthesis.

Formations cropping out on the sides of the canyon have been sampled over a vertical range of approximately 1,200 m. The lower 800 m of this section contain microfaunal remains of Oligocene to lower Miocene age: Sediment textures are generally fine-grained and indicative of a low-energy environment of deposition, although there is a slight increase in grain-size upward in the section. The sediments are composed of quartz, illite, chlorite, with an accessory suite that is mature to supermature in the lower part of the section but reflects the influence of an eroding land mass in the upper few hundred metres. A comparison of The Gully section with stratigraphic information obtained from other areas on the outer continental shelf suggest that depth conditions, during the time represented by most of the section, were similar to those of today. Fresh, terrigenous detritus appears in the upper part of the section, however, suggesting that depths may have decreased during the Oligocene and early Miocene. Mineral assemblages associated with specific formational groups on shore appear in the same interval, suggesting further that shallow-water processes played an increasingly significant role in the presumed post-Oligocene time.

Formations that crop out in The Gully appear, on the basis of areal compilation of data, to be offshore facies of sedimentary units which are correlative to deposits of similar age in Georges Bank and the emerged Atlantic Coastal Plain. Seismic evidence indicates that these units have the characteristic offlap structure of the Coastal Plain Province and hence suggest that cuestaform outcrops may lie in the up-dip direction beneath the unconsolidated sediment on the continental shelf.

J. I. Marlowe

Caribbean project

Grenada Trough and Aves Ridge. A geological investigation of the stratigraphy, structure and petrology of the Grenada Trough, in the eastern Caribbean Sea, was carried out as part of the Institute's cruise in that area from late January to late March 1968. Data were collected by bottom sampling, echo-sounder surveys, and bottom photography. Sixteen core samples with a maximum length of 40 ft were collected from the Trough and parts of the ridge, and 12 dredge stations were occupied on Aves Ridge.

Sediment in the Grenada Trough is composed of mixtures of pteropod tests, volcanic material and land-derived detritus, in varying proportions. Distinctive particles of volcanic glass occur in a downwind dispersal pattern to leeward of Martinique and St. Vincent and are traceable for approximately 100 miles. On Aves Ridge, localized deposits of certain volcanic deposits (vitric lapillae) suggest the existence of an extrusive centre in that area.

Dredge samples from Aves Ridge show that the ridge is made up in part of well-lithified limestone. Internal structures of this rock suggest strongly that the ridge was in the past exposed to water depth much shallower than the present depths over the ridge: the rock has a distinctive reefoid character and several samples contain probable algal structures. The diagenesis of calcareous rocks in this area is of especial interest, as the rocks appear to have been consolidated under marine conditions. This aspect of the investigation is now being stressed.

J. I. Marlowe

Southern Grenadines Islands. Sedimentological and related ecological studies of shallow-water coral reef environments in the southern Grenadines were started in 1968. Field work was carried out from a shore base on Carriacou Island, established as part of the *CSS Hudson* marine geological cruise to the Caribbean. By the use of small boats and Scuba and skin diving 400 bottom samples were collected in the nearshore areas of Carriacou, Petit St. Vincent, Petit Martinique, Union, Palm, Mayero Islands, and the Tobago Cays. Eh, pH, salinity, and temperature were determined and bottom fauna sampled at selected stations. To complement the shallow water sampling 40 grab samples were collected from the offshore areas of the Grenadines, 123 samples were collected from the beach, and continuous current measurements were made during the survey.

The 400 bottom samples give a preliminary concept of the nature and distribution of

the sedimentary texture found on the modern coral reefs of the Southern Grenadines Islands. The dominating sedimentary components consist of sand-size carbonate material derived from the mechanical breakdown of reef-building organisms, and terrestrial detritus from the erosion of volcanic formations on the Islands. Hard bottom composed of coral growth and algal balls is extensive. Practically no silt- and clay-size material was found on the Grenadines Bank and it is concluded that fines are swept by currents off the bank into the neighbouring slopes and deep basins.

K. M. Kranck

ToC

Regional Geology and Geochemistry

A major program is being conducted to map the near-surface structure and stratigraphy of the bedrock underlying the continental shelf off Nova Scotia, and to relate it to the regional geology.

Geochemical studies are being carried out on surficial material from the Scotian Shelf. As an understanding of the geological setting is basic to determining the relationship of the depositional environment to the chemical constitution of the organic matter associated with the sediment, considerable effort is devoted to the sedimentological and stratigraphic problems of the unconsolidated sediment, and detailed mapping of the surficial geology is being carried out.

Geological program

Surficial Geology of Scotian Shelf. Surficial sediments on the Scotian Shelf can be grouped into five major units, based on an interpretative detailed study of echograms, an examination of bottom samples, continuous seismic reflection profiles, radiogenic ages, and paleontological data. In Pleistocene times the continental shelf was covered with glacial debris. During the rise in the sea level from the low stand occupied at the peak of the glacial period much of the glacial debris was reworked and winnowed material deposited in littoral or sub-littoral environments. The presence of an end-moraine complex on the Scotian Shelf is of much interest and significance in interpreting the glacial history of the region. The unconsolidated sediments rest on an erosional unconformity developed across the bedrock surface.

Work currently in progress will provide surficial geological coverage for the whole of the Scotian Shelf. The practical value of these data was demonstrated in connection with submarine cable ploughing trials. These data may also be utilized in engineering fields (such as in laying future pipelines and anchoring drilling platforms), as a basis for further studies of the Scotian Shelf in the marine geological and biological sciences, in mineral and petroleum exploration and as an aid to the fishing industry.

Bedrock Geology of Scotian Shelf. A study of the near-surface bedrock stratigraphy and structure of the entire Scotian Shelf is being conducted utilizing continuous seismic-reflection profiles. Profiles representing nearly 4,000 miles of traverse have been accumulated. By analyzing uncomformable relationships and differences in acoustical characteristics, two major bedrock units can be recognized. These overlie and wedge out against the seaward extension of Ordovician and Carboniferous rocks from the land areas of Nova Scotia some 30 miles from the present shore line, and the strata dip gently seaward in a southerly direction. The major topographic features on the shelf are of erosional, rather than depositional origin and are mainly controlled by the configuration of the underlying bedrock,

Dredging operations carried out from *CSS Hudson* in 1967 at a site some 50 miles north of Sable Island yielded several hundred pounds of bedrock. Subsequent paleontological studies indicate that the material is Lower Cretaceous in age.

Field and Mapping Activities. Sampling for chart 4040, Halifax-Sable Island, was virtually completed during 1966 field season. Additional cores were obtained in the clay and silt units in 1967, and this chart is now ready for final drafting. Underwater television and still-camera photography was carried out from CSS *Kapuskasing* in 1968 at 19 stations on chart 4040 and bottom photographs representative of the various surficial geological units will be incorporated in the report to accompany the chart.

From April 12 to June 1 1967, geological sampling was carried out from *CSS Kapuskas*-ing at 286 bottom stations. This essentially completed the sampling required for completion of the surficial geology on chart 4012, Yarmouth

-Halifax, carried out in collaboration with G. Drapeau, a Ph.D candidate from Dalhousie University. A start was made on the sampling for chart 4041, Banquereau-Misaine. Approximately 1,236 miles of continuous seismic reflection profiles were obtained.

A coring and dredging program was carried out from *CSS Hudson* in September 1967. Nine piston cores varying in length from 40 to 60 ft were obtained in the clay and silt units and will be used for sedimentary, paleontological, and radiogenic studies. Forty-seven dredge hauls were made, seven of these being of special significance because of the recovery of samples of Cretaceous sediment.

From April 1 to May 23 and June 5 to 21, 1968, 584 sample stations were completed for chart 4041. An additional 1,288 miles of continuous seismic reflection profiles were obtained in 1968 and underwater photography was carried out at 21 stations.

Personnel also participated in a geophysical cruise aboard *R/V Chain* from Woods Hole Oceanographic Institution in 1967; in a cruise with D. H. Loring of MEL aboard CSS *Kapuskasing* engaged on a continuous seismic-reflection survey in the Gulf of St. Lawrence in 1968 ; and in a cruise aboard *CCGS John Cabot* in connection with cable ploughing trials on the Scotian Shelf southwest of Halifax, and experiments in conjunction with Woods Hole to obtain a long core from the continental rise in the same area.

Organic geochemistry

In an attempt to characterize the organic matter associated with the sediment samples from the Scotian Shelf, the organic extracts are being examined for their functional group content and molecular weight distribution.

Oxygen-containing *Functional Group Determination.* The major functional groups in the organic matter from marine sediments are: carboxyl, phenolic and alcoholic hydroxyls, and carbonyls. This organic matter possesses low acidic properties as compared to the organic matter of soils and coals. The carboxyl groups make a larger contribution to the acidic properties than the phenolic hydroxyl groups. The carbonyl group content in marine organic matter was found to be considerably higher than in terrestrial organic matter. These differences may be due to the restricted oxidative condition prevailing in marine sediments.

Molecular Weight Measurements. The molecular weight distribution measurements of humic acids extracted from different clay samples was determined by column chromatographic techniques using various grades of Sephadex gels. The results show a wide range of distribution in molecular weight from less than 700 to over 200,000 in all cases and over 2,000,000 in a few cases. In general the marine organic matter appears to have a considerably higher molecular weight than soil organic matter.

Fractionation of Humic Acids. The humic acids were fractionated on the basis of molecular weight to obtain components of different molecular weight ranges. Functional group study and elemental analysis of each component indicates that the major oxygen-containing functional groups are mainly concentrated in low molecular weight fractions. With increasing molecular weight the functional group content decreases. In all the fractions the carbon content increased with increasing molecular weight while the oxygen content decreased.

L. H. King
M. A. Rashid
B. MacLean

Inorganic geochemistry

Inorganic geochemical processes in the marine environment include all processes which result in chemical alteration of the aqueous and solid phases without the influence of biological processes or biogenic materials. Processes of this type have been responsible, in part, for the observed nature and distribution of marine sediments and for the evolved chemical composition of present-day seawater.

Endicott Arm Alaska. A program of research, which was in partial fulfilment of the requirements for a Ph.D degree at the University of Alaska, was undertaken by the author to gather specific information on the nature of land-derived sediments and to observe the diagenetic changes that occur as these sediments are transported through fresh, brackish, and finally marine environments. The Endicott Arm study area was selected because it possessed several desirable attributes: (1) it is located in an isolated section of Southeast Alaska where the contaminating influence of human activity is negligible; (2) the source of terrigeneous sediment is a monotype, being

singularly of the glacial type; (3) the estuary is restricted geographically to a narrow arm 30 miles long having a single outlet to the open sea.

Information gathered during this program includes : (1) quantitative determination of the suspended sediment load; (2) mineralogical identification of the suspended sediments ; (3) determination of the ionic adsorptive and exchange capacities of the clay minerals found in association with the several aqueous environments ; (4) evaluation of the chemical portion of six major and three trace cations between the aqueous phase and the solid phases ; (5) standard chemical, physical, and geological oceanographic data which describe the marine estuary.

An understanding of the processes of chemical exchange between suspended sediments and seawater is of immediate importance because of the need for information on the transport and deposition of pollutants and radio active material in the natural aqueous environments.

D. E. Buckley

ToC

Micropaleontology

Micropaleontological investigations at the Institute involve various aspects of the relationship of microorganisms to their environment. These relationships, from both laboratory and natural environment, are utilized in the interpretation of ancient 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 scanning electron microscope, x-ray diffraction and electron probe micro-analysis of modern and ancient benthic and planktonic microorganisms is continuing. A fairly complete stratigraphy of Mesozoic through Pleistocene sediments has been determined. These correlations have been based on the relative abundance of tests of different species, the appearance and extinction of key forms and the relationship of the constituent organisms to those in the type locality.

G. A. Bartlett

Arctic and Sub-Arctic studies

Arctic Archipelago. Continuous foraminiferal studies are in progress from bottom sediments of the inshore and offshore waters of the Queen Elizabeth Islands. In the 1967 and 1968 field seasons a total of 127 grab samples and 17 cores were taken from Marie Bay, Fitzwilliam and M'Clure Straits, and Crozier Channel (lat 74°30' - 70°00'N, long 115° - 125°W). In M'Clure Strait, in addition to the sampling of sediment, vertical plankton tows have been carried out at five localities and temperature and salinity measurements were taken at 50 m intervals, as part of the long-range studies of foraminiferal ecology carried out at AOL.

In comparing the results of recent studies with earlier work in Prince Gustaf Adolf Sea, Hecla and Griper Bay, and Hazen Strait, the following points emerge: (1) The faunal division of deep and shallow zones at the 200-m isobath is not present in Fitzwilliam Strait, Crozier Channel and in M'Clure Strait to the east of long 121°. The deep-water sediments of these areas lack the calcareous forms and planktonic Foraminifera abundant at corresponding depths in the previously worked areas. (2) Planktonic Foraminifera are present in surface waters and in sediment in M'Clure Strait west of long 121°.

G. Vilks

Hudson Strait and Labrador Sea. During September and October of 1967, vertical plankton tows and bottom sediment samples were taken in the northern part of Hudson Bay, Hudson Strait, and the Labrador Sea. The field work was carried out from aboard *CCGS Labrador.*

The purpose of the work was to investigate the extent to which planktonic Foraminifera are found in the surface waters of these marginal seas. Although remains of planktonic Foraminifera were found in the sediment in Hudson Bay, living planktonic Foraminifera were found only in the waters of Hudson Strait to the east of Big Island and in the Labrador Sea. It was concluded that surface waters entering the area from Foxe Basin lack planktonic Foraminifera and only waters originating in the Atlantic Ocean contain planktonic Foraminifera.

G. Vilks

Hudson Bay Area. During the Hudson Bay Oceanographic Project cruise in 1965, samples for faunal study were collected, both from the bottom of the bay, and from raised marine deposits around the bay. At least 263 species, fossil and recent, have been recorded

from the area. Foraminifera form the most abundant group (142 species), with Mollusca next in numbers (80 species). A comparison of the fossil collections with the species currently present in the bay suggests that water temperatures during the early stages of inundation of the area (Tyrrell Sea) were probably not too different from the present temperatures, but that at first the water was less saline than it is now.

F. J. E. Wagner

Canadian east coast studies

Foraminiferal Ecological Studies in the Inshore Marine Areas of the Atlantic Provinces. Recently completed were detailed studies of foraminiferal ecology in Tracadie, New London, and Malpeque Bays, P.E.I., Miramichi Estuary, New Brunswick, LaHave River and Annapolis Basin, Nova Scotia. Similar studies were initiated in St. Peters and Cardigan Bays, P.E.I., Merigomish, Canso, Ship Harbour and Lunenburg Harbour, Nova Scotia. The detailed environmental analysis is conducted on a weekly or semi-monthly basis throughout the year. These studies assist the determination of growth physiology and reproduction of microorganisms in the field, and therefore permit a better interpretation of ancient environments. Field studies are being co-ordinated with laboratory studies being conducted by D. Walker.

G. A. Bartlett

Prince Edward Island. Studies of the temporal and spatial variation of benthic Foraminifera populations are currently being conducted in New London Bay and the Gulf of St. Lawrence. It has been found generally that accurate quantification of foraminiferal data is only possible after consideration of many disturbing influences. Samples collected in New London Bay indicate a clumped spatial distribution for both living and dead foraminiferal populations. The limits of variation are considerably less for counts of dead specimens thereby suggesting post-mortem redistribution of tests.

Factors influencing the numerical accuracy of benthic Foraminifera population counts include: (a) pressure waves generated by samplers that disturb the sediment surface before the mechanism contacts the bottom; (b) turbulence and mixing caused by activation (triggering) of the sampling device; (c) partial loss of sample, together with sediment mixing, as the sampler is raised to the surface; (d) feeding and/or locomotive habits of invertebrates and certain species of fish.

A preliminary survey of the distribution of benthic Foraminifera in Northumberland Strait has been completed. Specimens of *Miliammina fusca* living in an atypical environment in the offshore areas of the Strait have been noted and will be studied in detail in the near future.

C. T. Schafer

Grand Banks. A study of distribution patterns and ecology of the Grand Banks Foraminifera was begun in November 1966. The field and laboratory work is now complete and two papers are being prepared (one jointly with Dr R. M. McMullen) on the data and their interpretations.

The first set of 27 bottom grab samples studied quantitatively could be analyzed only for total populations and not for living populations; a few of these samples were collected by the Pan American Oil Company in 1964 and the others were obtained during a hydrographic cruise of *CSS Baffin* in 1966. In July-August 1967, the author participated in a cruise of FRB on the *M/V A.T. Cameron* on the Tail of the Banks and obtained Van Veen grab samples and bathythermograph records from ‘70 stations. Subsamples of the top l-cm layer were obtained from the grabs that were apparently undisturbed. Forty-six of these subsamples were later used for the quantitative study of foraminiferal distributions ; the others were used to furnish supplementary qualitative information. A suitable split of every sample was processed in the Institute’s sedimentology laboratory for the mechanical analysis of sediments. Some plankton tows were also made during the 1967 cruise to collect living specimens of planktonic Foraminifera. The morphologic and taxonomic aspects of this foraminiferal study were greatly facilitated by an examination of some type material stored in the U.S. National Museum, Washington, D. C.

Eighty-eight benthic species have been identified in the total (living plus dead) foraminiferal assemblage; of these, 43 have been found living in the 1967 samples. The mean number of benthic species occurring in a sample is 22.3, with a coefficient of variation of 39.24%. Both the number of species and the

abundance of individuals (expressed in terms of unit volume or unit weight of sediment) are inversely related to the grain-size of the substrate. The percentage frequency of the most abundant species, *Islandiella islandica,* also increases in finer sediments. An opposite relationship, however, is observed with the attached form, *Cibicides lobatulus;* its abundance increases sharply in coarser substrates.

The living/total ratio in the 1967 samples varies between 0.1 and 45.7%, with the values somewhat erratically distributed. One well-defined area of high living/total ratios (over 20%), however, exists as a tongue extending from the middle part of the Tail of the Bank to the southeast edge; this is possibly an area of rapid sedimentation. In contrast, two small areas of low living/total ratios (below 1%) are found on the southwest shoal.

The percentage of planktonic individuals in the total foraminiferal content of any sample is apparently a function of water depth and currents. This percentage is low on the plateau of the Tail of the Bank (generally well below 10%) but increases rapidly away from the edge of the Bank, as the depth increases to about 110 m and more.

B. K. Sen Gupta

Recent Foraminifera on the Nova Scotian Shelf. Detailed descriptive and taxonomic studies of Foraminifera (both benthic and planktonic) in water masses and sediments of the Scotian Shelf are continuing for the purpose of determining the distribution of this fauna. The recent Scotian Shelf fauna is composed of more than 100 foraminiferal species. *Globobulimina auriculata arctica, Nonionellina labradorica, Bulimina marginata, Cribrostomoides crassimargo, Cibicides lobatulus* and *Elphidium incertum* "complex" dominate the recent benthic faunas. *Globigerina pachyderma, Globigerina dutertrei, Globigerina bulloides* and *Globorobolia inflata* are common planktonic forms. Sediment cores from the shelf contain a fauna with very few species. Generally, *Eliphidium incertum* "complex", *Elphidium orbiculare* and *Islandiella islandica* are the only species present. Apparently the sediment a few centimeters below the surface is relict. C^{14} dates confirm this suggestion.

G. A. Bartlett

Atlantic Ocean study

Recent Foraminifera of the Atlantic Ocean. For the past few years, deep cores have been obtained from the western Atlantic Ocean and the Mid-Atlantic Ridge. Detailed morphological studies and coiling directions of characteristic species are also continuing for the purpose of deducing ancient climatic and oceanographic conditions. The possibility of former warmer seaways through the Atlantic Provinces, and a more northerly occurrence of Gulf Stream circulation are being investigated particularly as evidence is on hand to corroborate these suggestions.

G. A. Bartlett

Mid-Atlantic Ridge. Between July and September 1968, eight deep-sea cores and 69 plankton tows were taken over the Mid-Atlantic Ridge (lat 45°00' - 46°00'N, long 25°30' - 29° 50'W). The material will be used to correlate the existing foraminiferal population in plankton with known oceanographic parameters and to extrapolate the information to the study of sediment cores taken in the same region.

The field work was carried out from *CSS Hudson* Cruise 22-68.

G. Vilks

Planktonic Foraminifera in the North Atlantic and the Caribbean Sea. Between January and April 1968, 128 plankton tows were taken from aboard *CSS Hudson,* Cruise 6-68. In the North Atlantic plankton stations were located at approximately 100-mile intervals along the ship's track from the vicinity of the Grand Banks, (lat 44°20'N, long 55°17'W) to the Anegada Passage, (lat 18°00'N, long 63°30'W). In the Caribbean Sea plankton was collected each day at least at noon and midnight regardless of the ship's position, but within lat 11° - 18°N and long 59° - 65°W.

The initial study of the material resulted in the following correlations of planktonic Foraminifera and various watermasses encountered within the area of survey:

Slope water *: Globigerina bulloides, G. pachyderma, G. falconensis, G. quinqueloba, Globorotalia influta;* Gulf Stream: *Globorotalia hirsuta, G. truncatulinoides, Globigerinella aequilateralis, Globigerinoides ruber* (white) in addition to the slope water forms;
Sargasso Sea : characterized *by Globorotalia hirsuta, Hastigerina pelagica, Globigerinoides ruber* (pink), and *Globigerinoides conglobatus;*

Caribbean Sea : Abundant *Globigerina dutertrei, Globorotalia tumida, Globigerinoides trilobus trilobus,*

G. trilobus sacculifera, Globorotalia menardii, G. crassaformis, Candeina nitida, and *Sphaeroidinella dehiscens.*

G. Vilks

Shallow Renthonic Foraminifera - St. Lucia, West Indies. A comparative ecological study of shallow-water tropical benthic Foraminifera was carried out on the bottom sediments of three bays on the leeward side of St. Lucia, namely, Choc, Port Castries, and Marigot. These bays were sampled by Scuba divers in February and March 1968. Subsamples were obtained of the top and second centimeter layers. Also, physical and chemical parameters of bottom waters, such as magnitude of currents, temperature, salinity, pH, oxygen, total phosphates, and nitrogen (as nitrates and nitrites), were measured. Sedimentary grain-size data have been obtained for all samples.

In the Port Castries Bay (average depth 11 m), the abundance of living Foraminifera is considerably less than that generally found in more northerly waters. A patchy distribution of living individuals is particularly evident in areas of relatively denser populations. The living Foraminifera observed in the second centimeter subsamples probably reflect mixing and shifting of the substrate. The total benthic foraminiferal assemblage consists of 112 species of which 46 are recorded as living. This living population is dominated by species belonging to the superfamilies Rotalicea, Buliminacea, and Miliolacea; *Ammonia beccarii* (Linné) is the most abundant species. The living/total ratio in the assemblage attains a maxium of 31% off the mouth of the Castries River and indicates a relatively rapid sedimentation rate in this part of the Bay. The planktonic/benthic ratio is very low, typical of shallow-water and near-shore conditions.

B. K. Sen Gupta
C. T. Schafer

Molluscan studies in Caribbean Sea. The author participated in the Marine Geology cruise to the eastern Caribbean area between February 26 and April 11, 1968. Molluscs are currently being studied from 32 grab samples (depth range, 21- 2,195 m) and 19 dredge samples (depth range, 14 - 1,630 m). Planktonic molluscs (e.g. pteropocls) greatly outnumber the benthic molluscs in the deep samples, while the reverse is true of the nearshore, shallow samples. In contrast with the large, showy molluscs found near shore, those from deep water are small (many are microscopic) and generally pale or uncoloured.

F. J. E. Wagner

Circum-Atlantic Paleoecologic and Stratigraphic Correlation Studies of Mesozoic, Tertiary and Pleistocene Formations. Field trips have been carried out in the Tertiary outcrop area of the London-Paris basin in the UK and France as part of a long term circum-Atlantic correlation study. Collections of sediments containing Foraminifera were also made in Germany, Switzerland, and Italy. In addition collections were made and stratigraphic sections were studied in the West Indies and. Venezuela. Certain drill cores from the Grand Banks and the Scotian Shelf together with dredge outcrop from the continental slope off Nova Scotia, were examined in connection with this study. Partial biostratigraphic sections have been completed so that a broad. outline of the Tertiary stratigraphy adjacent to the Atlantic Ocean will soon be available.

G. A. Bartlett

Central America (Costa Rica). A field sampling programme was conducted in Costa Rica in March 1968. The localities visited were within 50 miles of San José, the capital and principal city. The samples covered a composite marine Tertiary stratigraphic column ranging from the upper Eocene to the lower Pliocene. Of the several local sections visited, the most varied one is exposed along the Reventazon River and consists of the well-known Las Animas, Uscari, and Gatun (or Sensori) formations. Many of the local biostratigraphic zones are rich in Foraminifera, both smaller and larger. The material collected from Costa Rica will form a significant part of the Institute's stratigraphic-micropalaeontologic collection from the Caribbean area.

B. K. Sen Gupta

Special Instrumentation and Experimentation

Living Foraminifera Laboratory. During May 1968, the Living Foraminifera Laboratory was established, in which attempts are in progress to study the general behaviour, feeding habits, and reproduction of Foraminifera. Bethonic specimens have been collected from local sublittoral waters, from both sediments and algal fronds. The foraminiferids have been maintained in an incubator, as well as a modified version of Arnold's (1964) culture unit. It is

ToC

anticipated that planktonic foraminiferids will also be cultured.

Those Foraminifera which have been successfully cultured are *: Ammonia beccarii, Discorbis sp, Elphidium spp, and Quinqueloculina seminulum.* An interesting observation was that on the "regeneration" of a new test by an *A. beccarii* specimen. The test was accidentally crushed during one of the daily observations, but the specimen was kept for further studies. Within a week new test material was constructed. Within 4 weeks the new test was larger than the initial one, and was unrecognizable as being *A. beccarii.* Although the surface structure was identical, the organization of the chambers appeared completely random, lacking the typically coiled pattern.

An additional observation involved the possible feeding habits of *A.beccarii.* On a few occasions several flagellates were observed adhered to the pseudopodia; a certain amount of struggling indicated that a mucous, or mucous-like, material might be present on the surface of the pseudopodia, used as a means of capturing prey.

Most of the work completed thus far was conducted to test apparatus and methods. Controlled experiments will be carried out in the near future in order to determine the possible physiological limitations of these organisms. It is anticipated that studies of Foraminifera in the living state will lead to a better understanding of the biology and ecology of natural foraminiferal populations.

D. A. Walker

Shallow -Water Rock Core Drill. A shallow-water rock core drill has been designed for work on the ocean floor at depths as great as 150 fathoms. Parts for construction were obtained from standard land drilling equipment suppliers and subsequently modified for underwater use. This drill will be capable of penetrating 10 feet of sediment before continuing to obtain a 3-5 ft long rock core. It is powered by the electrical system of the handling ship and is remotely controlled. Various operational monitoring systems have been installed, together with electrical safety devices. The drill penetrated 3 ft of mud and 15 inches of bedrock on its first test, and 25 inches of bedrock on its second test at the same site adjacent to the sea wall at the Institute. A ship-board trial was carried out from *CSS Dawson* in Halifax Harbour where 8 ft of gravel and a few inches of bedrock were penetrated. The successful use of this drill, combined with seismic reflection profiling, will greatly enhance geological mapping on the continental shelf.

B. R. Pelletier
C. A. Godden

Deep-Diving Submarine Studies. A feasibility study with a deep-diving submersible was carried out in the Canadian Arctic Archipelago during a 6-week period in August and September 1968 for the purpose of appraising this type of vehicle for underwater geological exploration and research. The Vancouver based PISCES-I was chartered for the investigation and was housed aboard CSS *Labrador* of the Canadian Department of Transport, after being flown in an RCAF Hercules from Vancouver to Thule, Greenland. Several dives were made (nine for geology and seven for other .experiments) to depths as great as 1,520 ft, and for periods up to 4 hr in duration. Dives were generally terminated early due to drifting ice cover which hampered surfacing and recovery operations, the latter carried out by means of the ship's 12-ton crane. A bottom grabber hydraulic manipulating arm and claw, closed circuit underwater television with video tape replay, a strobe-lighted 70-mm camera, upward and forward ranging sonar, a conductivity meter, a gyroscopic compass, inside cameras, and a variety of acoustical equipment with recorders completed the inventory of apparatus used to carry out the study. Generally the submarine, as a mapping tool, proved to be successful in that the bottom could be observed directly, surveying with the aid of underwater reference points could be carried out, and sampling of bedrock as well as bottom sediments could be made directly with the use of externally mounted instruments operated from within the vehicle. These submersibles offer the full capability for carrying out geological exploration anywhere on the continental shelf and on a fairly practical basis. Time and distance though are the two major factors that must be shortened.

B. R. Pelletier

Improved Tools for Ecological Studies. Several sampling devices have been developed and improved and are currently being tested at the Institute. A Benthos Multiple Plankton Sampler

is being modified so that its depth and mechanical functions may be telemetered to the research vessel. A prototype sediment trap has also been designed and tested. The trap is constructed primarily from fiberglass and will be used to study the production rate of planktonic Foraminifera on the continental shelf off Nova Scotia.

Design of a multiparameter recording instrument for use in nearshore ecology and pollution studies was begun early this year. The prototype of this unit has already been employed to measure temperature, conductivity, pH, and oxygen over a 24-hr period at certain locations along the coast of Tracadie Bay, P.E.I.

Procedures have been developed to enable Scuba divers to collect uniform, undisturbed samples of bottom sediment for quantitative foraminiferal ecology studies. A device that permits divers to sample interstitial waters in the surficial layer of unconsolidated marine sediments has also been developed.

C. T. Schafer

Underwater Television. A remote-controlled, underwater television system with a depth capability of 1,000 ft was brought into service in 1967. Operations have so far been conducted in St. Margaret's Bay, on the Scotian Shelf, on the Institute's Caribbean Cruise, and in the Strait of Belle Isle. It proved advantageous to add a remote-controlled film camera and strobe light to the television over the side rig, for the purpose of obtaining selected underwater photographs of the sea bottom. A video tape recorder was also given operational tests and proved to be a valuable adjunct to the system. This equipment can continuously record the signal from the underwater television system, enabling the investigator to examine his information in the laboratory. The underwater television was used by the Defence Research Atlantic Laboratory in the search for a transducer system lost in Bedford Basin during trials and again in the tests of the shallow-water drill in the same vicinity. Experience gained during these operations proves the television to be a valuable asset.

C. A. Godden

Scanning Electron Microscope. Acquisition or a Jeolco scanning electron microscope has now been completed. This instrument is capable of magnifying images to 100,000x with a large depth of focus. Video tape information storage and retrieval facilities will be added later. It is expected that the demand for these microscope facilities will be high from scientists both within and without the Institute. Presently this instrument is being used to examine both external and internal morphology and structure of shelly micro-organisms such as Foraminifera.

C. A. Godden

Marine Geology Data Storage and Retrieval. Because of the great increase in the amount of data being collected by the marine geology staff and the lack of any coherent storage and retrieval system for it, it was decided in the autumn of 1967 to attempt to set up such a system. It was envisaged that all the relevant data both field and laboratory, concerning a sample, would be recorded on specially designed forms and put on to magnetic tape so that they could be machine processable. The initial forms, for field data, have been designed and were used during the Caribbean Cruise and the 1968 summer field season. This was to be a trial period and the forms are to be evaluated and if necessary redesigned in the autumn. Further forms, for laboratory data, will be designed during the autumn and winter.

R. M. McMullen

Miscellaneous Services. Equipment is in operation for the purpose of compounding and evaluating many types of plastics. These have been used for making emergency electrical cable splices at sea and for satisfying the needs of submersible electric instruments. In the latter case, the need for large, heavy, pressure-resistant housings has, in some installations, been eliminated, by replacing them with pressure-equalizing systems.

A high vacuum coating unit, operating at 10^{-5} torr and capable of producing coatings with a thickness range from 100 to 100,000 Angstroms has been installed. This equipment is used to coat specimens for the purpose of controlling refractive indices of specimen surfaces for optical microscopy. It will also be used to prepare specimens for examination by the scanning electron microscope.

In addition, a Zeiss Ultraphot microscope has been acquired and set up.

C. A. Godden

Hydrography

The prime responsibility of the AOL Hydrographic Section is charting all navigable waters within the Atlantic Region as applicable to navigational requirements. The Region is defined as Canada's Atlantic seaboard, the Gulf of St. Lawrence east of Pointe des Monts, Hudson Bay, and eastern Arctic. Within the Hydrographic Section, two auxiliary units are maintained; Draughting, Illustrations and Photography, whose function is to provide a service to the Institute; and Development, whose function is to develop new instrumentation and techniques for higher quality and greater efficiency in field data collection. Regional Tidal Surveys was a unit within the Hydrographic Section until July 1, 1967, when the responsibility for such surveys was transferred to the Inland Waters Branch.

At the beginning of 1967 there were 41 on staff; presently the establishment strength is 47, with two vacancies. Casual employees are used extensively during the survey season to supplement the field establishments; 14 were employed in 1967 and 12 in 1968

Hydrographic Surveys

R. C. Melanson

A. L. Adams
R. C. Amero
A. T. Bent
H. A. Boudrea[2]
W. E. F. Burke[2]
R. M. Cameron
G. G. Clark[1]
E. J. Comeau
P. L. Corkum
F. L. DeGrasse
S. S. Dunbrack
R. M. Eaton
R. G. Fairn[1]
V. J. Gaudet
R. P. Haase
M. A. Hemphill
G. W. Henderson
E. G. Howse[1]
R. P. Janes[1]
A. D. Kenney
G. H. King
C. G. Lagasse[1]
R. B. Lawrence[2]
D. D. LeLievre
R. C. Lewis
D. B. Mehlman
W. B. Millar[1]
C. G. Miller
L. P. Murdock[2]
A. R. Newman[2]
J. M. R. Pilote
M. D. Price[1]
L. D. Quick
J. I. Schneider[1]
J. G. Shreenan[1]
K. G. Spence[1]
T. B. Smith
M. G. Swim
R. L. Tracey[1]
R. G. Wallis[2]
J. S. Warren
K. T. White
R. K. Williams
G. M. Yeaton

[1] Joined AOL.
[2] Left AOL.

The main function of the Hydrographic Section is to chart all navigable waters within the Region. The field side, or data collection facet, is done over a 5½ month period, May-October, each year, and the remainder of the year is spent at the Institute processing the data to completed form. Only the field manuscripts, from which charts are compiled at Ottawa, are actually produced in the Region. Surveys are conducted from both ships and shore-based survey parties and range from a very detailed survey of an extensive area of the Continental Shelf, to reconnaissance in the eastern Arctic. Although electronic positioning systems are used quite extensively, in some instances older methods are still used advantageously.

The departmental ships from which the surveys are conducted are *Acadia*, *Baffin*, *Kapuskasing*, and *Maxwell:* while surveys of the eastern Arctic are undertaken from Canadian Coast Guard Ships. Shore-based parties are supported by two or three 31 ft survey launches and two land vehicles. The field chart revisions are conducted by the *CSL Tudlik*, a 37 ft launch. Hydrographers also participate' in oceanographic cruises to collect bathymetry for the General Bathymetric Charts of the Oceans (GEBCO).

Our main charting effort is presently concentrated in and about the Maritime Provinces with some reconnaissance surveys being carried out in the eastern Arctic. In 1967, there were six establishments engaged in charting the waters of the Maritime Provinces (Fig. 11) and one establishment operating from the CCGS *D'lberville* in the eastern Arctic (Fig. 12). The major offshore effort was made by the *Baffin*, under the direction of F. L. DeGrasse, as a continuation of the Grand Banks of Newfoundland hydrographic/geophysical charting. Surveys of this area began in 1963 and are part of the programme of systematically charting the east coast. The purpose of these surveys is to satisfy three main requirements :

a) Navigation - to provide modern navigational charts in accordance with the international charting programme ;

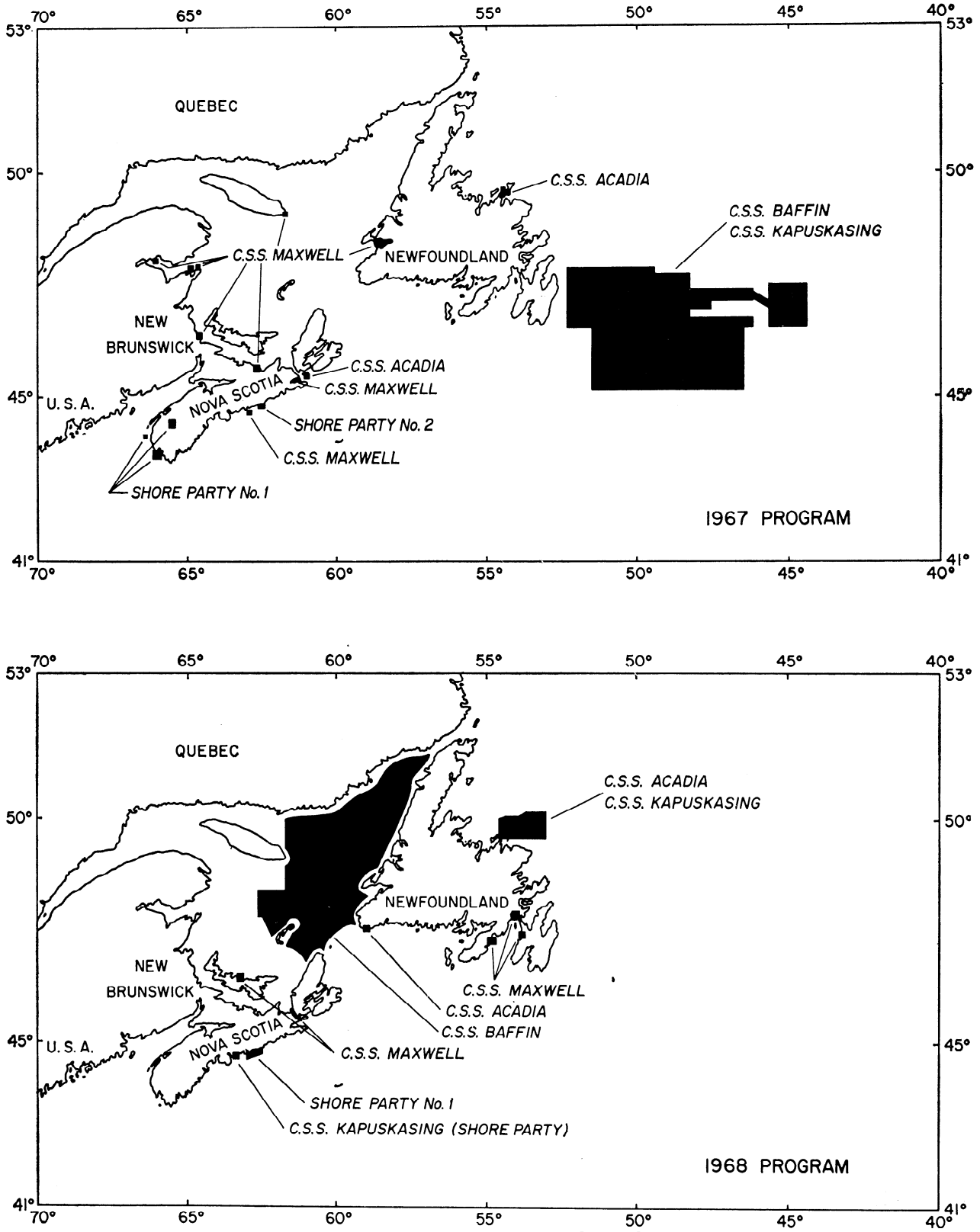

Fig. 11. 1967-68 Program (Hydrography).

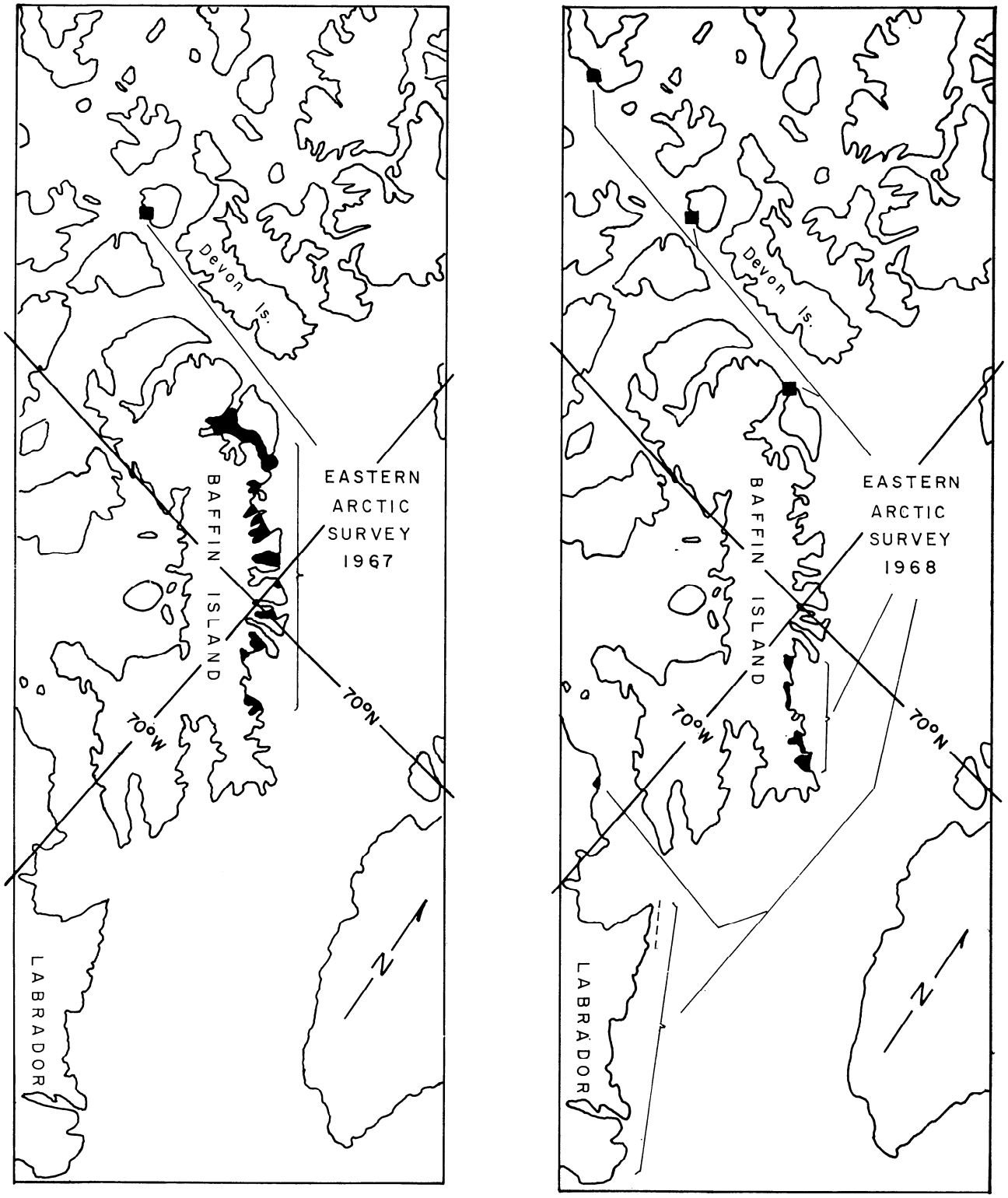

Fig. 12. 1967-68 Program (Hydrography) Eastern Arctic Surveys,

b) Fisheries-to provide fishermen with charts, tailored to their needs, as an aid in their exploration of one of the richest fishing grounds of the oceans:

c) Exploration-to provide petroleum geologists and geophysicists with charts as an aid in their search for oil on the Continental Shelf.

All positioning was done by Lambda (Low ambiguity Decca) in the range/range mode, with maintenance personnel provided by the Marine Electronics Group. As an experiment in parallel sounding, in an effort to increase production, the *Kapuskasing* was used in conjunction with the *Baffin* for part of the season. The *Baffin was* positioned accurately by Lambda, and in turn, positioned the *Kapuskasing,* running in parallel 2 miles off, by radar distance and bearing. It was found that although this kind of operation is feasible, the *Kapuskasing* was not the most economical satellite to use because of its short endurance and high daily operating costs. If this mode of operation is to be continued in future years, a small chartered vessel will be used.

The other five field establishments operating about the Maritime Provinces were chiefly concerned with detailed surveys in support of coastal development, general surveys for the production of modern navigational charts, and chart revisions.

P. L. Corkum, as Hydrographer-in-Charge of the *Acadia,* completed a survey of Petit-de-Grat, N. S., and then continued the survey of Sir Charles Hamilton Sound, Nfld. The purpose of the Petit-de-Grat survey was to provide a detailed chart of the harbour and approach in support of the processing plant expansion by Booth Fisheries Canada, Ltd. The Sir Charles Hamilton Sound survey has continued since 1964 and is part of the overall charting programme to provide modern charts along the east coast of Newfoundland. This passage, last surveyed by the British Admiralty in the 19th century, is being used more extensively each year and is unique in that it is relatively ice-free during the winter months, thus allowing year-round navigation.

J. M. R. Pilote, as Hydrographer-in-Charge of the *Maxwell,* was concerned with a number of small but high priority projects during the season. Eight projects were completed: three along the coast of Nova Scotia, two in New Brunswick, two in Newfoundland, and one in the Gulf of St. Lawrence. The Nova Scotia projects consisted of an examination of a shoal in Pennant Bay, just west of Halifax Harbour, reported by the *CCGS Narwhal;* the examination of a shoal in Cobequid Bay to resolve a discrepancy in depth between the British Admiralty chart and the Canadian chart; and an extensive chart revisory survey of the Pictou Harbour chart necessitated by the establishment of a pulp and paper mill by Scott Paper Limited, the construction of a causeway across the inner portion of the harbour, and recent changes in the town of Pictou waterfront. The New Brunswick projects consisted of a channel survey of Cocagne Harbour in response to a request by the Department of Transport for assistance in establishing appropriate ranges as an aid to fishermen; a clarification concerning a number of points arising from the 1964 to 1966 Chaleur Bay survey; and a revisory survey of the Shippegan to Caraquet chart, In Newfoundland, surveys were made of a portion of St. George's Harbour in response to a request by the Department of Public Works to assist them in determining whether tidal currents were changing the bottom topography of the harbour. In order to resolve a discrepancy between the topography displayed in the Stephenville chart and recent aerial photography, it was necessary to establish additional geographical control and tie it in to the 1927 North American network. In view of the probability that a major pressed board complex would be constructed in Stephenville, it was desirable that the chart be reconstructed using the most recent information. At the request of the Topographical Division of the Surveys and Mapping Branch assistance was provided in establishing geographical control by Aerodist on the eastern extremity of Anticosti Island, P.Q., for mapping and charting purposes. Geographic control will aid the survey of the eastern portion of the Gulf of St. Lawrence. This control not only assisted our operation and that of the Topographical Surveys, but also provided the Geodetic Survey of Canada with an excellent check on the major geographical network covering the Gulf.

Two shore parties were in operation during the season. Party No. 1 under the direction of T. B. Smith conducted surveys

of three areas in Nova Scotia. The major survey, that of Kejimkujik Lake, was made to provide charts for small pleasure craft, in support of the newly established Kejimkujik National Park. This survey was unique because it was the first lake survey undertaken by this office and methods different from those used in coastal surveys had to be applied. Small runabouts, powered by outboard motors, were used as survey craft, and a helicopter was used to spot isolated rocks and mark them for positioning. The survey of the Tusket Islands is part of a continuing programme to provide modern navigational charts. Unfortunately, this was an exceptionally poor year as heavy fog hampered progress continuously. All previous fog records were broken during July, August, and September, with fog horns sounding in excess of 600 hr monthly during that period. The last project provided an extensive survey of Trinity Ledge in order to clearly define its extent and configuration and to determine the least depth. The catalyst for this project was the report that a small coastal freighter, the "Nelson B", which sank in the vicinity after having struck a submerged object, may have struck an uncharted peak of Trinity Ledge. The last survey of this ledge was made in 1855 by the British Admiralty.

Shore Party No. 2 under the direction of R. K. Williams continued charting the east coast of Nova Scotia in the Sheet Harbour area. These surveys have been continuing since the 1950's with the objective of providing modern navigational charts.

M. G. Swim as Senior Hydrographer, Eastern Arctic Surveys, conducted surveys on an opportunity basis from the *D'IbervilLe.* A survey of the Resolute Harbour Channel was made in order to resolve some disagreement in depths from previous surveys and to assist the Department of Transport in establishing additional ranges. Reconnaissance surveys were made of fiords on the south side of Lancaster Sound and along the east coast of Baffin Island in an effort to provide preliminary charts of the archipelago.

L. D. Quick, using the *CSL Tudlik,* carried out chart revisory surveys of a block of thirty published charts of northern Nova Scotia and the Magdalen Islands, P.Q. The objective of this activity was to bring the charts up to date, and to provide information on whether an area covered by a specific chart requires a new survey in detail. The revisory programme will result in all charts of important ports being revised every four years with the remainder being revised on an 8-year cycle.

In 1968 there were six establishments engaged in charting the waters of the Maritime Provinces (Fig. 11) and one party in the eastern Arctic (Fig. 12).

Because of a change in priorities, the Grand Banks surveys were discontinued for this year and the *Baffin* activities transferred to the Gulf of St. Lawrence. F. L. DeGrasse directed the combined hydrographic/geophysical survey which had the same objectives as those previously given for the Grand Banks surveys.

The *Kapuskasing* returned to coastal surveys under the direction of P. L. Corkum. The only project undertaken by this establishment was a detailed survey of the eastern entrance to Fogo Island, Newfoundland. This is part of the overall charting scheme for the east coast of Newfoundland in the provision of modern navigational charts. The survey was supported by Hi-Fix in hyperbolic mode thus allowing the ship and four survey launches to position simultaneously during sounding operations. Due to the short duration of the survey season and the problems created by adverse weather this project could not be completed, so will be continued in 1969.

T. B. Smith, Hydrographer-in-Charge of the *Acadia,* conducted surveys in two locations on the Newfoundland coast. A detailed survey was completed of the harbour of Ile aux Morts on the south coast to provide a detailed chart in support of the large herring reduction plant being established there by Nelpack Fisheries Ltd. The *Acadia* then moved to Sir Charles Hamilton Sound to complete the initial charting of this important sheltered passage. During the Ile aux Morts survey, Hydrodist was evaluated for fixing the ship's position while running lines of sounding.

The *Maxwell,* under the direction of J. M. R. Pilote, was again used for small but important projects in Nova Scotia and Newfoundland. A detailed channel survey was made of the eastern portion of the Strait of Canso in support of the proposed British American Oil Company refinery for the Port Hawkesbury

area, and the intention to have 300,000 DWT tankers with a 79' draft frequent the port. The second project, Come-by-Chance, Newfoundland, was also in support of a proposed oil refinery. The Newfoundland Refining Company which proposes establishing a large refinery at this location, requested a detailed survey to ensure that tankers of 200,000 - 300,000 DWT could be accommodated. A survey was then completed of the new wharf and the approaches to it, at Long Harbour, Newfoundland, because a major mining development there will require 35,000 DWT carriers to utilize the wharf facilities. Following completion of the Long Harbour project, a survey to produce a detailed chart of the waterfront at Marystown, Newfoundland, was begun. However, this could not be completed as the ship had to be diverted to the strait of Belle Isle to chart a critical shoal.

Shore Party No. 1 with R. C. Amero in charge, continued charting the east coast of Nova Scotia in the Ship Harbour area.

Chart revisory surveys were made of a block of charts covering P.E.I. and a portion of the New Brunswick coast. L. D. Quick, who was in charge of this establishment at the season's outset, had to be replaced for medical reasons, and A. L. Adams completed the season. The *Tudlik,* because of her short endurance and lack of accommodation, is not suitable for this operation; therefore, it is proposed that a more suitable vessel be constructed early in 1969. This vessel, of the long liner design, will be 60 ft long and capable of sustaining a six-man complement for one month periods.

The CCGS *D'lberville,* with M. A. Hemphill as Senior Hydrographer, conducted a control survey along the northern portion of the Labrador coast to position the off-lying islands for the accurate delineation of the 12-mile fishing limit boundary. The second project for this establishment was a detailed survey of the inner portion of Wakeham Bay, P.Q., in support of mining development by Falconbridge Nickel Mines Ltd. After completing this project, the ship rendezvoused with the Canadian Coast Guard northern convoy and proceeded to Resolute Harbour where shoal examinations and a preliminary survey of Allen Bay were made. The latter project was in support of the Department of Transport feasibility study which proposed this site as an alternative to Resolute Harbour. During the ship's resupply call, a reconnaissance survey was made of Bridgeport Inlet. Upon the ship's return to Resolute Harbour in mid September, A. C. Grant of the Institute's Marine Geology Section joined the ship and from then until the end of October a combined hydrographic/geological programme was carried out along the east coast of Baffin Island and the Labrador Coast.

Over the 2-year period a number of small projects were undertaken by hydrographers on rotation operating directly from the Institute. At the request of the Department of National Defence, a survey was made of the HMC Dockyard waterfront and a radar dolphin was accurately positioned to facilitate the compilation of a radar calibration chart. A survey was made at the entrance to Halifax Harbour to assist the Department of Transport in extending the measured mile. A tide gauge was placed at Stephenville, Nfld., to establish chart datum as an aid to a firm of consulting engineers concerned with the proposed area development. A level traverse was run in Saint John, N.B., at the request of the Department of Public Works, to resolve a discrepancy in elevation between two bench marks.

From April 5 to May 8, 1967, Hydrographers on Baffin, with P. L. Corkum as project leader, attended the Ninth International Hydrographic Conference at Monaco. Interlines between the Navado lines were run on the Atlantic crossings and such parameters as bathymetry, magnetics, and bottom reflectivity were measured. Four staff members from the Institute of Oceanography, Dalhousie University, under the direction of Dr Wangersky, participated in the crossings to obtain a transcept of deep water samples for their studies of the organic particulates in the sea.

Hydrographers participated in the following AOL cruises to compile data for the General Bathymetric Charts of the Oceans programme :

a) Physical Oceanography cruise of the *Hudson* in Denmark Strait, 1967;

b) Marine Geology cruise of the *Hudson* in the Lesser Antilles, 1968;

c) Marine Geophysics cruise of the *Hudson* on the Mid-Atlantic Ridge, 1968.

Throughout the period the Oceanographic Research and Marine Geology Sections were provided with all necessary photographic assistance in the field.

Hydrographic Development

G. R. Douglas
K. S. Budlong (Mrs) D. E. Wells
D. H. Herman

A program to study and implement means of increasing the efficiency of all phases of hydrographic data gathering and chart production by the use of modern techniques and automated processes was initiated in late 1966.

Three working groups were established to carry out this study. One group, located at the University of Saskatchewan, is concerned with the development of automated chart compiling and drawing. A second group, located in Ottawa, is concerned mainly with the final processing of data from field surveys. The group located at the Institute is responsible for investigating and implementing means of improving and modernizing the techniques of hydrographic data collection and preliminary data processing.

Over the past 2 years AOL has concerned itself with several major projects. The more important projects of the group's activities are outlined below:

1) One aspect of the group's study revealed that a considerable amount of time, during conventional processing methods, was devoted to the scaling and reduction of echograms. To expedite this operation, a semiautomatic chart scaler has been designed; Four units have been built and were used successfully in the 1968 field season. The shorter time required to scale echograms and the reduced number of random errors when using these chart scalers have been the major factors in their success. Modifications, including paper tape output for correlation of digitized depth with digital position information, are currently being made.

2) A prerequisite to the design of new instrumentation has been the determination of an adequate set of accuracy standards. The factors influencing the accuracy of depth and position measurements at sea have been under study for the past year. Two Internal Notes (67-4-I) and (68-18-I) concerning the study have been issued. Because this study is an important aspect of the group's work, it will be continued in the future.

3) The lack of an adequate navigation system for shipboard use, extending more than a few hundred miles from land, led to the investigation of using man-made satellites.
The United States Navy Navigation Satellite System, developed in 1960 to provide a world-wide, all weather navigation system accurate to about 0.1 nautical miles using a specially designed polar orbit satellite, has been carefully studied in the light of this requirement. Two receivers capable of operating with the system have been purchased. One, manufactured by the Magnavox Company, was operated for 101 days on cruise *CSS Hudson 22-68.* A total of 1,950 satellite passes were received, from which 865 were selected to provide precise mid-ocean navigation fixes. Navigational control was consistent to 0.5 nautical miles while running long lines to and from the survey area. Radar transponder buoys were positioned within the survey area with an accuracy of the order of 0.1 nautical miles. The second receiver, manufactured by International Telephone and Telegraph Corporation, was operated for 69 days at the Institute, for 2 weeks at four locations in northern Greenland, and on cruise *CSS Baffin* 21-68. The fixes obtained ashore were scattered about mean positions with standard deviations between 0.1 and 0.2 nautical miles. The mean positions were displaced from known geodetic positions by between 0.01 and 0.2 nautical miles The results of the positions gathered on *CSS Baffin* have been referred to the Lambda positioning system. However, at the time of writing this data has not been processed. More sophisticated techniques of data analysis, now being

investigated, may improve the accuracy; figures; the analysis and results of the data gathered thus far have been issued as Internal Note 68-25-I.

4) Several smaller projects were undertaken and completed by the group:

a) The operational difficulties, encountered by field surveys in using the Hydrodist positioning system in small survey vessels, resulted in the design and construction of a counter and tracking unit and a left/right track indicator. These units provide the helmsman of a vessel with an easily readable, visual indication of his position or deviation from a specified track.

b) The search was made for a new method of guiding small survey vessels along the required track when conducting inshore hydrography. The instrument used to fulfil this requirement. resulted from the modification of an optical range device used to guide small aircraft during landings.

c) In accordance with future thoughts on automated data collection, a new survey echo sounder, based on AOL specifications, was purchased for evaluation. This echo sounder differs from the ones now in use, in that it is considerably more accurate, very portable and designed to provide information in a form that can be used by computers for data processing. The evaluation of this echo sounder resulted in a number of modifications being recommended. The modified units have now been purchased for hydrographic use in both Atlantic and Central Regions.

Draughting, Illustrations, and Photography Group

N. E. Fenerty

J. R. Belanger — J. A. Gasparac
T. M. Calderwood — J. R. Lord[1]

The illustrations and draughting unit, under the direction of T. M. Calderwood, provides services to the entire Institute, Production output was increased substantially with the engagement of J. R. Lord in 1967. The main workload was generated by the requirements of Hydrography, Marine Geology, Geophysics, and Physical Oceanography. Bathymetry collected on oceanographic cruises was processed for GEBCO

The GEBCO project is an international undertaking to provide general charts of all the oceans. To support this program, all Institute ships undertaking oceanographic cruises keep an accurate plot of the ship's track and a continuous profile of the ocean floor. At the end of the cruise this information is turned over to the illustrations and draughting unit where it is processed to completed form and placed on master collection sheets. Thirty-one thousand miles of bathymetry collected over the 2-year period have been processed. Scientific reports resulting from oceanographic cruises were perused, and data as applicable to navigational charts was extracted. This information consists chiefly of bottom characteristics and is being held in abeyance for future revised chart editions.

The services of the photographic unit, headed by N. E. Fenerty, were in heavy demand for laboratory and field undertakings throughout the Institute. In addition to providing routine photographic services, this unit is also involved in the development of facilities to meet specialized photographic problems of under sea investigations and marine surveys; including a large process camera for making enlargements or reductions of pictorial data, e.g., precise plotting sheets, without distortion of dimensions. In order to observe what is happening during the underwater photography, and to improve the techniques and instrumentation, one photographer has become a qualified Scuba diver.

Survey Vehicle Development and Construction

In close liaison with other sections of AOL and the Ship Division, the Hydrographic Section has become actively engaged in the design and acquisition of survey launches, and also in the preliminary planning of a proposed survey barge. Because the present antiquated launch fleet is deteriorating at a fairly fast rate, it is imperative that a replacement programme be implemented in 1969. Specifications have been drawn up for what is considered to be the ideal launch for the job and

[1] Joined AOL.

negotiations are now underway to have a prototype constructed. In comparison to the present wooden launches, the new craft will be constructed of fiberglass, thus reducing hull maintenance. It will have better sea-keeping qualities, be approximately twice as fast, and will satisfy the requirements of both the electronic and visual positioning type surveys. The present launches have a-displacement design, while the new launch design will combine both the displacement and planing hull qualities.

Because we were assigned the responsibility of chart revisions within the Region effective April 1, 1967, preparations are being made to construct a vessel suitable for the task, Although the basic design of the 60 ft. long liner, used so extensively by the fishermen in Nova Scotia, has been accepted, major changes in the interior and wheelhouse are proposed. This vessel, operating as far north as Hopedale, Labrador, and in many other areas of semi-isolation in the Maritime Provinces and Quebec, will be capable of sustaining the operation and a complement of six for periods of up to 5 weeks without resupply. When the craft is not engaged in revisory surveys it will be utilized for new coastal charting or some other facet of coastal studies, e.g., applied oceanography.

.In 1967, P. L. Corkum studied the feasibility of using a survey barge in support of some of the coastal surveys now being per-. formed from a ship. If this were possible, and a barge could be constructed, the surveys would progress more economically because ,the barge would carry more launches, and have a lesser complement than a ship. Also, the ship now assigned to such surveys could be utilized on projects more suitable to its capabilities, e.g., offshore sounding. Preliminary specifications were drawn up and in 1968 a meeting was held with AOL and Ottawa Ship Division personnel to discuss in detail the concept, the cost, and the suitability of such a craft to the discipline. It was decided that two studies should be made, one following the barge concept, and the other to ascertain if a craft more along the lines of a conventional vessel, but capable of carrying more launches than our present vessels, would be more suitable. The Ship Division is currently giving this further study; however, it would appear that regardless of the recommendations resulting from the study, the type ‘of craft selected will not become a reality until sometime in the future.

TABLE 1. Statistical summary of field work - 1967.

	Acadia	*Baffin*	*Maxwell*	S.P. 1	S.P. 2	E.A.P.	Total
Nautical miles sounded	896	28,142	1,030	1,014	111	24	31,217
Track sounding (n. miles)	-	-	-	-	-	4,404	4,404
Area Surveying (sq n. miles)	37	33,118	45	44	25	8,000[a]	41,269
Area triangulated (sq n. miles)	—	-	20	5	—	—	25
Tellurometer traverses (n. miles)	103	4	139	9	5	-	260
Shoals examined	1,101	50	331	431	374	6	2,293
Coastlining (n. miles)	67	-	25	45	-	-	137
Triangulation stations established	130	11	81	129	105	5	461
Stations monumented	36	1	32	5	-	-	74
Conventional Decca calibration checks	-	87	-	-	-	-	87
Tide gauges established	3	-	5	4	2	-	14
Bench marks established	3	-	8	14	-	-	25
Current meters used	3	-	-	-	-	-	3
Current meter stations occupied	8	-	-	-	-	-	8
Current meter data (days)	29 x 8	-	-		-	-	232
Bottom samples	176	640	474	300	493	6	2,089
Lambda chains established	-	2	-	-	-	-	2

a Reconnaissance survey-lines far apart.

TABLE 1 (continued). Statistical summary of field work - 1968.[b]

	Acadia	*Buffin*	*Maxwell*	S.P. 1	E.A.P.	*Kapuskasing*	Total
Nautical miles sounded	1,700	19,326	1,300		*	4,000	27,126
Track sounding (n. miles)	-	-	-		*	-	-
Area surveyed (sq n. miles)	50	14,196	45		*	975	15,299
Tellurometer traverses (n. miles)	-	-	46.3			10	56.3
Shoals examined	1,200	500	450			25	3,025
Coastlining (n. miles)	39	-	-			36	75
Triangulation stations established	72	9	87		*	35	313
Stations monumented	36	-	21		*	9	66
Conventional Decca calibration checks	-	176	-		*	-	176
Tide gauges established	4	-	4		*	2	11
Bench marks established	6	-	12		*	3	21
Current meters used	6	-	2		*	6	14
Current meter stations occupied	6	-	3		*	6	15
Current meter data (days)	28 x 6	-	28x3		*	28 x 6	420
Bottom samples	500	900	300		*	200	2,450
Lambda chains established	-	1	-		*	-	1
Hi-Fix chains established	-	-			*	1	1

[b] Projected figures based on 80% of field season.

* Statistics not available at this time.

Metrology

Metrology

R. L. G. Gilbert

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R. J. Vandal[1]
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D. E. Wells[3]
W. J. Whiteway
S. Young[1]

Since 1966, the Metrology Section has evolved to the point where the division between the electronic and the mechanical design groups is only administrative in nature. Within the section, research is now on a project basis rather than along functional lines and project leaders direct teams of staff from both groups; this structure is reflected in the description of the projects outlined in this report.

This intergroup structure has also extended into relations with the Hydrographic Development Group and the Engineering Services Section. The transfer of the Bedford Institute Oceanographic Data Logging System (BIODAL) from the production model stage to a completed shipboard installation, with trained technical support and adequate maintenance handbooks, was handled jointly by Engineering Services and Metrology under the direction of staff from Engineering Services. Projects have been handled on a similar basis with the Hydrographic Development Group, and in the future, it is hoped that this type of joint participation in a project will be achieved with other sections with whom communications have weakened as the Institute has increased in size.

Metrology has participated in two major cruises on CSS *Hudson*, in each case sharing ship time jointly with scientists of a different discipline. On cruise *Hudson* 19-67, carried out jointly with the Institute of Oceanography, Dalhousie University, (Biology Department), Metrology worked on 21 projects and without the shiptime available for purely developmental purposes, many of those developments would have languished. The second cruise, with Marine Geophysics, was similarly productive. It is expected that similar cruises will continue in the future. The joint nature of these cruises had several advantages. The interdisciplinary nature of the cruise meant that ship time could be utilized around the clock, particularly during the dark hours when the uncertain aspect of equipment development makes trials hazardous. Because of the balanced ship program, the use of a large ship was fully justified, and the increased accommodation enabled the majority of the section to go to sea as a group. Thus greater support was available for individual projects than would have been possible otherwise.

Since the preceding Institute report in 1966, a number of projects have been successfully completed and the equipment developed is now in general use by the Institute. Examples described in this report are the BIODAL Shipboard Data Logging System, the Multi Recorder Precision Sounding System and the Automatic Flat Bed Plotting Table. All of these systems have been routinely operated for at least six months and the responsibility for them has been transferred to other sections.

C. S. Mason

BIODAL[4]

In 1965, the development of a shipboard data logging system for the Marine Geophysics Group was completed. That system has proven to be rugged, reliable and adequate for its purpose, but because of the highly specialized

[1] Joined AOL.
[2] Left AOL.
[3] Transferred within AOL.
[4] Bedford Institute Oceanographic Data Logging

nature of the design, it could not be expanded to record additional parameters. Consequently, its use was restricted to Marine Geophysics. A new data logging system has been developed which records data from up to 10 different input sources onto paper tape. The system includes a solid state master clock system with display units throughout the ship, a punch paper tape drive unit, and a number of specialized units to interface oceanographic instruments to the system.

The construction of two logging systems for *CSS Baffin* and *CSS Hudson* has been completed and the equipment has been installed on both ships. Only minor modifications of the original prototype electronics and chassis system were required; and a direct interface for use beween BIODAL output and a PDP-8 computer has been incorporated. Manuals for the routine maintenance of the system are now available and the permanent installation of the system has been completed. Matching units for use with a gravimeter, magnetometer and a VLF[1] navigation system have been built and are in routine use on *CSS Hudson.* The design of a unit for matching ship's head and log has been completed. The only other design support required for this system is the construction of additional matching units to enable routine recording of other parameters; otherwise, the system now has become the responsibility of Engineering Services.

C. S. Mason
A. S. Bennett
E. A. Bendell
R. N. Vine
S. B. MacPhee
D. E. Wells

Rock Core Drill

Development work on the Rock Core Drill project both in the laboratory and at sea has continued through 1967 to the present. The immediate objective of this project was to drill cores, 6 inches long by 1 inch diam from hard rock of the ocean bed; the unit was to be designed so that it could be handled from any oceanographic ship.

The drill is self-contained, deriving its power from the hydrostatic pressure of the sea, and therefore, the only link between the ship and the drill unit is the handling wire or rope. During the Mid-Atlantic Ridge Cruise (1966), two short cores were obtained and since that time, several modifications have been made to the drill; the major change being the addition of a servo-system for loading the drill stem according to the work being performed by the motor. Considerable emphasis has also been placed on the instrumentation of the unit in order to assess the performance *in situ.* Drill bits, supplied initially on a trial basis by a Canadian manufacturer, have improved the drilling rate and incorporated an adequate core catcher.

Sea trials, which were made in 1967 and 1968 on board *CSS Hudson* and which used a captive rock as an assessment standard, have proven the effectiveness of the drill. Two bottom tests of the unit on Bermuda Banks in May 1968 indicated that the unit was ready for a hard surface trial; it drilled approximately 6'-0" into a sediment cover. In October 1968, 10 cores were obtained, two from San Pablo Seamount and the remainder from Rehoboth Seamount. The longest core was 10.4 inches and the overall average was 5.35 inches. The material was generally found to be carbonate covered by manganese.

To assist in the sea trials of the drill, deep sea cameras have been used extensively. An instrument camera has been fitted to the drill to record its performance; several series of bottom photographs have also been taken with a larger camera in order to select suitable areas of the sea-bed for drilling. Modifications of commercial cameras have been made to improve the reliability, and new techniques of shipboard film processing devised.

Instrumentation on the drill now includes a recorder which measures hydraulic pressure during the operation, and an acoustic link which telemeters the rate of drill extension and one or two hydraulic pressures.

The drill unit has been developed to the stage where it can be usefully used as a geological tool. It can be lowered to any reasonably flat part of the sea-bed and will recover short cores of rock; the instrumentation on the drill unit can be used to deduce the thickness of soft sediment covering the bed-rock, up to a maximum thickness of 6 ft.

[1] Very low frequency.

There is, however, a problem with soft manganese and carbonate which clogs the present drill bits. Therefore, further tests with different drill bits and experiments with the coolant flow will be conducted in a coming November cruise. To date, handling of the drill has been conducted by using wire rope with a "tail" of synthetic rope until an adequate capstan is available. Eventually a complete length of buoyant rope will be used to prevent bottom entanglement.

John Brooke
R. L. G. Gilbert
P. F. Kingston
C. S. Mason

A Multi Recorder Precision Sounding System

The design of a reliable precision echo sounding display system has been completed. Four precision echo sounders were in operation on the 1968 Mid-Atlantic Ridge Cruise and one display has been installed on *CSS Baffin.* The system, made up of commercially available sonar transceivers and precision display units combined with Institute designed control units, has been turned over to Engineering Services and no further design is anticipated. A users' handbook and a maintenance manual have been completed.

A course in the use of the system, using a simulator to replicate a performance similar to that encountered at sea, has been given. Varying depths as well as interference from a deep scattering layer were simulated. (Fig. 13) A course for maintenance technicians who are responsible for the repair and upkeep of the system was also given.

One sounder has been modified, on a trial basis, so that the horizontal scale can be manually varied to correspond to ship speed, thus providing a constant vertical exaggeration independent of ship speed variations.

C. S. Mason
P. G. Jollymore
S. B. MacPhee

The 60-inch x 45-inch Flat Bed Plotting Table

In the past, hydrographic field sheets have been prepared manually at the Institute. The achievement of the required accuracy is a time-consuming task and the work must be frequently re-checked to eliminate error. An automatic plotting table can prepare one or many similar field sheets with predictable and reproduceable accuracy. Such a table was available at the Institute and has been fitted with a control system suitable for point plotting, with an overall accuracy of ±0.005 inches.

Considerable time has been saved by using the table. For example, 40 hydrographic field sheets, involving the plotting of approximately 7,200 points, were completed by two men in 40 hr. The manual plotting speed is about four man-days per field sheet; thus a job taking 160 man-days has been reduced to 10 man-days. The table is now being used on a routine basis by hydrographers and geophysicists.

C. S. Mason
G. R. Douglas
A. S. Bennett

Radio-Controlled Launch

Development work continued on the 14-ft. radio-controlled unmanned launch. The project is based on the premise that several drone echo sounding launches controlled from one hydrographic ship should increase several fold the productivity of offshore bathymetric surveys. Sea trials were carried out during the summer of 1967. It was found that the original steering and speed control systems were unsuitable for operation in the harsh environment encountered. Furthermore, control of such a vehicle using a carrier frequency in the Citizens Band was shown to be unreliable.

At present, the entire control system is being rebuilt. A new gyroscope and steering motor are being selected, the speed control system is being modified, and a radio link in the VHF or VLF band is being considered. All these items will be required to meet much more stringent specifications than the original equipment. Tenders have been requested for the echo sounding system and a fish to contain the transducer has been designed. Laboratory testing of the various portions of the system will take place early in 1969. By the summer of 1969, it is expected that sea trials of the complete launch and a prototype echo sounding system will be carried out.

D. L. McKeown
G. A. Fowler

Temperature Measuring Sys'ems

In 1963, Marine Geophysics obtained by outside contract a digital thermometer intended as a portion of a sediment heat probe for measuring terrestrial heat flow at sea.

Fig. 13 Familiarizing Bedford Institute staff with the use of a shipboard echo sounder using a shore-based simulator.

Design of the sediment heat probe was completed and manuals were completed for the thermal probe and the playback system. A program (BI Computer Note 68-4-C) was written to plot the data on the Calcomp plotter. On *Hudson 19-67,* two measurements of the thermal gradient in the sediment were successfully made with the probe attached to a sediment corer, the shipboard computer being used to view the record shortly after the probe was retrieved. However, before the instrument could be used to measure heat flow easily in a routine fashion, a number of problems, particularly in the handling and performance of the piston corer, and the measurement of the thermal conductivity of the mud, remained to be solved. C. S. Mason took part in a cruise on the Woods Hole ship *RV Chain* to observe their method of heat flow measurement, and it was obvious that some of the initial concepts incorporated into the Institute probe were incorrect and that radical changes would be required. A review of AOL requirements indicated that equipment for precise measurement of temperatures in the deep ocean is required more urgently than the sediment heat flow probe; development of the latter has consequently been discontinued.

Temperature variations near the abyssal floor affect the accuracy with which terrestrial heat flow can be measured and temperature also serves as a convenient label for certain masses of sea water. The temperature measuring portion of the heat probe design is now being redirected for use as a sea-bottom, long-term recording thermometer, and design of an instrument to record sea water temperature with an accuracy of 0.01°C over a period of 1 or 2 months is well advanced. It is hoped that sea trials of this equipment will be started early in 1969.

A device for telemetering water temperatures from abyssal depths has been assembled by fitting a short time-constant thermistor and an amplifier to a commercial telemetering acoustical pinger. Measurements of temperature are displayed on a precision echo-sounder recorder. Trials of this equipment were carried out by physical oceanographers as part of the 1968 *Hudson* Mid-Atlantic Ridge cruise.

In order to investigate the accuracy, precision and stability of temperature-measuring devices, a high quality platinum resistance thermometry system has been purchased together with an ice bath. Thermometers may be calibrated in the laboratory to 0.001°C near 0°C and to better than 0.005°C over the oceanographic temperature range.

A. S. Bennett
C. S. Mason
E. A. Bendell
D. R. Harvey

Automatic Bathythermograph

Measurement of the water temperature is of prime importance in oceanography. The standard techniques are time consuming and expensive, and give a single location temperature profile. To improve this situation, an automatic bathythermograph is being developed. It will consist of a porpoising fish, towed at cruising speed and designed to oscillate automatically in depth between two preset levels, initially, 50 and 250 ft. The unit will carry a pressure transducer and a thermistor which will send depth and temperature signals to the ship through the armoured towing cable. The porpoising fish could be adapted to carry other probes such as a plankton sampler or light intensity meter. The electronics for the fish have been completed and fully tested. The towed body has now been tested on three cruises and the most recent results indicate that the body is not perfectly balanced and that it is following a ‘(cork-screw” path. More instrumentation has been developed to telemeter the body performance under tow to the ship and further sea trials are underway. In an attempt to devise means of coping with the vast amount of data a working fish will produce, the temperature depth output of the probe has been interfaced to a computer. Data was recorded on punched paper tape and simultaneously displayed. The most interesting features of the data could be visually displayed, the scale adjusted and then selected data plotted on an X-Y recorder.

J.-G. Dessureault
C. S. Mason

Miscellaneous Projects

Magnetic Measurements. The shipboard proton precision magnetometer used by the Marine Geophysics Group was obtained from the Geological Survey. That magnetometer had performed very well for several years, but the vacuum tube circuits used in the front end

amplifier were becoming less reliable because of age, and the unit was quite bulky. To compensate for these deficiencies, a new front end for a shipboard magnetometer incorporating a switching circuit and specially tuned amplifier was built. The front end development was incorporated into the design of a matching unit to interface a magnetometer into the BIODAL system. The unit has worked successfully at sea. A maintenance handbook has been completed.

C. S. Mason
E. A. Bendell

Pressure Test Facilities. The installation of a pressure test facility at the Institute has been completed. Two pressure tanks are available: one chamber is 19 inches in diam by 11 ft in length, and can be raised to 1000 lb per square inch (~400 fathoms) ; the second chamber is 9 inches in diam by 28 inches long, and can be pressurized to 15,000 lb per square inch (~6,000 fathoms). The high pressure chamber is equipped with viewing port, interior light, electrical inputs and a listening device. These shore facilities, under the direction of the Metrology Section, are generally available to the Institute, and have been used to perform various tests which must otherwise be conducted at sea. These facilities have aided such projects as the Rock Core Drill program and the design of several measuring instruments.

A portable pressure tank has also been designed and three units built, two for Marine Geophysics and one for Metrology. These tanks are used at sea for testing instrument pressure cases which may have had modifications or where there is any indication of possible failure; considerable savings in over the side station work is achieved by their use. The chamber is 8 inches in diam and 40 inches long, and can be raised to 2,000 lb per square inch (~800 fathoms).

J. Brooke
J.-G. Dessureault
G. A. Fowler

Data Processing System. Marine Geophysics, Air-Sea Interaction, Hydrographic Development, and Metrology have all been recording analogue data on magnetic tape using the principle of Multiplex frequency Modulation recording. A system for recovering the data from the field-recorded magnetic tape was built up. The system consisted of a set of FM discriminators, a Multiplexer switch, an analogue to digital converter, and a high speed paper tape reperforator.

In 1966, the system was expanded to include a multipen chart recorder and an automatic tape control unit, and was used to reduce a backlog of air-sea data ready for computer input. It has now been replaced by a commercial system interfaced directly to the Institute computer.

A new parallel to serial coupler has been designed and assembled to replace the previous summer student model which was plagued by a succession of minor faults. The system is now being equipped to assist in the manual digitization of bathysonde data and no further design work should be required. Three chassis for holding voltage controlled oscillators used for recording in the field have been assembled and a set of discriminators for monitoring the data in the field have been purchased.

E. A. Bendell
D. E. Wells
C. S. Mason

Oblique Echo Sounder. The oblique echo sounder will measure and record the sea bottom reflectivity in a strip 400 - 500 yards wide on either side of a ship's track. Intended for use in depths of water up to 100 fathoms, the sounder has an immediate application in geological studies of the Nova Scotia Continental Shelf, and it is a potential tool for use by hydrographers in shoal investigations. In 1965, trials of the Kelvin-Hughes oblique sounder were conducted by the Institute. That equipment proved unsuitable for use in this area because of the large temperature gradients that are characteristic of the region in the summer.

A system, suitable for use on this coast, is under development; commercially available transducers are to be mounted in a towed body designed by Defence Research Establishment Atlantic and the associated electronic units are being designed to provide the required characteristics.

W. D. Childlow
J.-G. Dessureault

Low Power Consumption Systems. Many electronic devices have limited application for *in situ* recorders because of their very high power consumption. For operation of a month or more, the battery pack required to power

such devices is impossibly large. Design of electronic circuits with very low power consumption has been attempted, initially, to produce an electronic digital clock.

The development of a low power digital clock has continued without producing a reliable system. A number of versions have been evaluated in detail but have proved too sensitive to electrical interference. A commercial clock now under evaluation shows promise of meeting our needs. Design of low power circuits for other long-term recording applications (e.g., temperature recorder) is continuing, and the modulator circuitry of a seismic system has been adapted for use in a temperature recorder.

A buoy seismic recording system has been built by D. Simpson of Dalhousie University and successfully used on the Mid-Atlantic Ridge Cruise, 1968. The frequency modulation recording electronics have very good stability and low power consumption. A matching demodulation system has also been built for replay. An important feature of the system is the use of a cheap domestic battery-operated tape recorder instead of the extremely expensive aerospace quality recorder normally necessary in a rugged environment. On the 1968 Mid-Atlantic Ridge Cruise, D.L. McKeown participated in the trials of this buoy recorder and a unit developed at Cambridge University for the same purpose.

A. S. Bennett
P. A. Gouldthorpe
D. W. Simpson

The Use of a Small Computer. The group took delivery of a PDP - 8 computer in October 1967 and the computer has been used for the development of hardware and software for data acquisition and display. An oscilloscope display and X-Y chart recorder are interfaced to the computer and have been used with the continuous bathythermograph. D. E. Wells has built an interface for connecting the computer directly to the data logging system. Development of a system of data display is continuing with the aim of simplifying data evaluation by a human operator who can "communicate" with the machine.

A. S. Bennett

Programmed Indexing Table. It is desirable to calibrate self-recording current meter compasses periodically in order to apply corrections to the data collected in the field. In the past, a complete check cycle for calibration of four magnetic compasses required the attention of a man for nearly 7 hr. A programmed indexing table has been designed and built to reduce the man hours required for this work. The system rotates the current meters through 360° by 10° steps, pausing 5 min between each step to ensure stabilization. There is a 10-min pause at 180°, and 20-min pause at 360°. The rotation then reverses, and the timing system stops at the end of the completed cycle. When the current meters are fixed in position and the cycle initiated, it can be left unattended.

J.- G. Dessureault

Engineering Services

The Engineering Services Section provides engineering, maintenance, and overhaul services for electronic and mechanical equipment as required by the research and survey operations at the Institute. It is organized in three groups, Marine Electronics, Depot Workshops, and Systems Engineering, with a total strength of 43. The largest group, Marine Electronics, is responsible not only for the repair, maintenance and overhaul of all electronic equipment installed aboard our six major ships and 35 launches, but also of much of the scientific instrumentation of the laboratory. It has shops specializing in equipment for use in various portions of the frequency spectrum from sonar devices to "X-Band" radars and transponders. To provide the other technical services required by the scientific and survey staff, the Depot Workshops have a number of skilled tradesmen employed in specialties such as welding, machining, engine repair and overhaul, carpentry, electrical, and sheet metal fabrication. The Systems Engineering Group provides the engineering design service required for the manufacture of special electronic devices, machines or equipment that although conventional in design, are not available from private industry.

A. S. Atkinson

Marine Electronics

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K. M. Nicholson
A. D. Parsons
C. E. Peterson[1]
C. E. Polson
W. F. C. Shearman
S. F. W. Spencer
A. C. Stuart[1]
H. B. Sutherland
R. Vandal[3]
J. G. Vezina
G. Weber
S. J. F. Winter
R. A. Young[1]

[1] Joined AOL.
[2] Left AOL.
[3] Transferred within AOL.

The shops which form this group, although sub-divided in general terms according to the frequency spectrum, i.e., Sonar, Electronic Position-fixing Systems, Communications, Standards and Computers, and Microwave, work together whenever one of our ships is on a scientific cruise or a hydrographic survey. Technicians are assigned to shops for the repair and overhaul of electronic equipment, but they spend nearly a third of their time on field assignments. They are employed as ship's technicians or are put in charge of the remote shore stations which are used as part of an electronic system for fixing the ship's position during hydrographic survey operations.

When a ship is at sea, on nearly all operations, it is imperative that the depth of water be known accurately. This is especially important for the production of hydrographic data and for the mooring of equipment; it is also a necessary requirement when geophysical or geological surveys are conducted. The Sonar personnel, therefore, have the responsibility of providing and maintaining the most modern and accurate depth recorders and associated equipment. Although these technicians have not been exposed to the "electronic revolution" as much as technicians working on more sophisticated equipment, such as radar and computers, new equipment and techniques are appearing gradually. Electron tubes, relays, and mechanical contactors are giving way to more sophisticated, solid state devices. The initial order of six EDO Model 9040 echo-sounders has been placed and is representative of the new look in launch equipment. The new Gifft/Alpine transceiver/recorder combination, developed by Metrological Research, is providing increased reliability and flexibility for the scientific staff at sea, and a new challenge for the sonar technicians. The multiplicity of choice of pulse-width, repetition rate, etc., and the adaptability for pinger tracking, make these instruments a valuable asset to any scientific cruise. This group is also providing assistance, by investigating inherent sounding problems associated with increased launch speeds, and in some of the Marine

Geology seismic projects and ocean bottom layering studies.

For the hydrographic programs in which one of our ships is used for collecting the bathymetric data, the position of the ship is determined by the use of one of our Decca electronic position-fixing systems. These are systems operating at multiples of 14KHz, usually 12f, where the ship's position is determined relative to two fixed ground stations. The equipment on board the ship and at the shore stations is operated and maintained by technicians from the Marine Electronics group. During the winter months this equipment is repaired and overhauled by the Electronic Position-fixing Systems shop. A new, portable system has been developed by the technicians from this shop for use in surveys where ships are working less than 50 miles from shore. The system has undergone field trials during the past season and is now nearing completion. The Hydrodist, which is a compact, line-of-sight electronic survey instrument, was installed on *CSS Acadia*, rather than a launch, for the first time during the past field season, and her more stable platform provided better performance and reliability. Some limitations, such as the requirement for continuous antenna rotation, still exist, but these are being investigated.

Because ships operate in different areas most of the year, there is a need for communications with the Institute and with the shore stations, as well as between ships, so that information may be exchanged and direction given to ensure success of the operation. We have established a Communications Centre at the Institute which is the nucleus of a network linking the ships at sea with the various scientific groups and other experts ashore. This system provides a kilowatt of output power in the single sideband mode of operation and although it is used primarily for experimental voice and W/T communications at present, it is planned to use the system as a data link in the immediate future. The assignment of frequencies in the Maritime Mobile Band is expected shortly, so plans are underway for the reception and distribution of data from moored stations. (Normal ship's traffic is still, and will continue to be, handled by the government-operated coast radio station complex.) Equipment has also been fitted to our major ships for receiving and recording data from existing shore stations, such as the Dominion Public Weather Office and Ice Control Central; thus, information such as weather maps, ice charts, wave heights, and bathythermograph synopsis are now available to ship's officers and scientific personnel. It is planned to incorporate a similar facility into our communications system for the transmission of plotted scientific data.

The actual voice communications betweeen ships, launches and shore stations in the past was provided by low power (40W) amplitude-modulated radiotelephones. The conversion to 100W single-sideband transceivers is now nearing completion and a more recent conversion to VHF/FM for short range requirements, such as between *CSS Baffin* and her launches for parallel-sounding operation, has proven very successful.

With the introduction of the computer as a scientific tool aboard our ships, data can now be processed and analyzed rapidly so that an assessment of data accuracy and equipment performance may be made quickly. In addition to maintaining several PDP-8 computers and peripheral equipment (such as teletype machines, paper tape punches, high speed readers, plotters, etc.), the technicians of the Computers and Microwave sub-group are responsible for the development of interfaces between various data sensors and the computers. Recent developments of this type are a light pen, which was an experimental project for training purposes, and a radar interface which provides digital input to the computer of range and bearing of a target.

The microwave portion of this group's activities concerns the employment of X-Band equipment, such as shipborne radars and transponders, for navigational purposes. A program to replace obsolete radars with modern "state-of-the-art" equipment is underway and considerable work is also being done in conjunction with the engineering staff to provide a low-cost, reliable transponder system. The most recent acquisition of equipment for maintenance by these technicians are two Satellite Navigation receivers and two shipborne digital clock systems. The clock systems, developed by the Metrological Research Section, are used to provide timing pulses and synchronization of data sensors. The satellite receivers, in conjunction with computers, provide accurate ship's position from signals transmitted by programmed radio satellites orbiting the earth. Similar equipment has been installed on *Hudson* and *Baffin.*

The equipment maintained by the personnel mentioned in previous paragraphs is normally installed on a ship; their efforts, therefore, are directed toward keeping the ships operational. The Standards Laboratory personnel, however, maintain secondary electronic standards and repair and calibrate all the electronic test equipment being used at the Institute. Although some of the test equipment is used aboard ships, the major portion of it is used by scientific personnel at the Institute. For this reason, the Standards Laboratory personnel differ from the other staff members of Marine Electronics, however, they do spend some time on field assignments aboard ships and at remote shore stations. The inventory for which they are responsible has grown from practically nothing 5 years ago to 1,300 pieces of test equipment today, most of it modern and sophisticated. With such a large inventory it was necessary to automate the calibration system, so by using the AOL computer, information such as equipment due for calibration, or overdue for overhaul, is now available on request.

C. R. Peck

Systems Engineering

S. B. MacPhee[1] R. N. Vine[1]

There has been an increasing demand for a group at the Institute to provide a design service to the scientific staff by which standard engineering practices can be used to produce a mechanical or an electrical/electronic device. Also, there has been a demand for a staff which could take an instrument or a system developed by others at the Institute and provide the engineering required so that it can be installed on a ship and operated at sea. These services were being provided in one manner or another by Metrological Research and Engineering Services so it was decided to combine the personnel concerned from each section into one group under Engineering Services. The program for this group, however, is decided jointly by the two section heads, in consultation with other staff members.

Some of the projects completed by this group during its first year of operation are as follows :

1) In order to eliminate the need for D.C. powered ships of the AOL fleet to operate their auxiliary generators when alongside, a shore-based system for supplying the required power was designed and constructed. Using the 440V., 3 phase shore supply, it provides 300 amp at 220V D.C. In the 1 year since installation, it has operated without fault.

2) There is a requirement for a low-cost radar transponder/buoy system for navigational purposes in areas beyond the range of conventional navigation systems, e.g., Mid-Atlantic Ridge. A local electronics firm was given the requirement and they decided to develop the transponder at no cost to the government. Assistance was provided by the Systems Engineering Group, in the development and testing of a "VHF/X-Band" transponder, and many design improvements have been made. The prototype is operational but requires some additional improvements before it is ready for scientific survey use.

3) A request came from the Marine Geology section for a system to record pH, oxygen content and salinity of water samples on a strip chart recorder continuously and to operate unattended for periods up to two weeks. The system was designed and constructed by the Engineering Services Section.

4) A precision echo-sounding system, which is controlled by a master clock, was developed by the Metrological Research section for installation aboard CSS *Hudson*. (The clock signal is processed in a system timing generator that provides synchronization pulses to control units at echo-sounder locations throughout the ship. These control units supply a phasing signal so that all transceivers transmit at the same time, or multiples of the fastest transmission time, to prevent interference between units. Fathom lines

[1] Joined AOL.

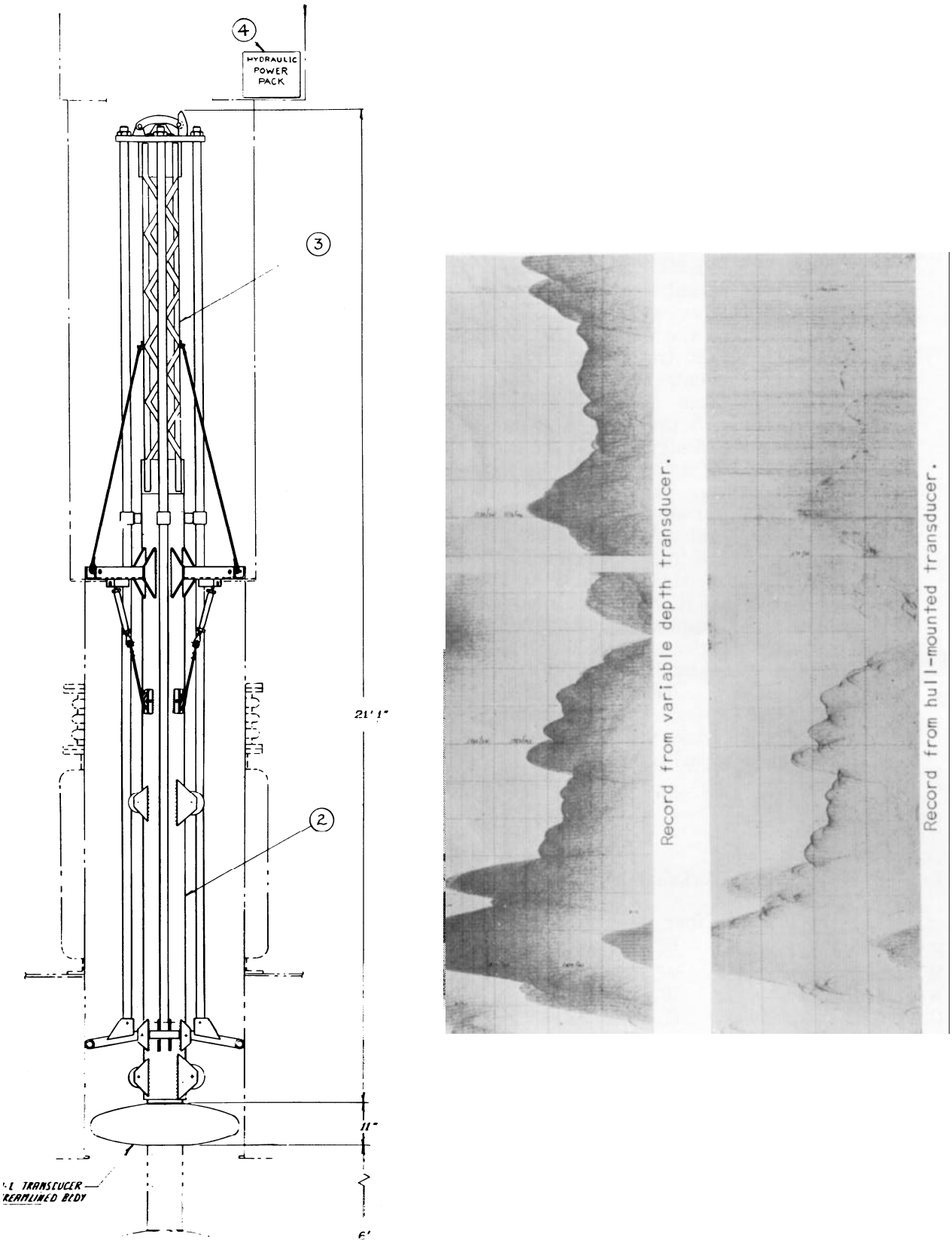

Fig. 14. Variable depth transducer prototype as installed in the oceanographic well on *CSS Hudson.*

and time pulses are also produced by the control units to mark the record.) The prototype system was given to the Systems Engineering group for final engineering and preparation for installation aboard the ship.

5) A major project which is still in progress is the provision of a Variable Depth Echo-sounder Transducer for use on *CSS Hudson* (and probably *Baffin)* to permit the ship to sound in rough weather. (When the ship is underway into the wind in inclement weather, air is trapped under the hull and prevents the transmission of energy from the hull-mounted transducer.) A prototype hydraulic assembly was designed and manufactured in conjunction with Fairey Canada Ltd. to determine whether lowering a transducer 4 - 5 ft below the keel would solve the problem. It was installed in the oceanographic well of *Hudson* and proved to be so successful that it was refurbished to withstand exposure to sea water for at least 4 months, so it could be used on the Mid-Atlantic Ridge Cruise 1968. It is planned to modify *Hudson* in 1969 to incorporate a variable depth sonar dome so that this problem can be solved permanently (Fig. *14).*

S. B. MacPhee
A. S. Atkinson

Depot Workshop

R. Balfour

F. C. Armitage
W. J. Findley
A. S. Gilhen
C. O. Grant
J. E. Horne
H. P. MacDougall[3]
J. D. MaeLaughlin[1]
W. H. Marshall
W. A. Moore
C. M. Newell
R. M. Smith[2]
R. E. Underwood

The normal requests for services from the Depot Workshops consist of short-term jobs requiring a few man-days, such as construction of special plywood instrument cases, fabrication of winch mounting pads, machining of engine or equipment parts, installation of electrical/hydraulic winches, etc. There are some long-term projects, however, and among those completed during the period of this report are the following:

1) The large stable platform used by the Air-Sea Interaction Group had to be completely rebuilt because of its exposure to severe environmental conditions; this meant renewing all the structural welds and the rigging. Assistance was then provided in mooring the platform near the approaches to Halifax Harbour for the continuation of the Air-Sea Interaction program.

2) The 37-ft survey launch *Tudlik* was converted for inshore work by removing the cabin and all the fittings, rebuilding a larger cabin, relocating the auxilliary power unit and after steering position, and fitting dual echo-sounders and all the associated wiring for equipment, lights and instruments.

3) A new Communications Workshop to house the equipment for AOL Radio Ground Station and to provide much-needed work space was constructed in the penthouse portion of the main building. The area was soundproofed, air-conditioned, and shielded from local electrical interference.

4) A portable diesel-driven, hydraulic pumping unit required at short notice for powering winches in a charter ship, was assembled from spare parts in less time than a new one could be obtained from a supplier.

R. Balfour

[1] Joined AOL.
[2] Left AOL.
[3] Transferred within AOL.

Ships

S. W. Howell
D. H. Chamberlain
J. M. Higgins[2]
A. M. Holler?
J. W. Pritchard"
G. Smith

In the period covered by this report the AOL fleet of five research vessels, *Acadia, Baffin, Hudson, Kapuskasing* and *Maxwell* was increased to six by the delivery of CSS *Dawson*, in February 1968, from the builders, G. T. Davie Shipyard, Lauzon, Quebec. She was designed for general oceanographic research with special emphasis on arrangements for the safe and efficient handling of bulky equipment over the side such as moored current meter arrays. With an endurance of 10,000 miles, a top speed of 16 knots, large laboratories, and accommodation for 13 scientific staff, she is capable of extended research operations at sea. Her main specifications together with those of the other ships are given in Table 2, and a composite portrait of the fleet will be found in Fig. 15.

The five older vessels of the fleet met all of their planned operational committments with but minor delays; however, *CSS Dawson*, not unexpectedly in a new ship, experienced difficulties with some of her machinery and equipment. Having undergone repairs and adjustments she has been in continuous operation since early September.

Through the courtesy of the Department of Transport, Marine Division, time was made available during the regular northern supply runs of the icebreakers *D'Iberville* and *Labrador* for studies of a scientific nature which were carried out by personnel from the Institute. During 1968 *Labrador* acted as support ship for a marine geological ocean bottom exploration using the small submersible *Pisces*, see p. 53.

To meet project requirements that could not be accommodated by AOL vessels, four ships were chartered, namely, the motor vessels *Theta, Ambrose Foote, Fairmorse* and *Brandal.*

Cooperation continued to be extended by the Canadian Armed Forces making the Canadian Naval Auxiliary Vessels *Bluethroat* and *Sackville* available to the Institute. The *Sackville*, a Corvette, saw naval service during World War II and since then has been almost continuously employed in oceanographic surveys. Late in 1967 work commenced on extensive modifications principally to improve her habitability. By mid-1968 she was back in service much better equipped to carry on her role as an oceanographic research ship.

Operational statistics are given in Table 3, for the AOL fleet and for other ships employed on projects programmed at the Institute.

AOL vessels participated in 10 search and rescue missions in the 2 year period. *Baffin* extended assistance in two incidents in the Caribbean, one off the Grand Banks and one in the Gulf of St. Lawrence. *Kapuskasing* was called on twice in quick succession to aid disabled fishing vessels off southern Nova Scotia, and on a third occasion in the Banquereau Bank area to provide assistance for an injured seaman. *Maxwell* participated in two investigative searches, one off St. Margaret's Bay, N. S., the other near Stephenville, Newfoundland. *Dawson* assisted a yacht in distress some 300 miles south of Halifax.

In June 1967, Mr J. M. Higgins, Regional Engineer Superintendent, left the Institute to take up a similar appointment at the new Canada Centre for Inland Waters, Burlington, Ontario. Pending his replacement, Mr G. Smith, Regional Hull Superintendent, has assumed these duties in addition to his own.

In May 1968 another key man of Ships' Division, Captain A. Holler, Regional Operations Officer, left to become the Technical Operations Officer also at the Canada Centre for Inland Waters. His duties at the Institute have been taken over by Mr J. W. Pritchard from the Applied Oceanographic Section.

The cruise schedules of the AOL fleet make heavy demands on the some 300 officers and men who man our ships. It is indeed a credit lo them that the operational readiness of the fleet has been maintained to a high standard and that they enjoy an enviable reputation of effective cooperation with the scientific and survey personnel carried in the ships.

[2] Left AOL.
[3] Transferred within AOL.

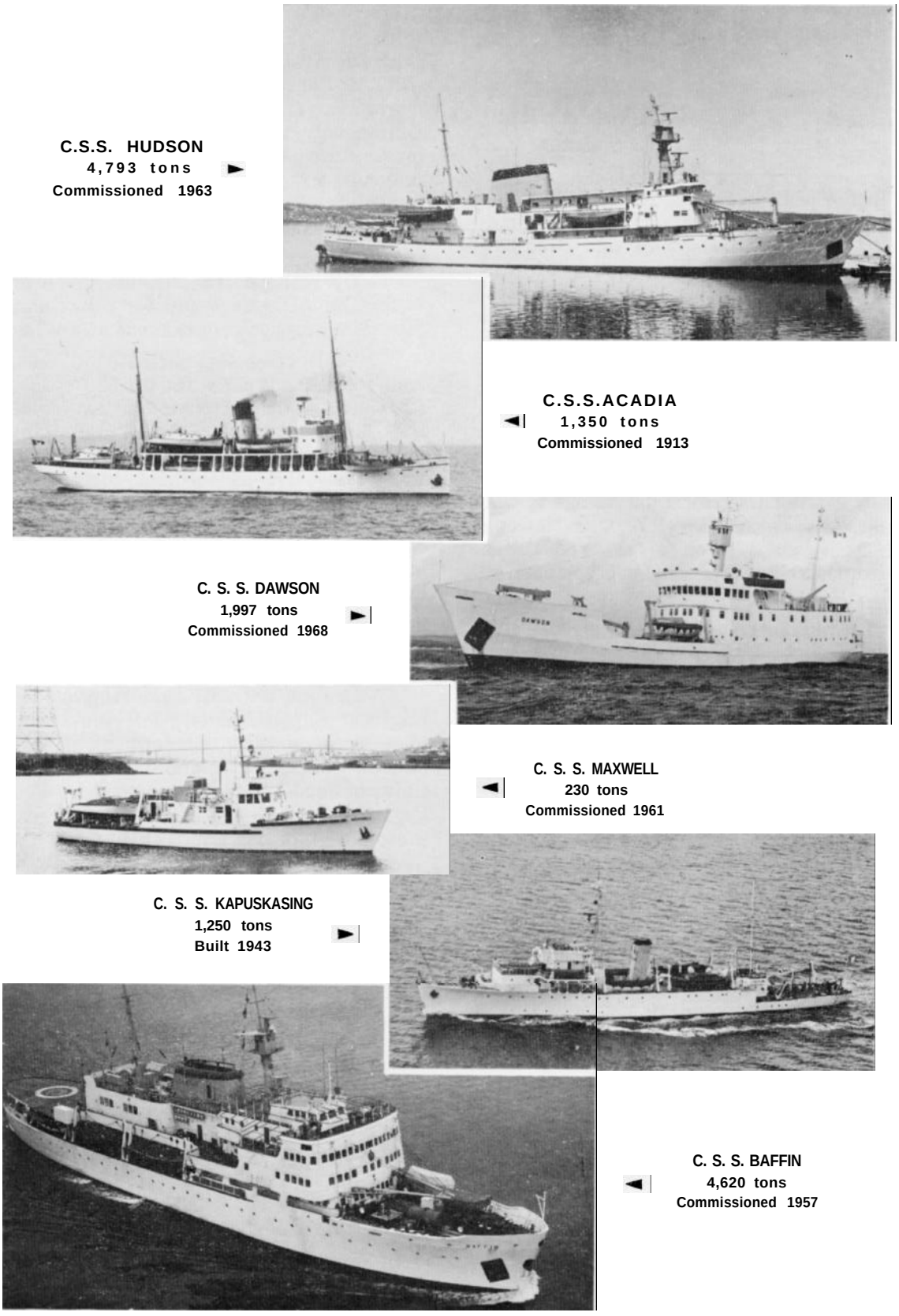

Fig. 15. The ships of the AOL fleet.

TABLE 2. Principal specifications of AOL ships and other ships programmed by the Institute during 1967 and 1968.

Name of vessel	Built	Length	Breadth	Draft	Displacement	Master
AOL Ships						
CSS Acadia	1913	182'-0"	35'-7"	13'-6"	1350 tons	Capt. J. W. Taylor
CSS Baffin	1957	285'-0"	49'-6"	18'-3"	4620 tons	Capt. P. M. Brick
CSS Dawson[a]	1968	211'-9"	40'-0"	15'-3"	1997 tons	Capt. M. J. A. Wagner
CSS Hudson	1963	293'-6"	50'-0"	20'-6"	4793 tons	Capt. W. N. Kettle
CSS Kapuskasing	1943	222'-0"	35'-6"	12'-6"	1250 tons	Capt. W. J. Vieau
CSS Maxwell	1961	115'-0"	25'-1"	7'-0"	230 tons	Capt. S. Baggs Capt. W. Thorne (Relief)
Others						
MV Theta (charter)	1952	183'-2"	28'-0"	13'-1"	1310 tons	
MV Ambrose Foote (charter)	1965	106'-0"	23'-2"	10'-10"	500 tons	
MV Fairmorse (charter)	1965	118'-0"	26'-0"	14'-0"	161 tons	
MV Brandal (charter)	1965	137'-0"	26'-6"	13'-0"	371 tons	
CNAV Sackville	1941	205'-3"	33'-1"	13'-9"	1250 tons	
CNAV Bluethroat	1955	156'-11"	33'-10"	10'-7"	870 tons	
MV E. E. Prince (FRB)	1966	130'-1"	27'-4"	12'-0"	520 tons	
CCGS Labrador	1953	269'-0"	63'-6"	29'-1"	6490 tons	
CCGS d'Iberville	1953	310'-0"	66'-0"	30'-0"	9090 tons	

[a] Accepted from builder in February 1968.

TABLE 3. Operational statistics of ships programmed by the Institute.

Name of vessel	No. of cruises		Days away from base		Mileage steamed	
	1967	1968	1967	1968	1967	1968
AOL Ships						
CSS Acadia	1	1	143	168	3,436	3,883
CSS Baffin	3	3	266	235	43,907	41,831
CSS Dawson	-	12	—	109	-	20,000
CSS Hudson	7	6	194	236	28,907	39,179
CSS Kapuskasing	4	10	153	195	23,848	23,895
CSS Maxwell	4	2	172	167	6,346	7,283
Others						
MV Theta (charter)	4	4	119	174	10,180	15,443
MV Ambrose Foote (charter)	2		15	-	12,000	-
MV Fairmorse (charter)	-	1		35	-	500
MV Brandal (charter)	-	1	-	30	-	2,100
CNAV Sackville	8	6	135	90	18,727	8,027
CNAV Bluethroat	1	-	5	-	900	-
MV E.E. Prince (FRB)	2	2	14	10	800	5500
CCGS Labrador	1	1	15	42	576	3,000
CCGS d'Iberville	—	1		37		4,500

Administration and Personnel Services

Administration Staff

S. H. Scott

Scientific Information Service and Library

R. M. McMullen[3]
Miss C. S. Allan
Mrs M. L. Smoth[3]
Mrs I. Ineson[2]

Finance

V. W. Hilchey
Miss J. Dehmel[2]
Mrs S. G. Furlong
Mrs D. M. MacDonald[1]

Central Registry

Mrs C. Gallant
Miss G. P. Sanford
Miss P. MacLeod[3]
K. E. Casey[1]
Mrs D. M. Fultz[2]

Stores

B. G. Martin
R. W. Fudge
R. Jollimore
M. W. Campbell
S. P. Hartling
G. D. Anderson
B. M. Nickerson

Computing Services

R. C. Richards
V. N. Beck
K. S. Budlong[1]
D. A. Dalby[1]
D. Gandhi[1]
D. H. Herman
A. V. LeBlanc
R. R. Lively[1]
I. Phyo[2]
M. S. Talwar[1]
P. S. Trites
J. C. Sutherland[2]
M. E. Warnelll

Civil Engineering

V. D. Conrad
J. Greig
G. E. Higgins
C. E. Rose
N. S. Higgins
J. A. Chisholm
B. G. Schwartz
R. B. Higney
J. H. Herman
W. G. Matheson[2]
W. Lovett
T. Breen
H. L. Gorma,n
D. B. Westhaver[1]
Mrs R. Desrosiers[1]

Secretarial Staff

Mrs J. Sim,[3] Sec., Director
Mrs P. Condy,[1] Sec., Administrative Officer
Miss C. J. Forsythe, Sec., Marine Geology
Mrs C. Gobeill,[1] Sec., Oceanographic Research
Mrs C. A. Webber, Sec., Regional Hydrographer
Mrs V. E. Clark,[3] Sec., Engineering Services
Miss L. A. Wright,[1] Sec., Metrology
Miss M. Faulkner,[1] Sec., Marine Superintendent
Mrs J. A. Lake,[2] Sec., Ships
Miss H. Dunn,[1] Sec., Hydrography
Miss P. Landry,[1] Sec., Oceanography

[1] Joined AOL.
[2] Left AOL.
[3] Transferred within AOL.

Personnel Staff

P. Sutherland'

Laboratory Staff

Mrs M. D. Dalzell
Mrs S. J. Jones[2]
Mrs R. N. Pettipas[1]
Miss J. Graves[2]
Mrs C. Leveck[2]

Ships Staff

G. W. Booth
R. H. Stone
J. F. MacLean
Miss F. G. MacLaren[3]
F. W. Grant
H. F. Buck

In the administrative area a number of changes have been made to improve services in support of the Laboratories' operations. In keeping with a reorganization of the personnel function throughout the Department, AOL personnel services covering both shore-side and shipborne employees were consolidated under a personnel administrator reporting to the Director. Mr Paul Sutherland came to the Institute in August 1968 from the Public Service Commission to take up the duties of this new position. In 1967 the function of the Institute library was broadened and strengthened by the transfer of Dr R. M. McMullen from Marine Geology to a new position, Head, Scientific Information Services and Library. His report appears below. The Computing Services group, headed by Mr R. C. Richards came into being under the aegis of the Oceanographic Research section but rapidly developed as a service to all elements of the laboratory. Accordingly it was transferred to the Administration section for organizational purposes. A review of its activities follows below. In recognition of the need for professional attention to the many civil engineering problems arising in the Institute, including those resulting from the construction program referred to in the Foreword, Mr V. D. Conrad was appointed in April 1967 to take charge of this function.

S. H. Scott

Scientific Information Services and Library

The library of the Institute serves and is supported by AOL and MEL. A considerable number of changes have taken place in the last 2 years and are discussed below.

One aspect is in the holdings of the library and in its physical appearance. In the 2 year period covered by this report the number of bound volumes (books and journals) has increased from 4,919 to 8,182 (64%). The number of periodicals, excluding abstract journals, but including material received on exchange, has increased from 317 to 388 (22%). The number of abstract journals has shown the greatest increase, from 14 to 23 (65%). This latter reflects a policy to obtain as many relevant abstract journals as possible, although it is not feasible to subscribe to all the relevant published journals.

To contain this large increase in holdings, the library was completely refurnished, with 61 stack units of shelving, a reading area with new periodical display racks, and six study carrels.

The holdings of reprints, manuscript reports, and separates of all kinds have in-increased considerably also. As this material is largely unindexed, one of the primary objectives will be to gain control of it, through a computer constructed key-word index, with the material being. stored on microfilm. The computer programmes for this will be available in 1969.

Late in 1968, the National Science Library announced that it would introduce a service called Selective Dissemination of Information (SDI). This is a current awareness service whereby scientists are informed of recent papers in their fields of interest, through a carefully prepared interest profile. Several of the scientific staff of the Institute participated in the experimental project in 1968 and there has been an enthusiastic response to the announcement of the expanded scheme.

Also in 1968, the Institute collaborated with the Chief Librarian, Dalhousie University, on the preparation of a proposal for a regional scientific and technical information centre. This proposal was ratified by the heads of nine institutions and establishments in the area and submitted to the Study Group on Scientific and Technical Information in Canada, sponsored by the Science Council of Canada. Some aspects of the proposal are already being implemented; the others will await action on the report of the Study Group.

The coming year will see the publication of the first volume (for 1968) of collected reprints of staff of the Institute.

R. M. McMullen

Computing Services

The Computing Services Group provides support to all research and survey activities in the Institute. This support ranges from the mathematical development of computer techniques and complex computer programming, to the routine operation of keypunching data and programs. The rapid growth in activity in the group since 1966 has been accompanied by a similar increase in staff, which has entailed a considerable effort in training. Many scientists and surveyors still write their own programs and carry out the actual computer operation, and it is not proposed to change this arrangement.

The main computer in the building is a Control Data 3100 computer with 16 K words of memory, two disk drives, three tape drives, one paper tape station, one line printer, one card reader, and one typewriter. The computer also has the capacity of using eight channels of digital to analogue equipment, 24 channels of analogue to digital equipment and a 24 position relay unit. A Tektronix 611 memory scope is attached to two of the digital to analogue channels and four of the relay closures for monitoring plotter outputs. A camera for recording information from this scope is being assembled for future use.

The Institute now possesses four PDP-8 computers, each of which has a high speed paper tape reader and punch along with Dectape recorders. Two of the computers are for use on board ship. The other two are used for hardware and software development in the laboratory.

The following sections outline some typical projects which have been carried out in support of Institute programs; a representative selection has been made in order to demonstrate the variety in the work of this group.

R. C. Richards

Measurement and analysis of random data

It is frequently convenient to record signals from oceanographic sensors as a frequency-modulated signal on a magnetic tape. Several such signals, with different carrier frequencies, may be recorded on a single channel tape recorder. One major user of this system is the Air-Sea Interaction Group, who record signals from thrust anemometers, temperature sensors, and wave sensors (see p.

6 -10). Programs have been developed to analyse this data automatically. Data is fed from the tape recorder to the computer through the analogue to digital equipment, which converts the signals from analogue form to digital numbers at regular intervals. The tape recorder is automatically controlled by the computer via the relay unit.

The basic data is transformed to obtain the required components for analysis and the digital values are recorded on magnetic tape in a standard format. A variety of statistical analyses can be performed on the data by using a system of programs consisting of a master routine which calls a number of specialized subroutines as required. This system is frequently used to calculate and plot power spectra. Inclusion of the Fast Fourier Transform in the subroutines is in progress.

K. S. Budlong
I. Phyo
P. S. Trites

PDP-8 software development

Software development for the shipboard PDP-8 computers was concentrated on support for the geophysics research and survey program (see p. 18-27). Navigational computations can now be carried out aboard ship using basic data from conventional Decca and Decca Lambda in a form suitable for compilation with the magnetic and gravity data collected simultaneously. Considerable effort was expended to assemble programs for efficient handling of data from the new satellite navigation equipment and in modifying programs to improve the fixes computed from satellite data (see p. 23 and 61).

Following modifications to data gathering equipment and the addition of Dee-tape transports to each PDP-8, a number of changes have been made to existing programs.

The assembly of PDP-8 programs has been simplified by the development of a program enabling the Control Data 3100 computer to be used to prepare the assembled PDP-8 program. Therefore, it is possible to start from a source program on cards or paper tape and compile a complete PDP-8 program quickly and conveniently.

J. C. Sutherland
D. A. Dalby

Analysis of gamma-ray spectra

Instrumental activation analysis using high resolution lithium-drifted germanium gamma ray detectors depends for its success upon the quantitative measurement of the gamma ray emissions from the radioisotopes present in an irradiated sample (see p. 17). The use of digital computers for the analysis of spectra is well established, and in the case of trace elements in geochemical samples is desirable owing to the complexity of the spectra and the need for analysis of many samples.

The analysis of samples containing several elements with overlapping spectral lines requires the comparison of intensities of observed sample spectra with a catalogue of data for the radio-isotopes possibly present. The computer programs developed to solve the system of equations for the abundances of the isotopes must make use of a catalogue, compiled from published data, and also take account of the experimental variation of detector efficiency.

J. C. Sutherland
V. N. Beck
M. S. Talwar

Hydrographic development

Effective use of satellite navigation requires advance knowledge of the times when suitable passes occur. A set of “alert” programs has been prepared which calculates rise and set times, maximum elevation, and other parameters for each satellite pass above the horizon. The parameters are then sorted and printed in tabular form giving day by day chronological information. These programs are being used to predict and identify the satellite passes received with satellite navigation receiving equipment.

The speed and accuracy of preparation of hydrographic survey field sheets has been much improved by automating the plotting of the lattice projections needed. The coordinates of the points required are computed and punched on paper tape which is then read by the Gerber plotting table. These points can then be manually joined to produce a lattice for a finished chart for navigational purposes.

V. N. Beck
K. S. Budlong

Data processing

A large part of the work of the group is concerned with the processing of large volumes of oceanographic data; there is a great deal of routine computer operation in this respect, as well as the continuing development of programs to provide more efficient and more extensive computation facilities. As an indication of the magnitude of this effort, 20 programs were written to process data from self-recording current meters, and were used in the analysis of over 100 current meter records of more than 2,200 days total operation. Data reports on the daily magnetic variation recorded at land stations are produced on a regular year-round basis; all aspects of these reports, including the final output plots, are automatically produced. Virtually all the ocean temperatures and salinities measured by physical oceanographers (whether by the continuous-profile salinity-temperature-depth recorder, or by reversing thermometer) are now processed with the aid of the computer, which can apply corrections to the raw data using calibrations stored on magnetic tape files.

A beginning has been made in the application of the computer facilities for inventory control purposes. The standards laboratory group of Engineering Services uses a computer system to maintain a running inventory of electronic test equipment. The system has the ability to update data files, process several information retrieval requests simultaneously, list all equipment which is due for calibration, and list all equipment which is ready for issue.

P. S. Trites

Appendices

Appendix A-l - Publications and Reports

Publications

AUMENTO, F. 1968. The Mid-Atlantic Ridge near 45° N: II. Basalts from the Area of Confederation Peak. *Cdn. Jour. Earth* Sci., 5: l-21. BI Contrib. *No. 88.*

Assisted by detailed bathymetric and bottom photographic coverage, a series of closely spaced rock dredgings were undertaken on a traverse from the centre of the Median Valley to the adjacent crest mountains. The specimens show a continuous sequence from tholeiitic to alkali basalts. Chemical variations can be correlated with the depth of extrusion.

AUMENTO, F., and B. D. LONCAREVIC 1968. The Mid-Atlantic Ridge near 45° N: III. Bald Mountain. *Cdn. Jour. Earth Sci.* (in press). BI Contrib. No. 137.

Regionally metamorphosed and metasomatized basalts, and un-metamorphosed equivalents, were recovered from the steep slopes of Bald Mountain, a north-south elongated seamount lying 60 km west of *the Median Rift Valley at* 45°N. *The seamount had been block-faulted and repeatedly uplifted* 1,000 *m or more along old lines of weakness. The uplift, and the removal by submarine erosion of extrusives capping the seamount, has resulted in the exposure of the more deep-seated metamorphosed horizons along the fault scarps. The block-faulted topography of Bald Mountain suggests that brittle fracturing of the upper crustal layers of the Mid-Atlantic Ridge has occurred as a result of the low ocean floor spreading rates calculated to occur at* 45°N.

BARRETT, D. L. 1968. Frequency Modulation of a Shipborne Proton Magnetometer Signal due to the Hydrodynamic Instability of the Towed Vehicle. *Jour. Geophys. Res., 73: 5327-5334.* BI Contrib. No. 110.

Oscillatory motion of the towed sensor is examined as a source of scatter in the readings of the shipborne nuclear precession magnetometer. Experimental investigation into the stability of the towed vehicle shows ***that*** *significant errors can be introduced into magnetic field measurements if the hydrodynamic properties of the vehicle are neglected, or if it is towed in the turbulent waters astern of the ship. These errors can be reduced to* ± 0.1 *gamma by lengthening the vehicle and increasing the length of the towing cable,*

BARTLETT, G .A. 1967. Scanning Electron Microscope : Potentials in the Morphology of Microorganisms. *Science,* 158: 1318-1319. BI Contrib. No. 105.

Morphological characteristics related to ecology, evolutionary sequences, specific, generic and familial relationships can now be determined with the Scanning Electron Microscope. These detailed morphological characteristics will help to establish a more natural faunal classification and will enable more accurate ecological and biostratigraphic correlations to be carried out.

BARTLETT, G. A. 1968. Planktonic Foraminifera -New Dimensions with the Scanning Electron Miscroscope. *Cdn. Jour. Earth Sci., 5:* 231-233. BI Contrib. No. 92.

Extremely fine, detailed morphological characteristics of micro-organisms, hitherto unavailable, can now be determined with the Scanning Electron Microscope. Morphological characteristics related to evolutionary sequences, specific, generic and familial relationships will permit more natural faunal classifications and enable more accurate ecological and biostratigraphic correlations.

BARTLETT, G. A. 1968. Mid-Tertiary Stratigraphy on the Continental Slope off Nova Scotia. *Maritime Sediments,* 4: 22-31. BI Contrib. No. 124.

Tertiary microfaunas from sediments on the Scotian Shelf and Slope are comparable to those described from established sections in the Caribbean. A tentative correlation with the Globorotalia opima opima through Globorotalia mayeri zones in the Caribbean is proposed. A relationship between slope faunas off Nova Scotia and world-wide planktonic foraminiferal zones is suggested.

BARTLETT, G. A. Planktonic Foraminifera-A History of the Oceans. *Jour. Paleontology* (in press). BI Contrib. No. 91

Faunal evidence of alternate warm and cold sequences in sediments from the Scotian Slope and Mid-Atlantic Ridge supports the hypothesis of a fluctuating sub-Arctic convergence in close proximity to a *Mid-Atlantic gyral during the Pleistocene and late Tertiary. This evidence requires a re-evaluation of paleoclimatology, paleogeography and paleo-oceanography.*

BARTLETT, G. A. Foraminifera Distribution in Tracadie Bay, Prince Edward Island. *Geol. Surv. Can. Paper* (in press) RI Contrib. No. 47.

The foraminiferal fauna of Tracadie Bay is lagoonal in character and is composed of eurybathic species. This fauna lacks the characteristic miliolid species of southern latitudes and arenaceous species of Arctic environments.

BARTLETT, G. A. Benthonic Foraminiferal Ecology in St. Margaret's Bay and Mahone Bay, southeast Nova Scotia. *Geol. Surv. Can. Bulletin* (in press). BI Contrib. No. 25.

Four biofacies are established (intertidal, back-bay lagoon, nearshore and open ocean). Foraminifera are micro-environmentally distributed within each of the biofacies. Consequently, geographic position and spacing of sample stations are as important as environmental factors in the interpretation of foraminiferal distributions.

BECK, V. N. 1967. Tests of a Miniature Electrical Humidity Sensor. *Proc. First Cdn. Conf. Micromet*. (1965) Part I, 93-104. BI Contrib. No. 41.

A miniature electrical humidity sensor is described that may be useful in measuring high-frequency fluctuations. Further testing is required but it appears that the instrument has a time constant of about 0.2 sec. in a wind of 16 *m/sec. and a sensitivity permitting attainment of a resolution of 0.2% relative humidity.*

BOWER, M. R., and B. D. LONCAREVIC. 1967. Sea-Gravimeter Trials on the Halifax Test Range aboard *CSS Baffin,* 1963. *Publs. Dom. Obs.,* 36 (1):137 p. BI Contrib. No. 49.

Two precisely located and calibrated lines on the Halifax Sea Gravimeter Testing Range were traversed back and forth for a total of 100 *times while gravity measurements were made with both the LaCoste and Romberg and the Askania-Graf sea-surface gravimeters. During the 3-week test, the rms heave accelerations varied from 2 to* 78 *gals with a median value of* 13 *gals. Useful gravity readings were obtained with the LaCoste gravimeter up to heave accelerations of about 30 gals and up to at least 50 gals for the Askania.*

BROOKE, J., and R. L. G. GILBERT, 1967. Undersea Rock Drill. Canadian Upper Mantle Report. *Geol. Surv. Can.* Paper 67-41, 179-180. BI Contrib. No. 79.

BROOKE, J., and R. L. G. GILBERT, 1968. The Development of the Bedford Institute Deep Sea Drill. *Deep* Sea *Res.* 15: 483-490. BI Contrib No. 116.

A new concept for drilling short cores of rock from the floor of the deep ocean is described. The power for operating the drill is obtained from water which moves from the normal ambient hydrostatic pressure into a low pressure void. A general description is given of the complete drill assembly and its method of operation.. The results of three series of experiments at sea and a number of tests on land are given, from which the abilities and limitations of the drill in its present form may be inferred. The plans for experimental work to be carried out this summer are described, and long-range plans and objectives are outlined.

DOE, L. A. E. 1967. Air-Sea Interaction Studies at the Bedford Institute of Oceanography-General Program. *Proc. First Cdn. Conf. Micromet.* (1965)) Part I, 257-60. BI Contrib. No. 38.

The air-sea interaction program of the Bedford Institute of Oceanography is described. Much of the early work has been devoted to the development of suitable sensors, a data-logging system, and an ocean platform. Attention is now being directed to the calculation of momentum, heat, and water vapour fluxes by the eddy correlation method.

DOE, L. A. E. 1967. A Series of Three-Component Thrust anemometers. *Proc. First Cdn. Conf. Micromet.* (1965), Part I. 105-114. BI Contrib. No. 39.

The historical development is given of the design of a three-component thrust anemometer. The latest model, Mark V, may be used over water (or over land) in conjunction with bead thermistors or a miniature humidity element to compute the sensible and latent vertical heat fluxes by the eddy correlation method.

FORRESTER, W. D. Geostrophic Approximation in the St. Lawrence Estuary. Submitted to *Tellus.*

A 1965 *survey of currents and geostrophic currents in the St. Lawrence estuary is described. An innovation employed in the survey was to moor the strings of oceanographic bottles in the cross-section and trip them simultaneously. A tidal oscillation was detected in the vertical shear of*

the geostrophic current as well as in the vertical shear of the axial and cross-channel current components.

GRANT, A. C. 1967. A Continuous Seismic Profile from Halifax Harbour, Nova Scotia. *Maritime Sediments,* 3, 64. BI Contrib. No. 101.

A continuous seismic profile across Halifax Harbour indicated the occurrence of a pre-glacial valley presently filled with 60 ft of modern sediments. Structure of the underlying bedrock was also determined, and in places, a thickness of of only 10-15 *ft of mud was present near shore.*

GRANT, A. C. 1968. Seismic-Profiler Investigation of the Continental Margin, Northeast of Newfoundland. *Cdn. Jour. Earth Sci.,* 5: 1187-1189. BI Contrib. No. 125.

Unconsolidated sediments on the continental shelf unconformably overlie stratified bedrock that dips gently eastward toward the continental slope. To a water depth of 3,000 m the continental slope truncates bedrock layers, and at greater depths the truncated bedrock surface is buried by slumped deposits.

GRANT, A. C. Some Aspects of the Bedrock Geology of Hudson Bay as Interpreted from Continuous Seismic Reflection Profiles. In *Hudson Bay Symposium Volume, Geol. Surv. Can., Paper Series* (in press). BI Contrib. No. 119.

Palaeozoic sedimentary rocks in Hudson Bay form a north-south basinal structure. The major topographic features, especially the "central shoal", are considered to be a reflection of bedrock structure.

KEYTE, F. K. 1967. Computer vs. Manual Calculations of Temperature and Depths. *Jour. Fish. Res. Bd. Can.,* 24: 2491-2495. RI Contrib. No. 78.

Temperatures from oceanographic reversing thermometers have traditionally been corrected by hand calculation, but there is now a move toward programming computers to make these corrections, In this note a comparison is made between 9,038 hand-corrected temperatures and the corresponding computer-corrected temperatures. It was found that 19% *of the hand-corrected were in error by* 0.01°C *or more, with some errors as large as* 1° C.

KING, L. H. 1967. Use of a Conventional Echo-Sounder and Textural Analyses in Delineating Sedimentary Facies: Scotian Shelf. *Cdn. Jour. Earth Sci.,* 4: 691-708. BI Contrib. No. 60.

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

KING, L. H. 1967. On the Sediments and Stratigraphy of the Scotian Shelf. In *Geology of the Atlantic Region,* Geol. Assoc. Can., Spec. Pub. No. 4, p. 71-92. RI Contrib. No. 80.

The paper describes the surficial geology and near-surface stratigraphy of a portion of the Scotian Shelf. Extensive use is made of the acoustical data from echograms.

KING, L. H. Submarine End Moraines and Associated Deposits on the Scotian Shelf. *Geol. Soc. Amer. Bull.* (in press). BI Contrib. No. 112.

Describes an end-moraine system off the coast of Nova Scotia, presumably a continuation of the New England system.

KING, L. H. Chemical, Mineralogical, and Textural Variations in Sediments from the Scotian Shelf. Submitted to *Chemical Geology.* BI Contrib. No. 114.

The study shows the interrelationship between the chemical, mineralogical and textural parameters of seventeen sediments from the Scotian Shelf. ranging in texture from gravel to clay. It also 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 natural mechanical fractionation.

KRANCK, K. 1967. Bedrock and Sediments of Kouchibouguac Bay, New Brunswick. *Jour. Fish. Res. Bd. Can.,* 24: 2241-2265. BI Contrib. No. 90.

Textural and mineral analyses were performed on 220 samples from Kouchibouguac Bay and the adjacent part of Northamberland Strait. On the basis of this data and interpretation of echograms, the study area is divided into four bottom lithologies: bedrock, gravel, sand, and mixed sand and gravel. The petrological composition of the gravel fraction of sediment samples is used as a guide to the composition of the bedrock underlying the study area. Textural parameters of the sediment samples are related to the bottom topography, coastline and currents in the area and the factors responsible for their origin and present distribution are discussed.

LAWRENCE, D. J. 1968. Observation of Inertial Oscillation in the Northwest Atlantic at 42° N. *Jour. Fish. Res. Rd. Can., 25:* 1079-1083. BI Contrib. No. 103.

Analyses of current meter data from two moorings at 42V12' N; 56°42' *W in* 1964 *showed that at a depth of* 180 *m, an inertial oscillation was present over a 2-week period.*

LEWIS, E. L. 1967. Heat Flow Through Winter Ice. Proc. Intl. Conf. Low Temp. Science (1966), *Physics of Snow* & Ice, 1, Part I, p. 611-631. BI 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. 1967. Gravity Measurements at Sea, Techniques of. *International Dictionary of Geophysics,* Pergamon Press, London, Vol. 1, p. 694-700. RI Contrib. No. 27.

Survey of methods from early pendulums to present shipboard instruments;. operational requirements for data reduction are considered.

LONCAREVIC, B. D., and G. N. EWING. 1967. Geophysical Study of the Orpheus Gravity Anomaly. *Proc. Seventh World Petroleum Congress,* 2: 827-835. BI 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.

LOUCKS, R. H. 1967. Measurements Required for Momentum and Energy Flux Determinations over the Sea. *Proc. First Cdn. Conf. Micromet.* (1965). Part I, p. 262-270. BI Contrib. No. 43.

Eddy correlation methods of determining fluxes of momentum, energy, heat and water vapour are reviewed in the light of the instrumentation being developed at the Bedford Institute.

McMULLEN, R. M., and D. J. P. SWIFT. 1967. An Occurrence of Large-Scale Rhomboid Ripples, Minas Basin, Nova Scotia. *Jour. Sed. Pet., 37: 706-706.* BI Contrib. No. 72.

Some large-scale rhomboid ripples were observed and photographed during a flight over the emergent intertidal sediments of the Minus 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.

MANN, C. R. 1967. The Termination of the Gulf Stream and the Beginning of the North Atlantic Current. *Deep-Sea Res.,* 14: 337-359. BI Contrib. No. 74.

A basic current system between the Tail of the Grand Banks and the Azores is proposed from a study of data obtained on CSS Baffin in 1963 *and* 1964. *The Gulf Stream turns southeast after crossing* 50° *W long and forms a northeast boundary to the Sargasso Sea. The Atlantic Current is fed by the Slope Water Current which crosses* 50° *W long between the Gulf Stream and the Tail of the Bank and by a branch of the Gulf Stream which separates in the vicinity of* 38°30' *N,* 44° *W.*

MANN, C. R. 1968. A Summary of Variability Observed with Monitoring Sections off the East and West Coasts of Canada. *Progress in Oceanography,* 5: 17-30. BI Contrib. No. 122.

Data from monitoring sections off the East and West coasts of Canada and from Ocean Station Papa were examined to determine their suitability as a time series. It was concluded that the sections were inadequate as they were not run often enough and that the rate of sampling at Station Papa should be increased by instrumenting the second weather ship. At present only one weather ship is instrumented and data is only obtained during every alternate 6-week period.

MANN, C. R. Temperature and Salinity Characteristics of the Denmark Strait Overflow. *Progress in Oceanography* (in press). BI Contrib. No. 132.

A detailed set of temperature and salinity observations made by CSS Hudson in the Denmark Strait in 1967 shows considerable changes in the thickness of the overflow and its temperature-salinity characteristic in periods of two days. Turbulent mixing within the Strait contributes to the variability. The overflow mixes with Atlantic water and water derived from the Iceland-Scotland overflow as it moves down the continental slope east of Greenland. Its temperature-salinity characteristics are remarkably constant by the time it reaches Cape Farewell.

MANN, C. R., and G. T. NEEDLER. 1967. Effect of Aliasing on Studies of Long-Term Oceanic Variability off Canada's Coasts. *Jour. Fish. Res. Bd. Can.,* 24: 1827-1831. BI Contrib. No. 76.

A study of the time series run at Ocean Station Papa, on the line to it, and on the Halifax section; and of the masking of low frequency phenomena by high frequency signals.

MARLOWE, J. I. 1967. A Piston Corer for use through Small Ice Holes. *Deep* Sea. *Res.,* 14: 129-131. BI Contrib. No. 61.

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

MARLOWE, J. I. 1968. Unconsolidated Marine Sediments in Baffin Bay. *Jour. Sed. Pet., 38.* BI Contrib. No. 106.

Sediment in Baffin Bay is predominantly mud with minor amounts of sand and gravel. Median grain sizes are generally related to bottom topography (e.g. coarses over highs and finer in the central basin). Sediment texture in cores indicates a decrease in current competence with time and also indicates that some of the material was transported by submarine slumps.

NEEDLER, G. T. 1967. A Model for Thermohaline Circulation in an Ocean of Finite Depth. *Jour. Mar. Res.,* 25: 329-342. BI 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.*

PAGDEN, I. M. H. The Resolving Power of Ge (Li) Gamma Ray Coincidence Spectrometry and its Applications to Multiple Radio-Isotope Analyses. *Anal. Chem.* (under review). BI Contrib. No. 115.

Computer analyses have been made to determine the number of coincidence gamma rays which could be uniquely identified in radio-chemical mixtures from a variety of sources. It appears that at certain limits the resolving power is such that parent radio-isotopes could be identified without recourse to chemical separations.

PELLETIER, B. R. 1967. Geological Exploration around Sable Island, Nova Scotia. *Oilweek,* June 26. BI Contrib. No. 86.

The history of geological exploration is reviewed with comments on current work undertaken by the oil companies, universities and government agencies. Some photographs of dredging and coring operations, and a list of selected references are included.

PELLETIER, B. R. 1967. Sedimentation in Arctic Waters of the Western Queen Elizabeth Islands, District of Franklin, Canada. *Maritime Sediments,* 3: 90-99. BI Contrib. No. 117.

Results from the analyses of several hundred bottom samples are related to several Arctic sedimentary environments e.g lucustrine, fluvial, deltaic and non-deltaic marine, channel and continental shelf. Under the influence of a flow field the mechanical properties of sediments vary exponentially with distance of sedimentary transport. Exclusive of this influence the mechanical properties of sediments are related to topographic features. Other mineralogical and chemical criteria are assigned to the products of deposition in the environments discussed.

PELLETIER, B. R. Submarine Physiography, Bottom Sediments and Models of Sediment Transport in Hudson Bay. *In Hudson Bay Symposium Volume, Geol. Survey Can., Paper Series* (in press). RI Contrib. No. 121.

Submarine physiography of Hudson Bay is discussed in terms of its development from a pre-Pleistocene drainage system, its relation to the underlying geological formations and structures and, its modification by glacial action, marine invasion and subsequent sedimentation. Sediments are described according to mechanical and certain chemical properties. Origin of the sediments is related to contributions from rivers as well as from ice. Models of sediment transport are drawn to illustrate the dispersal of sediments over the bay due to the combined agents of ice and marine currents, and secondly to show the dispersal by marine currents only.

PELLETIER, B. R. Submarine Physiography and Sediments of Hudson Bay. In *Geology and Economic Minerals of Canada, Geol. Surv. Can. Econ. Geol.* Series No. 1 (in press). BI Contrib. No. 67.

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. The Hudson Bay Oceanographic Project of 1965. *Cdn. Geog. Jour.* (under review). BI Contrib. No. 68.

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,

PELLETIER, B. R. 1968. The Submersible PISCES Feasibility Study in the Canadian Arctic. *Maritime Sediments* (in press). RI Contrib. No. 140.

The seven-ton submersible PISCES 1 was *used in a feasibility study for underwater geological exploration, study, and mapping. A series of* 16 *dives were made in Baffin Bay, Jones Sound, Norwegian Bay, Lancaster Sound, McClure Strait and Pond, and Milne Inlets. Rock structures and physiography were followed to a depth of* 1,520 *ft in the most northerly operations for a vessel of this class. Work was carried out from CCGS Labrador in conjunction with programs of the Defence Research Board, FRB, and Johns Hopkins University, Baltimore, Md., USA. Manipulating claws, hammers, closed circuit underwater television, cameras, and sonic equipment were carried on the submarine.*

PELLETIER, B. R., F. J. E. WAGNER, and A. C. GRANT. 1968. Marine *Geology* in *Science, History and Hudson Bay.* Vol. 2, Ch. 9, Part III, p. 557-613. Canada, Department of Energy, Mines and Resources. BI Contrib. No. 77.

Fauna of raised beach deposits from the relic Tyrrell Sea are discussed and related to similar deposits of modern Hudson Bay. Submarine physiography is described and an ancient stream system is inferred. Sedimentary trends are shown and an analysis of lithology of bottom samples, mineralogy, physiography, and known geological features around Hudson Bay is used to interpret and delineate bedrock features beneath the bay.

POTTIE, B. G. 1967. A Fast-Response Thermistor Thermometer. *Proc. First Cdn. Conf. Micromet.* (1965), Part I, p. 82-89. BI Contrib. No. 40.

A thermistor thermometer is described that responds nearly linearity to changes of up to about 10 cycles per second, detecting a change of 0.0l° C *over any* 10° *C range from 0° to 30° C, and yielding a maximum output of 5 v for a* 10° *C fluctuation.*

PRAKASH, A., and M. A. RASHID. 1968. Influence of Humic Substances on the Growth of Marine Phytoplankton. *Limnol. & Oceanog., 13* (in press) BI Contrib. No. 102.

The positive effect of humic substances on phytoplanklon growth, for Ihe most part, is independent of nutrient concentration and cannot be attributed entirely to chelation processes. It appears that growth enhancement in the presence of humic substances is linked with stimulation of physiological and biochemical processes associated with algal cell metabolism. Because of their high concentrations in coastal waters, humic substances may thus be regarded as one of the ecologically significant entities influencing coastal phytoplanktonic production.

PRAKASH, A., and M. A. RASHID. The Influence of Humic Substances on Coastal Phytoplankton Productivity. *Proc. Inter. Sym. Coastal Lagoons* (UNESCO, 1967) (in press). BI Contrib. No. 107.

Small concentrations of humic and fulvic acids exert a stimulatory effect on marine phytoplankton which is reflected in higher yield and increased growth rate. Low molecular weight, water soluble fractions of humic acid are more active in promoting growth.

QUON, C. Time Dependence of Thermal Convection in a Bounded Rotating System. *The Physics of Fluids* (in press). BI Contrib. No. 136.

The time dependence of the velocity and the temperature field of an axisymmetric state in a *rotating annulus where convection is a dominant mechanism for heat transfer, is studied numerically. The development of the various terms in the momentum and heat equations is followed through time until steady state is achieved. Inertial oscillations dominate the interior motion at the initial stage. Sixteen revolutions of the annulus are necessary for the system studied here to attain the quasi-steady state. It is found that both heat and momentum diffusion are important in the interior, even though convection dominates the heat flow in the boundary layers.*

RASHID, M. A., and L. H. KING. Molecular Weight Distribution Measurements on Humic and Fulvic Acid Fractions from Marine Clays on the Scotian Shelf. *Geochim. et Cosmochim. Acta* (in press). RI Contrib. No. 109.

The molecular weight of humic and fulvic acids extracted from a marine clay shows a wide distribution ranging from less than 700 to over 2,000,000 with an estimated average of approximately 400,000.

RASHID, M. A., and L. H. KING. A Study of the Major Oxygen-containing Functional Groups present on Humic and Fulvic Acid Fractions of

Different Marine Clays. Submitted to *Chemical* Geology. BI Contrib. No. 108.

The quantities of carboxyl, phenolic and alcoholic hydroxyl, and carbonyl groups found on organic matter of a marine clay seem to have been influenced by the depositional environment. This conclusion is drawn through a comparison with similar studies on solid organic matter.

REINIGER, R. F., and C. K. ROSS. 1968. A Method of Interpolation with Application to Oceanographic Data. *Deep Sea Res.*, 15: 185-193. BI Contrib. No. 98.

A method has been devised to interpolate any single-valued function of one independent variable with special emphasis on oceanographic parameters. No model for the dependence of the function on the independent variable is assumed but an effort is made to minimize spurious extrema in the interpolated values. A method of estimating the accuracy of the interpolated values is also presented. The interpolation scheme has been applied to oceanographic data with favourable results.

ROSS, D. I. 1967. Magnetic and Bathymetric Measurements across the Pacific-Antarctic Ridge South of New Zealand. *N.Z. Jour. Geol., & Geophys.*, 10: 1452-1465. BI Contrib. No. 82.

Magnetic and bathymetric records across the Pacific-Antarctic Ridge between long 160° *E and* 180° *E are discussed. The northern flanks can be divided into step provinces and a narrow rift valley probably exists along the crest, Magnetic records in general show large anomalies over the crest.*

SANDSTROM, H. Effect of Topography on Propagation of Waves in Stratified Fluids. *Deep Sea Research* (under review). BI Contrib. No. 84.

Two-dimensional propagation of waves in stratified fluid is considered in terms of ray theory. The effect of topography is shown to give rise to anomalous reflection of waves and leads to energy transfer between wave components of different wave number. Simple analytical models of wave fields agree with experiments.

SCHAFER, C. T. 1967. Factors Influencing the Numerical Accuracy of Benthonic Foraminifera Population Counts from Bottom Sediment Samples, Gulf of St. Lawrence. *Maritime Sediments, 3,* (71). RI Contrib. No. 99.

Meaningful quantitative ecological studies of nearshore benthonic Foraminifera populations require seasonal and subsampling techniques. Agents that can influence the quantitative accuracy of individual benthonic foraminiferal samples are both physical and biological in nature. They include periodic wave-generated turbulence, disturbance of the sediment by the sampling device, the mode of locomotion and feeding habits of larger marine organisms.

SCHAFER, C. T. 1967. Preliminary Survey of the Distribution of Living Benthonic Foraminifera in Northumberland Strait. *Maritime Sediments,* 3: 105-108. BI Contrib. No. 113.

Differentiation of Foraminifera species in Northumberland Strait is discussed in terms of existing ecological conditions. Population differences are also described with reference to both living and dead Foraminifera in order to show the shift in population due to the shift in ecological conditions.

SCHAFER, C. T., and A. PRAKASH. 1968. Current Transport and Deposition of Foraminiferal Tests, Planktonic Organisms and Lithogenic Particles in Bedford Basin, Nova Scotia. *Maritime Sediments, 4:* (in press). RI Contrib. No. 138.

Foraminiferal tests that have been abandoned because of the death of the living animal are especially susceptible to erosion and transportation due to their size and low envelope density. The diameters of the observed specimens are within the range of particle sizes that allows them to be most easily eroded and transported.

SCHAFER, C. T., and B. K. SEN GUPTA. 1968. Benthonic Foraminiferal Ecology in Port Castries Bay, St. Lucia: A Preliminary Report. *Maritime Sediments, 4:* (in press). BI Contrib. No. 139.

In the Port Castries Bay, which has an average depth of 11 *m, the bottom water of the central part shows relatively high concentrations of phosphates, nitrates and nitrites. The abundance of living Foraminifera in the bay is less than that generally found in more northerly waters. The benthonic foraminiferal suite consists of* 112 *species of which* 46 *are recorded as living in February and March,* 1968. *The living/total ratio attains a maximum of* 31% *off the mouth of the Castries River and indicates a relatively rapid sedimentation rate in this part of the bay.*

SEN GUPTA, B. K. 1967. Distribution of Foraminifera in the Sediments of the Grand Banks: A

Preliminary Report. *Maritime Sediments,* 3: 61-63. BI Contrib. No. 100.

The overall abundance of Foraminifera in the surface sediments of the Tail of the Grand Banks is inversely related to the grain-size of the sediments. Although the benthonic species form a large suite, only 12 *attain a maximum frequency of* 5% *or more in any sample, the most abundant species being Islandiella islandica (Norvang). A minor species Cribrostomoides crassimargo (Norman), exhibits an extremely localized distribution. The planktonic suite consists of six species.*

SEN GUPTA, B. K., and R. M. MCMULLEN. Foraminiferal Distribution and Sedimentary Facies on the Grand Banks of Newfoundland. Submitted to *Canadian Journal of Earth Sciences.* BI Contrib. No. 134.

The southern part of the Grand Banks can- be divided into three sedimentary regions. The northwestern region is dominated by gravel-size material; this is probably a reworked glacial sediment and its limit may indicate the seaward edge of the Quaternary ice-sheet. The other regions are both dominated by sand-size preglacial material reworked in post-glacial times. The southwestern region includes a *large area of finer sediment which shows the highest density of foraminiferal tests. On the Tail of the Bank an inverse relationship is commonly present between the density of the benthonic tests and the grain-size of the sediment. Of the 88 species present in the benthonic assemblage,* 31 *occur in* 30% *or more of the stations and only 5 occur in more than* 90% *of the stations. The percentage of planktonic tests in the total foraminiferal population decreases sharply on the shallow plateau, inward from the edge of the Bank.*

SRIVASTAVA, S. P. Inland, Coastal, and Offshore Magnetotelluric Measurements. Presented at Meeting of Can. Assoc. Physicists, June, 1967. Submitted to *Cdn. Jour. Earth Sci. BI Contrib. No. 83.*

For 6 weeks during the summer of 1966 simultaneous magnetic and electric field recordings were made at Fredericton, Halifax and Sable Island. The main purpose was to obtain a conductivity profile inside the earth across the eastern coast of Canada and to study the effect of the coast on the magnetic variations. The data from these stations has been analysed using power spectral techniques. A gradual increase in the intensity of vertical component of the magnetic field variations is observed from Sable Island to Fredericton. The paper deals *with the possible mechanism which may be responsible for this variation.*

SWIFT, D.J.P., R.M. MCMULLEN, and A.K. LYALL, 1967. A Tidal Delta with an Ebb-Flood Channel System in the Minas Basin, Bay of Fundy : Preliminary Report. *Maritime Sediments, 3:* 12-16. RI Contrib. No. 87.

The area of intertidal and subtidal sediment in Windsor Bay is described and considered in the light of its being analogous to a delta complex. Tidal duration and current velocity studies indicate that a mutually evasive ebb-flood channel has been established.

SWIFT, D. J. P., and R. M. MCMULLEN. 1968. Preliminary Studies of Sand Bodies in the Minas Basin, Bay of Fundy, Nova Scotia. *Can. Jour. Earth Sci.* 5: 175-183. BI 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 of mutually evasive ebb-flood channels formed and maintain these bodies.

VILKS, G. 1968. Foraminiferal Study of the Mag dalen Shallows, Gulf of St. Lawrence. *Maritime Sediments,* 4: 14-21. BI Contrib. No. 123.

Distribution of Foraminifera from the Magdalen Shallows is compared with the Arctic and North Atlantic forms.

VILKS, G. 1969. Recent Foraminifera in the Canadian Arctic. *Micropaleontology* 15 (1) : 35-60. BI Contrib. No. 93.

The distribution of recent Foraminifera was correlated to two bathymetric zones at the 200m *isobath. The information was used to support a theory of a regional lowering of sea-level during the Holocene. The rate of sedimentation during the past* 8,000 *years is suggested to be* 4.4 *cm per* 1,000 *years.*

WAGNER, F. J. E. 1967. Additional Radiocarbon Dates, Tyrrell Sea Area. *Maritime Sediments,* 3: 100-104. BI Contrib. No. 111.

Eleven shell samples from Tyrrell Sea deposits that were collected in connection with the Hudson Bay Oceanographic Project, 1965, *were radiocarbon dated. Dates ranged from* 7115 ± 100

years B.P. for shells from 300 *ft above present sea-level to* 385 ± 80 *years B. P. for shells from* 12 *ft above sea-level. Dates and uplift curves derived therefrom agree with those determined by H. A. Lee* (1960) *and B. Matthews* (1966).

WAGNER, F. J. E. Faunal Study, Hudson Bay and Tyrrell Sea. In *Hudson Bay Symposium Volume, Geol. Surv. Can., Paper Series* (in press). BI Contrib. No. 118.

Published records of fossil and living species of Hudson and James Bays, and their fore-runner, the Tyrrell Sea, date back to 1862. *Two hundred and sixty-three species have been recorded, of which* 26 *are known only as fossils, and* 120 have *been found only in recent deposits. The species collected from Hudson Bay in* 1965 *showed distributional variation to be related primarily to bottom sediment texture and dissolved oxygen content of the water, with depth being apparently of secondary importance. Bottom temperature, salinity, and hydrogen-ion concentration were relatively uniform at the depths sampled (between* 35 *and* 286 *m) and were not significant with regard to distribution of species.. Faunal changes shown by fossil assemblage from Tyrrell Sea suggest that water temperatures were probably not dissimilar to those of Hudson Bay, but that the waters were probably less saline than at present. Radiocarbon dates on marine shells indicated Tyrrell Sea may have reached its maximum extent between* 5,000 *and* 6,000 *B. C.*

WAGNER, F. J. E. 1968. Illustrated Check-List of Marine Pleistocene Invertebrate Fossils of Quebec. *Le Naturaliste Canadien* (in press). RI Contrib. No. 130.

Marine fossils are found in the areas of the Province of Quebec that were inundated at the close of the last Ice Age and then raised above present sea-level. The areas involved are those bordering James, Hudson and Ungava Bays, along the St. Lawrence and Ottawa Rivers, and in the vicinity of Lake St. John.. Two hundred and sixty-nine species are here recorded from the literature and from collections examined by the writer. Nomenclature of the species is brought up to date. The more common species are illustrated.

WESTPHAL, K. O. 1967. Series Solution of Freezing Problem with the Fixed Surface Radiating into a Medium of Arbitrary Varying Temperature. *lnternat. Jour. Heat & Mass Transfer,* 10: 195-205. BI Contrib. No. 34.

The series solution of the one-dimensional freezing problem has been found for the case that Newton's law of cooling holds at the fixed boundary. Using a method due to Portnov the position of the progressing phase-change front has been obtained by a series expansion in powers of v/t. The coefficients up to the power n = 8 are given. The formulae have been applied to an example. An estimate for the truncation error as a function of a dimensionless parameter has been obtained.

AOL Reports

67-1 G. Vilks

Quantitative Analysis of Foraminifera in Bras d'Or Lakes.

Foraminiferal ecology in Bras d'Or Lake was studied using the following statistical methods: (1) *relationship between sample variance and mean to establish the pattern of distribution; (2) analysis of variance to establish possible changes in population in time and space; (3) association analysis to relate species occurrences with the environment.*

67-2 L. H. King

On the Sediments and Stratigraphy of the Scotian Shelf.

The paper describes the surficial geology and near-surface stratigraphy of a portion of the Scotian Shelf. Extensive use *is* made *of the acoustical data from echograms.*

67-3 R. R. Weiler, J. Butters, and W. B. Bailey

The *Canus-1-64* cruise-Synoptic Oceanographic Conditions and their Variation over 5-day Periods.

This report describes the synoptic oceanographic conditions and their variation over 5-day periods of the Gulf Stream between Bermuda and Long Island in November and December 1964.

The most interesting feature that was observed was a large cyclonic eddy south of the Gulf Stream.

67-4 L. H. King

Isolation and Characterization of Organic Matter from Glacial-Marine Sediments on the Scotian Shelf.

Pertains to the procedures for extracting organic matter from marine sediment and the characterization of this material by graphs and elemental analysis. These data are compared with results on soils.

67-5 W. D. Forrester

Currents and Geostrophic Currents in the St. Lawrence Estuary.

A survey of currents and oceanography in the St. Lawrence estuary near Father Point in 1965 *is described. A new technique was successfully employed to moor strings of reversing water bottles, so that simultaneous sets of observations were obtained in a section across the estuary.*

67-6 Mrs J. Henderson (nee Penelope Wise)

Textural Study of Sediments of Barrow Strait-District of Franklin.

Submarine physiography, bottom sediments and their textural characteristics are discussed and classified. Conclusions on origin and dispersal agents of the sediments with reference to the general role of ice, currents, and topography are also given.

67-7 C. J. Yorath

The Determination of Sediment Dispersal Patterns by Statistical and Factor Analyses, Northern Scotian Shelf.

Physical and oceanographic parameters are subjected to factor analyses along with textural analyses of bottom sediments of this portion of the Scotian Shelf. On the basis of all analyses, three major energy environments were assigned to the origin of these sediments.

68-1 Doreen M. Heaps

Chart Storage and Retrieval Project, Instruction Manual.

This report describes in detail a pilot project in storage and retrieval of marine geophysics charts and documents. The system has been designed in a manner that will allow for expansion to accommodate charts and documents generated or held by other groups or sections 'within the Institute.

68-2 M. P. M. Reddy

Wave Conditions and Littoral Drift near Belledune Point, Chaleur Bay.

Using mean monthly wind data, wave conditions and the nature of long shore currents are computed at a proposed harbour site near Belledune Point, New Brunswick. In this area the eastern fetch is effectively many times greater than in any other direction and the swell from the Gulf of St. Lawrence gives rise to heavy wave action on the eastern side of Belledune Point. It is concluded that the predominant littoral drift near the Point is westward.

68-3 H. Neu

Waves in Halifax Harbour.

Phenomena which cause ships to oscillate in Halifax Harbour are described. From this analysis, design concepts were derived

which will guide the layout of future harbour developments. Recommendations are submitted to improve the harbour in general and the layout of the proposed Pier "C" in particular. A proposal is included which would permit undisturbed container handling.

68-4 C. Schafer

Lateral and Temporal Variation of Foraminifera Populations Living in nearshore Shallow Water Areas.

Populations of nearshore benthonic Foraminifera in Smithtown Bay, New York; New London Bay, Prince Edward Island; and the Gulf of St. Lawrence are characterized by significant temporal variation as well as lateral variation over short distances. Generally, larger populations of both living and dead specimens of Foraminifera may be expected in ripple troughs, as opposed to crests, in the area studied.

68-5 Ocean Circulation Group

Atlas of Oceanographic Sections-Temperature, Salinity, Dissolved Oxygen, Silica,-Davis Strait, Labrador Basin, Denmark Strait, Newfoundland Basin, 1965-67.

A compilation of physical oceanographic data collected in the Northwest Atlantic by the Institute. The data are reproduced in the form of sections.

68-6 J. Brooke, and R. L. G. Gilbert

A Deep-sea Rock Core Drill. Part I. May 1965 - October 1966.

This report is an historical review of the work performed between May 1965 *and October* 1966 *in developing an undersea drilling tool. It reviews the tests of various components and assemblies conducted at the Institute and at sea during three cruises. Details of the results and tentative conclusions are discussed and an outline of future work is included.*

68-7 W. D. Forrester, and P. E. Vandall, Jr.

Ice Volumes in the Gulf of St. Lawrence.

The Gulf of St. Lawrence has been divided into ten geographical regions and the volumes of ice present in these regions at 2-*weekly intervals through the six ice seasons of* 1962-67 *have been estimated from information contained in the weekly ice charts prepared by D.O.T. The results are presented in tabular and in graphical forms for each region, for each season, for the entire Gulf, and for the 6-year mean season. It is the purpose of this report to present the ice information in forms that will be more readily useful in such quantitative investigations as heat and water budget studies.*

68-8 Charles T. Schafer

Ecology of Benthonic Foraminifera in Western Long Island Sound and Adjacent Nearshore Areas.

Distribution of benthonic Foraminifera in western Long Island Sound is controlled, in part, by concentration of industrial pollutants and treated sewage. Species that appear to be sensitive to pollution include Quinqueloculina seminulum, Q. seminulum var. jugosa, Q. subrotunda, and Pseudopolymorphina novangliae. A decrease in the number of marsh species of Foraminifera in the western part of the Sound can be attributed to the effects of localized pollution conditions.

AOL Internal Notes

AOL Internal 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.

67-l-I	H. B. Sutherland	Investigation of the interference from Loran "C" on proposed Decca Lambda (12 f ranging) operations - Newfoundland, 1967.
67-2-I	G. R. Douglas, and D. E. Wells	Proposed program for Hydrographic Development - Group A.
67-3-I	F. J. Barteaux	Conception and trial of fibreglass parabolic acoustic reflectors for 26B echo sounder.
67-4-I	G. R. Douglas, R. L. G. Gilbert, and D. E. Wells	Accuracy standards-a basic requirement for automation -some initial proposals.
67-5-I	R. T. Haworth	Notes on the construction and use of a cross-coupling computer.
67-6-I	W. F. C. Shearman	Evaluation of Racal "Squadcal" single sideband man-pack radios.
67-7-I	W. F. C. Shearman	An evaluation of single sideband radio telephones with a view to standardization upon a type of equipment suitable for use in BIO launches and ships for communication on scientific projects.
67-8-I	B. D. Longarevic, R. F. Reiniger, and D. E. Wells	Shipboard operation of digital computers.
67-9-I	C. A. Godden	Plastic models of Foraminifera.
67-10-I	T. Kuwamoto, and I. M. H. Pagden	Progress report on the analysis for several trace elements in sea-water samples.
67-11-I	A. R. Coote	Activation products from impurities present in high grade graphite.
67-12-I	W. F. C. Shearman	Practical means of increasing efficiency and capability of a single sideband voice transmitter.
67-13-I	Digital Systems and Associates Ltd.	Shipborne computer operator training and qualifications.
67-14-I	A. R. Coote, and R. S. Hiltz	Preliminary results on the extraction of trace elements from sea-water by scavenging.
67-15-I	A. R. Coote, and W. Young	Impurities present in same quartz tubing.
67-16-I	I. Pagden, R. Weiler, and A. R. Coote	Preliminary results of activation analysis of a standard rock sample G-l.
67-17-I	I. Pagden, and R. Weiler	The measurement of low-level gamma-ray activities using a lithium-drifted gamma ray detector.
67-18-I	I. Pagden	The resolving power of lithium-drifted germanium gamma-ray detectors.
67-19-I	R. R. Weiler	The calibration of germanium gamma-ray detectors.

67-20-I	I. Pagden, and R. R. Weiler	Coincidence measurement of sodium iodine and lithium-drifted germanium detectors.
67-21-I	K. S. Manchester	Manual for coding and keypunching underwater camera station data.
67-22-I	A. R. Coote, W. Young, and R. S. Hiltz	Preliminary results of activation analysis of a manganese nodule.
67-23-I	M. J. A. Wagner, A. Holler, and D. P. Dale	Reports on participation in the Navado Projects by BIO ships.
67-24-I	R. G. Stevens	An experimental inquiry into growth and generation of water waves.
67-25-I	D. J. Lawrence	Ocean currents near Sable Island 1965.

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68-l-I	S. P. MacPhee	Interim report-Dual frequency V.H.F. X-band transponder.
68-2-I	H. MacPhail	Sonar buoys.
68-3-I	G. R. Douglas, and D. E. Wells	1968 Program-Hydrographic development Group A.
68-4-I	D. R. Harvey, and C. S. Mason	The Digibridge . . . Instrumental details of AOL marine sediment temperature probe.
68-5-I	D. Harvey	Precision interval timer for E.G. and G. pinger.
68-6-I	D. R. Harvey	A playback system for a special purpose digital tape recorder.
68-7-I	B. D. Loncarevic	Preliminary users manual for shipboard magnetometer watchkeepers.
68-8-I	R. L. G. Gilbert	Thermal array measuring system.
68-9-l	D. R. Harvey, and C. S. Mason	The measurement of temperature gradient in marine sediment-First progress report.
68-10-I	D. R. Harvey	A note on the purchase and use of Yardney Silvercel batteries.
68-l 1-I	H. MacPhail	Electronic bathythermograph recording.
68-12-I	C. S. Mason, and R. Cassivi	Deep-sea photography on Metrology Cruise 19-67.
68-13-I	C. T. Schafer	Testing and evaluation of the Model 1990 multiple plankton net.
68-14-I	D. Wells	Notes on U. S. Navy Navigation Satellite System.
68-15-I	V. C. Kerr, and L. A. Wright	Samples of various type faces for possible use in AOL reports.
68-16-I	D. J. Lawrence	Harmonic analysis of tidal streams : Preliminary investigation based on Cabot Strait, 1966.
68-17-I	David W. Simpson	Recording seismic system for refraction studies at sea.
68-18-I	R. M. Eaton	Sounding accuracy.
68-19-I	C. S. Mason	The Bosco punch programer.
68-20-I	K. Budlong	Alert calculations for the satellite navigation systems.

68-21-I	C. S. Mason	Bedford Institute sounding system. (Users Manual).
68-22-I	C. T. Schafer	A moored deep-sea sediment sampler.
68-23-I	C. A. Godden	Techniques for submerging electrical instrumentation without the use of pressure resisting housings.
68-24-I	E. A. Bendell	A guide to the design and construction of matching units for BIODAL.
68-25-I	D. I. Ross, and D. E. Wells	Experience with satellite navigation equipment during summer 1968.
68-26-I	M. J. Keen, and K. S. Manchester	Reflection profiling using air-guns on *MV Theta.*
68-27-I	John Brooke	A proposal to prevent hazards from lost equipment..
68-28-I	E. Banke, and S. D. Smith	Evaluation of Kaigo Denkai Model Pattern 311-1 Ultra Sonic Anemometer.
68-29-I	S. P. Srivastava	Diurnal Corrections to Sea Magnetic Surveys.
68-30-I		Summer Students' Reports.

AOL Computer Notes

67-l-C	W. R. Bezanson	An experiment in computer graphics on the PDP-8 computer.
67-2-C	D. M. Ness	Calculations of maxima, minima, and points of inflection for magnetic residual data.
67-3-C	D. I. Ross	Storage and retrieval of geophysical data.
67-4-C	D. A. Dalby, D. E. Wells, and C. K. Ross	Four word floating point routines.
67-5-C	D. M. Ness	An improved polynomial approximation to North Atlantic regional magnetic field.
67-6-C	F. J. Vine, and R. F. Macnab	Upward continuation of magnetic and gravity anomalies: the two-dimensional case.
67-7-C	F. J. Vine, and R. F. Macnab	A program for fitting the magnetic effect of a three-a dimensional structure to an observed anomaly by calculating the required magnetization vector.
68-1-C	F. R. Keyte	Computer sub-routine for least-square curve fittings in 2, 3, and 4 dimensions using the Crout reduction.
68-2-C	D. A. Dalby	Decca navigation routines.
68-3-C	S. P. Srivastava	Digiplot - an interrupt program for PDP-8 data processors.
68-4-C	A. S. Bennett	Plots resistance readings for three temperature probes on incremental CALCOMP plotter.
68-5-C	C. K. Ross, R. Reiniger, and A. B. Grant	Physical oceanography data reduction programs for the PDP-8.
68-6-C	R. Haworth	A set of programs for the power spectrum analysis of gravity cross-coupling data.
		Paper tape to binary cards.
68-7-C	I. Phyo	Magnetic diurnal variations programmes.

68-8-C	K. S. Budlong	Fortran satellite alert programs for the Control Data 3100.
68-9-C	I. Phyo	Programs to calculate daily magnetic variations.

AOL Data Reports

67-l-D	D. I. Ross	Monaco cruise BIO *Baffin* 07-67.
67-2-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for July, 1967.
67-3-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for August, 1967.
67-4-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for September, 1967.
67-5-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for October, 1967.
67-6-D	R. T. Haworth	Gravity cross-coupling power spectra.
67-7-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for November, 1967.
67-8-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for December, 1967.
68-l-D	D. I. Ross, and D. M. Porteous	Caribbean cruise *Baffin* 03-68, January-March, Part 1.
68-2-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for January, 1968.
68-3-D	D. I. Ross, and D. M. Porteous	Caribbean cruise *Baffin* 03-68, January-March, Part 2.
68-4-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for February, 1968.
68-5-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for March, 1968.
68-6-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for April, 1968.
68-7-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for May, 1968.
68-8-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for June, 1968.
68-9-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for July, 1968.
68-10-D	D. J. Lawrence	Current meter data from Cabot Strait.
68-11-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for August, 1968.
68-12-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for September, 1968.
68-13-D	Marine Geophysics	Demonstration cruise, October 19, 1968, BIO 58-68.
68-14-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for October, 1968.
68-15-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for November, 1968.
68-16-D	S. P. Srivastava	Magnetic variations for ground stations, BIO for December, 1968.

Appendix A-2 - Lectures and Talks

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

BARTLETT, G.A., with J. I. MARLOWE. Presented paper on "Oligocene-Miocene Strata in a Submarine Canyon off Nova Scotia" to Southeastern Section, Geological Society of America, March 1967.

BARTLETT, G.A. "Planktonic Foraminifera and climatic change". CCO Symposium Dalhousie University, April 1967.

BARTLETT, G. A. "Micropaleontology of Marine Bottom Sediments". SCOR Working Group Symposium, Cambridge, England, September 1967.

BARTLETT, G. A. "Tertiary Biostratigraphy". World Planktonic Conference, Geneva, Switzerland, September 1967.

BROOKE, J. "Rock Core Drill". CCO Symposium, Dalhousie University, April 1967.

BUCKLEY, Dale E. "Inorganic Geochemical Investigations in a Glacial Fiord, Southeast Alaska". Presented to visiting review committee of the Atomic Energy Commission of the United States at Institute of Marine Science, University of Alaska, March 1967.

BUCKLEY, Dale E. "Mechanisms and Implications of Clay-Organic Association." Seminar on Ogranics in the Marine Environment, Institute of Marine Science, University of Alaska, May 1967.

BUCKLEY, Dale E. "Structure and Evolution of the Arctic Ocean Basin". Seminar on Oceanography in the Arctic Ocean, Institute of Marine Science, University of Alaska, February 1968.

BUCKLEY, Dale E. "Transitions of Terrigenous Clays to Marine Clays". Seminar, Geology Department, Acadia University, November 1968.

BUCKLEY, Dale E. "Marine Inorganic Geochemistry". Seminar, Geology Department, St. Francis Xavier University, December 1968.

EWING, G. N. "Shipborne Gravimeter and Magnetometer Measurements on the Tail of the Grand Banks of Newfoundland". CCO Symposium, Dalhousie University, April 1967.

EWING, G. N. "A Preliminary Interpretation of the 1966 and 1967 Gravity and Magnetic Surveys of the Grand Banks of Newfoundland". Geological Association of Canada, Kingston, Ontario, August 1967.

EWING, G. N. "Geophysical Study of the Orpheus Gravity Anomaly". Seventh World Petroleum Congress, Mexico City, April 1967.

FORRESTER, W. D. "The Geostrophic Approximation and Internal Waves". I.U.G.G. meetings, Berne, Switzerland, October 1967.

GILBERT, R. L. G. "Some Developments in Marine Geophysical Instrumentation". Given at symposium on Sub-bottom Exploration Methods, Bedford Institute, October 1968.

GILBERT, R. L. G. "Exploration Beneath the Sea". Public Lecture sponsored by Canadian Society of Exploration Geophysicists, Calgary, October 1968.

GRANT, A. C. "Some Aspects of the Bedrock Geology of Hudson Bay as Interpreted from Continuous Seismic Reflection Profiles". Earts Science Symposium on Hudson Bay, Ottawa, February 1968.

HEMPHILL, M.A. “Hydrographic Surveying”. Fisheries Training Centre, Pictou, N. S., April 1967.

KING, L. H. “Submarine End Moraines and Associated Deposits on the Scotian Shelf". N. E. Section, Geological Society of America, at Boston, Mass., March 1967.

KING, L. H. “Geology of the Scotian Shelf". Nova Scotia Technical College, January 1968.

KING, L. H. “Geology of the Scotian Shelf". DREA, Dartmouth, March 1968.

KING, L. H. “Use of Acoustical Data in the Detailed Regional Mapping of the Scotian Shelf". Symposium on Marine Sub-bottom Exploration Methods, at Bedford Institute, October 1968.

LAZIER, J. R. N. “Formation of Labrador Sea Water”. Woods Hole Oceanographic Institution, June 1968.

LEWIS, E. L. “Possibilities of sea ice thickness measurement by radio techniques”. I.U.G.G. at Strasbourg, France, September 1967.

LEWIS, E. L. “Growth of the Sea Ice Cover”. D.R.E.P. at Victoria, B.C., April 1968.

LEWIS, E. L. “Brine drainage during sea ice growth and vertical circulation in the underlying water”. AGU, Seattle, Washington, October 1968.

LONCAREVIC, B. D. “Physical properties of rocks from Mid-Atlantic Ridge near 45° N”. Presented at the meeting of C.A.P. at Toronto, June 1967.

LONCAREVIC, B. D. “Field operation of small digital computers”. Presented at the meeting of C.A.P., Toronto, June 1967.

LONCAREVIC, B. D. “The Earth Sciences : Geophysics”. Invited lecture to the International Youth Sciences Week, EXPO, Montreal, August 1967.

LONCAREVIC, B. D. “Surveys of Mid-Atlantic Ridge near 45° N”. Woods Hole Workshop on mid-Ocean Ridges (by invitation) Woods Hole, Mass., September 1967.

LONCAREVIC, B. D. “Geophysical applications of small digital computers”. Symposium on Geophysical Theory and Computers, UMP, Trieste, Italy, September 1967.

LONCAREVIC, B. D. “Physiography and magnetism of the Mid-Atlantic Ridge near 45° N”. Symposium on mid-Ocean Ridge System, UMP, Zurich, Switzerland, September 1967.

LONCAREVIC, B. D. “Shipboard operation of Digital Computers”. Symposium on Computers in Oceanography, IAPSO, Lucerne, Switzerland, September 1968.

LONCAREVIC, B. D. “Gravity and Magnetic Methods in crustal exploration”. Symposium on Marine Sub-bottom Exploration Methods, at Bedford Institute, October 1968.

LONCAREVIC, B. D. “Geophysical Exploration of the Oceans”. BI-Physical Sciences Program of invited lectures. Presented at UBC, Vancouver and University of Alberta, Edmonton, November 1968.

MCMULLEN, R. M. “Modern Sedimentation in the Mawddach Estuary, Barmouth, North Wales”. Gesner Geological Society, University of New Brunswick, January 1967.

MCMULLEN, R. M. “Sediment and Heavy Mineral Patterns on the Grand Banks of Newfoundland”. Seminar to graduate students, Geology Department, University of New Brunswick, January 1967.

MCMULLEN, R. M. “Modern Sedimentation in the Mawddach Estuary, Barmouth, North Wales”. Geology Department, University of Pennsylvania, March 1967.

MCMULLEN, R. M. “Intertidal Sand Bodies in the Minas Basin Bay of Fundy, Nova Scotia”. Northeast Section of the Geological Society of America, Boston, Mass, March 1967.

MCMULLEN, R. M. Talk on the Bedford Institute of Oceanography to students and staff of the Marine Biological Station, University College of North Wales, Menai Bridge, Anglesey, UK, June 1967.

MCMULLEN, R. M. “Recent Developments in Information and Document Handling”. Oral report to Departmental Committee on Scientific and Technical Information Services and the Standing Committee of Chief Librarians, Ottawa, June, 1968.

MANCHESTER, K. S. “An Underwater Photograph Data, Interpretation and Retrieval System”. A. G. U. meeting, Washington, D.C., April 1968.

MANN, C. R. “Temperature, Salinity Characteristics of the Denmark Strait Overflow”. Woods Hole Oceanographic Institution, Woods Hole, June 1968.

MANN, C. R. “Advective and Diffusive Processes in the Ocean”. McGill University, February 1968.

MARLOWE, J. “Geological Reconnaissance of Parts of Aves Ridge”. Talk given to 5th Caribbean Geological Conference, St. Thomas, July 1968.

MARLOWE, J. “Research by the Atlantic Oceanographic Laboratory, Bedford Institute, in the Caribbean area during 1968” (co-authored with K. Kranck and C. R. Mann). International Oceanographic Conference on the Caribbean at Curacao, N.W.I., November 1968.

MURDOCK, L. P. “Development of Ocean Bathymetry”. Summer students at Bedford Institute, July 1967.

NEEDLER, G. T. “A Model of Thermohaline Circulation”. IUGG meetings, Berne, Switzerland, October 1967.

PELLETIER, B. R. “Recent Uplift in the Canadian Archipelago”. Symposium on the Atlantic Continental Margin, Dalhousie University, February 1967.

PELLETIER, B. R. “An exponential law of prograding sediments operating throughout geologic time”. Talk to the International Meeting of Geological Association of Canada, Kingston, Ontario, September 1967.

PELLETIER, B. R. “The accumulation of elastic sediments under prograding conditions”. Seminar, Department of Geology, Dalhousie University, Halifax, N. S., November 1967.

PELLETIER, B. R. “Submarine physiography, bottom sediments, and models of sediment transport in Hudson Bay”. Earth Sciences Symposium on Hudson Bay, Upper Mantle Studies, National Research Council, Ottawa, February 1968.

PELLETIER, B. R. “Geological Exploration in Northern Waters”. Talk given to the Marine Engineering Institute of Halifax, April 1968.

PELLETIER, B. R. “Recent sediments of the Bay of Fundy”. Given at Fundy Science Seminar of the University of Pennsylvania, held at Parrsboro, N. S., July 1968.

PELLETIER, B. R. “The migration of elastic sedimentary bodies under conditions of uplift at the source area”. Seminar given to Department of Geology, Memorial University, Newfoundland, November 1968.

PELLETIER, B. R. “Scientific Programs of the Bedford Institute”. University lecture, Memorial University of Newfoundland, St. John’s, November 1968.

QUON, C. “Time Dependence of Thermal Convection in a Bounded Rotating System”. Paper presented to International Symposium on High Speed Computing in Fluid Dynamics, Monterey, Calif., August 1968.

QUON, C. “Some Problems in the Numerical Study of Non-Linear Fluid Dynamics”. Seminar at the Institute of Geophysical Dynamics, Florida State University, Tallahassee, May 1968.

ROSS, C. K., and C. R. Mann. “Oceanographic Observations in the Jungfern Passage and Over the Sill into the Venezuelan Basin”. Symposium on Investigations and Resources of the Caribbean Sea and adjacent Regions, November 1968.

ROSS, D. I. “A Data Storage and Retrieval System for Marine Geophysical Data”. Washington, D. C., April 1968.

SANDSTROM, H. “Calculation of Internal Wave Fields using Ray Theory”. Presented at IUGG meetings at Berne, Switzerland, October 1967.

SCHAFER, C. T. “Evolution of Deep Diving Submarines (Submersibles)“. Bedford Institute, July 1968.

SMITH, S. D. “Turbulence Theory”-Series of 12 lectures, given at McGill University, November 1968.

SRIVASTAVA, S. P. “Inland, Coastal and Offshore Magnetotelluric Measurements in Canada”. Given to Canadian Association of Physicists in Toronto, June 1967.

SRIVASTAVA, S. P. “Inland, Coast and Offshore Magnetotelluric Measurements in Canada”. Given at IUGG Meetings in Zurich, October 1967.

VILKS, G. “Recent Foraminifera in the Canadian Arctic”. Given at Bedford Institute, December 1967.

WAGNER, F. J. E. “Faunal Study, Hudson Bay and Tyrrell Sea”. Given at Hudson Bay Symposium, Ottawa, February 1968.

WAGNER, F. J. E. “Illustrated Check-List of Marine Pleistocene Invertebrate Fossils of Quebec”. Given at the Symposium on the Quartenary of Quebec, Chicoutimi, P. Q., September 1968.

WALKER, E. R. “Diffusion Experiments at Suffield, Alberta, Canada”. Given to American Met. Society, at Santa Barbara, Calif., March 1967.

WELLS, D. E. “Satellite Navigation”. Given at N. S. Technical College, March 1968.

WILLIAMS, R. K. “Hydrographic Surveying”. Given to Dartmouth Kinsmen Club, April 1967.

WOODSIDE, J. “Gravity Anomalies in the Eastern Mediterranean Sea”. Given at AGU Meeting, Washington, D. C., April 1968.

WOODSIDE, J. “Gravity and Magnetic Anomalies Associated with the Red Sea Hot Brine Deeps”. Given at AUG Meeting, Washington, D. C., April 1968.

Appendix A-3 - Affiliations

During the years 1967-68 a number of members of AOL assisted in teaching.

Dr C. R. Mann holds an honorary Associate Professorship in the Institute of Oceanography, Dalhousie University where he has been lecturing in Fluid Mechanics and supervising Ph.D. students. Dr G. Needler and Dr H. Sandstrom were appointed honorary Research Associates IODAL in the autumn of 1968 and jointly are giving a course in Dynamical Oceanography. Dr B. D. Longarevic is a Research Associate in Geophysics lecturing and supervising graduate students at Dalhousie University. Dr S. P. Srivastava gave three lectures in a seminar course in Geophysics at Dalhousie. In early 1967, Dr L. A. E. Doe and Dr S. D. Smith lectured at IODAL. Dr Smith was appointed as a visiting Professor at McGill University giving a series of lectures

on Air-Sea Interaction in November 1968 and sharing supervision of an M.Sc candidate. Dr W. Forrester lectured on oceanography to cadets of the Coast Guard College, Sydney, N. S., in October and November 1968.

Drs L. H. King, J. Marlowe, and B. R. Pelletier are associated with the staff of the Geology Department, Dalhousie University. Dr Pelletier is an associate member of the faculty of Graduate Studies of Dalhousie; and also is Editor of the journal, "Maritime Sediments". Dr G. A. Bartlett is on nine months leave of absence to lecture and conduct research at Queen's University as visiting Professor in Micropaleontology.

Appendix A-4 - Students on Seasonal Staff

The temporary employment of selected students is of great value because it gives both the student and the Laboratory the opportunity to assess one another in terms of future permanent employment and at the same time it provides welcome assistance in the busy summer field operations as well as gainful employment for a sizeable number of students. In 1967 the program operated at about the same level as in previous years but numbers were limited in 1968 by Government austerity measures; the figures were respectively 44 and 16 university and 19 and 6 other students. It is expected that in 1969 the number employed will return to a level near that of 1967.

1967

Name	Institution	Allocation in AOL
Baker, R. A.	Carleton	Marine Geology
Bezanson, W. R.	Dalhousie	Marine Geophysics
Bond, I. E.	N. S. Inst. of Tech.	Engineering Services
Bowes, D. C.	N. S. Inst. of Tech.	Engineering Services
Bowser, L. M.	Dalhousie	Marine Geophysics
Boyd, R. E.	Eastern Ont. Inst. of Tech.	Hydrography
Broughton, D. S.	Waterloo	Air-Sea Interaction
Clatworthy, W. C.	Loyola College	Marine Geophysics
Crutchlow, M. R.	Eastern Ont. Inst. of Tech.	Hydrography
Dudiak, J. J.		Frozen Sea Research
Doyle, F. W.	N. S. Tech. College	Computing Services
Elliott, K.	MacDonald College	Marine Geology
Faulkner, L.	Eastern Ont. Inst. of Tech.	Hydrography
Ferguson, R. A.	Dalhousie	Air-Sea Interaction
Fitzgerald, A. F.	St. Francis Xavier	Air-Sea Interaction
Galbraith, J. H.	Toronto	Marine Geology
Gatien, M. G.	New Brunswick	Ocean Circulation
Gaudry, G. L.	Queen's	Applied Oceanography
Geitzler, C. W.	Acadia	Marine Geophysics
Gorveatt, M. E.	Acadia	Marine Geology
Graham, W. F.	Sask. Tech. Inst.	Hydrography
Guptill, L. D.	Dalhousie	Air-Sea Interaction
Hartling, A. J.	N. S. Inst. of Tech.	Engineering Services
Hexemer, D. B.	Ryerson Inst.	Hydrography
Hubley, K. D.	N. S. Tech. College	Engineering Services
Huff, G. E.	Queen's	Marine Geology
Irwin, P. S.	Eastern Ont. Inst. of Tech.	Hydrography
Kirsch, G. A.		Frozen Sea Research
Langer, H. M.	Dalhousie	Chemistry & Radiochemistry
Lovering, A. R.	Alberta	Metrological Research
Low, s. L.	Queen's	Marine Geology
MacDonell, S. J.	Eastern Ont. Inst. of Tech.	Hydrography
MacDougall, J. D.	Toronto	Marine Geology
MaeIsaac, D. J.	N. S. Inst. of Tech.	Engineering Services

Name	Institution	Allocation in AOL
MacKinnon, C. D.	N. S. Inst. of Tech.	Metrological Research
Macnab, R. F.	Dalhousie	Marine Geophysics
MaeRoberts, J. H. E.	Queen's	Marine Geology
Ness, D. M.	Waterloo	Marine Geophysics
Ness, W. D.	Waterloo	Ocean Circulation
Pilkington, D. G.	Eastern Ont. Inst. of Tech.	Hydrography
Rehbien, R. G.	Eastern Ont. Inst. of Tech.	Hydrography
Retallack, D. G.	N. S. Tech. College	Metrological Research
Retallack, L. J.	Acadia	Metrological Research
Rive, E. J.	Queen's	Marine Geology
Russell, K. J.	Memorial	Air-Sea Interaction
St. John, B. E.	Queen's	Marine Geology
Schrumph, B.	St. Mary's	Hydrography
Sharkey, R. J.	Carleton	Air-Sea Interaction
Shearer, J. M.	Carleton	Marine Geology
Simo-Pla, J.	N. S. Tech. College	Metrological Research
Sloan, R.	Windsor	Hydrography
Smeathers, D.	Eastern Ont. Inst. of Tech.	Hydrography
Stephenson, D. B.	Mount Allison	Marine Geophysics
Sweet, L. G.	Acadia	Air-Sea Interaction
Tapley, S. G.	Queen's	Marine Geology
Theriault, R.	Sherbrooke	Applied Oceanography
Turner, R. E.	N. S. Inst. of Tech.	Metrological Research
Vandall, P. E.	Windsor	Ocean Circulation
Waller, N. B.	Mount Allison	Ocean Circulation
Wentzell, J. W. F.	N. S. Inst. of Tech.	Metrological Research
Zwicker, S. O.	Mount St. Vincent	Chemistry and Radiochemistry
	1968	
Bowlby, J. R.	Queen's	Marine Geology
Clark, T. W.	Dalhousie	Hydrography
Collins, W. D.	Vocational	Hydrography
Grant, J. W. P.	N. S. Land Survey Inst.	Hydrography
Hicks, C. G.	St. Mary's	Air-Sea Interaction
Humphries, G. W.	St. Mary's	Hydrography
Killam, G.	Acadia	Marine Geophysics
Knowles, S. M.	N. S. Teachers College	Hydrography
MeAlpine, D.	McMaster	Marine Geology
McMullin, S. J.	St. Mary's	Hydrography
McRoberts, J. H. E.	Queen's	Marine Geology
Moar, J. A.	Vocational	Marine Geology
Rive, E. J.	Queen's	Marine Geology
Rossiter, M.	Carleton	Marine Geology
Sandilands, M.	McMaster	Marine Geology
Sellars, G. R.	N. S. Land Survey Inst.	Hydrography
Simo-Pla, J.	N. S. Tech. College	Metrological Research
Smeathers, D.	Algonquin College of Applied Arts and Technology	Hydrography
Smith, R. W.	Queen's	Marine Geology
Sparkes, R.	St. Mary's	Marine Geophysics
Stephenson, D.	Mt. Allison	Marine Geology
Tapley, S. G.	Queen's	Marine Geology
Walker, D. A.	Dalhousie	Marine Geology
Wilson, M.	Toronto	Marine Geology
Zwicker, S.	Mount St. Vincent	Chemistry and Radiochemistry

Appendix A-5 - Directory of Professional and Senior Technical Staff

Ford, Wm. L.	Director	B.A., M.A., British Columbia, Ph.D., Northwestern, Illinois
Atkinson, A. S.	Head, Engineering Services	B. Eng. (Elect.), Dalhousie and Nova Scotia Technical College
Gilbert, R. L. G.	Head, Metrological Research	B.A., M.A., Ph.D., Cantab.
Howell, S. W.	Regional Marine Superintendent	Master Mariner (Foreign Going), Cdr. C.D., RCN (Ret'd)
Maunsell, C. D.	Senior Oceanographer	B.A., M.A., British Columbia, Ph.D., California (Berkeley)
Melanson, R. C.	Regional Hydrographer	Prov. Land Surveyors Cert., Nova Scotia
Pelletier, B. R.	Head, Marine Geology	B.Sc., McGill, M.Sc., McMaster, Ph.D., Johns Hopkins
Scott, S. H.	Administrative Officer	
Sutherland, P. H.	Head, Personnel	B.Sc., Acadia
Trites, R. W.	Head, Applied Oceanography	B.Sc., New Brunswick, M.A., Ph.D., British Columbia
Allan, C. S. (Miss)	Librarian	B.A., Dalhousie, B.L.S., Toronto
Amero, R. C.	Hydrography	Prov. Land Surveyors Cert., Nova Scotia
Bailey, W. B.	Applied Oceanography	B.Sc., Acadia
Balfour, R.	Engineering	1st Class Eng. (Marine), Cdr. (Eng), RCN (Ret'd)
Barrett, D. L.	Oceanographic Research	B.A., M.Sc., Dalhousie
Bartlett, G. A.	Marine Geology	B.Sc., Mt. Allison, M.Sc., Carleton, Ph.D., New York
Bendell, E. A.	Metrological Research	B.Sc. (Elect. & Eng.), Alberta
Bennett, A. S.	Metrological Research	B. A., Ph.D., Cantab.
Betlem, J. J.	Engineering	Dip. (Elect. & Math.), Tech School, Holland
Bewers, J. M.[1]	Oceanographic Research	B.Sc., Ph.D., Exeter
Brooke, J.	Metrological Research	P.Eng., (Ont.)
Buckley, D. E.	Marine Geology	B.Sc., B.Sc.(Hons), Acadia, M.Sc., Western Ontario
Budlong, K. (Mrs) [1]	Hydrography	B.A., Grinnell, B.Sc., Case Inst. of Tech.
Butters, J.	Applied Oceanography	Master Mariner (Foreign Going)
Calderwood, T. M.	Hydrography	Ottawa Tech. Dip. (Aeronautics)
Cameron, R. M.	Hydrography	
Chidlow, W. D.[1]	Metrological Research	B.Sc., Univ. of Alberta
Conrad, V. D.	Administration	B.Eng. (Civil) Dalhousie and N. S. Tech.
Coote, A. R.	Oceanographic Research	B.A., M.Sc., British Columbia
Corkum, P. L.	Hydrography	
Dalby, D. A.	Oceanographic Research	B.Sc., Univ. of Alberta, M.Sc., Univ. of British Columbia
DeGrasse, F. L.	Hydrography	
Dessureault, J. G.	Metrological Research	B.Sc. (Mech. Eng.), Lava1
Dimmers, J. A.[2]	Metrological Research	Dip. (Elect. Eng), Adelaide
Dobson, D.	Applied Oceanography	Master Mariner (Foreign Going)
Doe, L. A. E.[2]	Oceanographic Research	B.A., M.A., Toronto, Ph.D., New York
Douglas, G. R.	Hydrography	Land Surveying Dip.
Drapeau, G.[1]	Marine Geology	B.ScA., Laval, M.Sc., M.I.T.
Dunbrack, S. S.	Hydrography	Prov. Land Surveyors Cert., Nova Scotia
Eaton, R. M.	Hydrography	

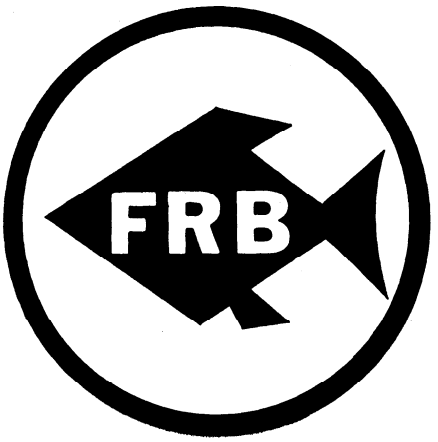
[1] Joined AOL.
[2] Left AOL.

Elliott, J. A.	Oceanographic Research	B. Eng.. Saskatchewan, M.Sc., British Columbia
Ewing, G. N.	Oceanographic Research	B.Sc., St. Francis Xavier, M.Sc. Dalhousie
Foote, T. R.	Applied Oceanography	
Fowler, G. A.[1]	Metrological Research	B.A.Sc., Toronto
Forrester, W. D.	Oceanographic Research	B.A., Toronto, M.Sc., British Columbia, Ph.D., Johns Hopkins
Gandhi, D. I. K[1]	Oceanographic Research	B.A., Punjab, B.Ed., Delhi, M.A., Dalhousie
Garner, D. M.[1]	Oceanographic Research	B.Sc., Univ. of N. Z., Ph.D., Univ. of New York'
Gaudet, V. J.	Hydrography	Prov. Land Surveyors Cert., Nova Scotia
Gouldthorpe, P. A.	Metrological Research	B.Sc., Dalhousie, B.Eng., N. S. Tech.
Grant, A. B.	Oceanographic Research	
Grant, A. C.	Marine Geology	B.A., Acadia, B.Sc., Dalhousie, M.Sc., New Brunswick
Hall, W. W.	Metrological Research	Nat. Cert. of Mech. Eng.
Hallett, T. M.[1]	Applied Oceanography	B.Eng., Carleton
Hartling, B. B.	Metrological Research	Cert. Radio Constr. & Repair, N. S. Tech. College, Dip. Advanced Elect., Capital Radio Eng. Inst., Washington
Haworth, R. T.[1]	Oceanographic Research	B.Sc., Durham, Ph.D., Cambridge
Hemphill, M. A.	Hydrography	
Herman, D. H.	Hydrography	BE Nat. Univ. Ireland, M.Sc., Trinity College, Dublin
Higgins, J. M.[2]	Ships	1st Class Eng. (Marine), Lt. RCNR (Ret'd)
Holler, A. M.[2]	Ships	Master Mariner (Foreign Going)
Kenney, A. D.	Hydrography	
Keyte, F. K.	Applied Oceanography	B.A., Sydney, Australia, B.A. (Hons), Alberta, M.A. Toronto.
King, L. H.	Marine Geology	B.Sc., Acadia, Ph.D., M.I.T.
Kingston, P. F.	Metrological Research	
Kranck, K. M. (Miss)	Marine Geology	B.Sc., McGill, M.Sc., Uppsala, Sweden
Lake, R. A.	Oceanographic Research	B.Sc., British Columbia, M.Sc., Univ. of Washington
Lawrence, D. J.	Applied Oceanography	B.Sc., M.Sc.. Dalhousie, Ph.D., Queen Mary College
Lazier, J. R. N.	Oceanographic Research	B.A., Toronto, M.Sc., British Columbia
LeLievre, D. D.	Hydrography	Prov. Land Surveyors Cert., Nova Scotia
Levy, E. M.[1]	Oceanographic Research	B.Sc., M.Sc., Dalhousie, Ph.D., McGill
Lewis, E. L.	Oceanographic Research	B.Sc., M.Sc., Ph.D., London, England
Loncarevic, B. D.	Oceanographic Research	B.A., B.Sc., M.A., Toronto, Ph.D., Cantab.
Loucks, R. H.	Oceanographic Research	B.Sc., M.Sc., British Columbia
McMullen, R. M.[3]	Administration	B.Sc., M.Sc., Alberta, Ph.D., Reading, England
MacLean, B.	Marine Geology	B.A., Acadia
MacPhail, H. W.[2]	Metrological Research	1 credit Elect. Eng., I.C.S.
MacPhee, S. B.	Engineering	Eng. Dip., St. Francis Xavier, B. Eng. N. S. Tech. College.
McKeown, D. L.[1]	Metrological Research	B.Sc., M.Sc., N. S. Tech., Ph.D., Cantab.
Manchester, K. S.	Oceanographic Research	B.Sc., Connecticut, M.Sc., Dalhousie
Mann, C. R.	Oceanographic Research	B.Sc., M.Sc., New Zealand, Ph.D., British Columbia

[1] Joined AOL.
[2] Left AOL.
[3] Transferred within AOL.

Marlowe, J. I.	Marine Geology	B.Sc., Florida State, Ph.D., Arizona
Mason, C. S.	Metrological Research	B.Sc., M.Sc., Western Ont., Ph.D., Cantab.
Murdock, L. P.[z]	Hydrography	5 credits B.Sc.
Needler, G. T.	Oceanographic Research	B.Sc., M.Sc., British Columbia, Ph.D., McGill
Neu, H. J. A.[1]	Applied Oceanography	Diploma (Stuttgart) Regierungs Baumeister
Pagden, I. M. H.	Oceanographic Research	B.Sc., Ph.D., Exeter
Pearson, G. J.[1]	Oceanographic Research	B.Sc., M.Sc., Queens
Peck, C. R.	Engineering	
Pilote, J. M. R.	Hydrography	Navigation Course, Tech. Inst., Rimouski
Phyo, I [2]	Oceanographic Research	B.Sc., Yonsei, M.A., Dalhousie
Quick, L. D.	Hydrography	Master Mariner (Foreign Going), 2 years Navigation
Quon, C.	Oceanographic Research	B.Sc., M.Sc., Alberta, Ph.D., Cantab.
Rashid, M. A.	Marine Geology	B.Sc., Hyderabad, India, M.S., Oklahoma, Ph.D., Utah
Reiniger, R. F.	Oceanographic Research	B.Sc., Saskatchewan, M.A., Toronto
Richards, R. C.	Oceanographic Research	B.Sc., British Columbia
Ross, C. K.	Oceanographic Research	B.Sc., M.A., Toronto
Ross, D. I.	Oceanographic Research	B.Sc., M.Sc., Ph.D., Victoria, New Zealand
Sandstrom H.	Oceanographic Research	B.A., Toronto, M.A., Ph.D., California
Schafer, C. T.[1]	Marine Geology	B.S., M.S., Ph.D., New York Univ.
Seibert, G. H.[1]	Applied Oceanography	B.Sc., George Williams, M.Sc., McGill
Shreenan, J. G.	Hydrography	B.Sc. (Forestry), New Brunswick, 1 year Teacher Training
Smith, G.	Ships	Naval Architect, SNAME, Nat. Cert. Architecture
Smith, S. D.	Oceanographic Research	B.Eng., McGill, Ph.D., British Columbia
Smith, T. B.	Hydrography	Prov. Land Surveyors Cert., Nova Scotia
Srivastava, S. P.	Oceanographic Research	B.Sc., IIT, India, Ph.D., British Columbia
Stevens, R. G.	Oceanographic Research	B.A., Iowa, Ph.D., New York
Swim, M. G.	Hydrography	
Sudar, R. B.	Metrological Research	B.A.Sc., Univ. of Toronto
Sutherland, H. B.	Engineering	
Talwar, M. S.	Oceanographic Research	B.A., Marnel, India, M.A., Dalhousie
Trites, P. S.	Oceanographic Research	
Vilks, G.	Marine Geology	B.Sc., McMaster, M.Sc., Dalhousie
Vine, R. N.	Metrological Research	Ord. Natl. Cert., Southampton Tech. Col., England
Wagner, F.J.E. (Miss)	Marine Geology	B.A., M.A., Toronto, M.S., PhD., Sanford
Walker, E. R.	Oceanographic Research	B.Sc., Univ. of Manitoba, M.A., Univ. of Toronto, Ph.D., McGill.
Weiler, R. R.[2]	Oceanographic Research	B.A., M.A., Toronto, Ph.D., Dalhousie
Wells, D. E.	Metrological Research	B.Sc., Mount Allison, B.A.Sc., M.A.Sc., British Columbia
Williams, R. K.	Hydrography	
Woodside, J. R.	Oceanographic Research	B.Sc., Queen's, SM., M.I.T.
Yeaton, G. M.	Hydrography	

1 Joined AOL,
2 Left AOL.



Part B

Marine Ecology Laboratory,
Fisheries Research Board of Canada

Part B

Marine Ecology Laboratory, Fisheries Research Board of Canada

Director's Remarks

Program Review;

The concept of food chains has been widely used as a convenience in generalizing problems in biological production, and is useful in viewing the developing research program of the Marine Ecology Laboratory (MEL). The concept treats fisheries yields as the end of a chain of events which begins with the accumulation in small organic particles of energy derived in various ways from solar radiation. A ratio of fisheries yield to the amount of organic matter (or the equivalent in energy units) present at any link in the food chain constitutes a measure of transfer efficiency between the two trophic stages. Marine ecological studies are ultimately concerned with understanding the relationships of these efficiences to the biological and physical characteristics of the system, as a basis for predicting yield potential.

Experience of recent years has shown that it is not a simple matter to derive efficiency measures which will reflect the character of the mechanisms determining production and yield. In fisheries studies, the ratio of the yield from a fish stock to the recruitment has been frequently employed in an attempt to generalize about the effects of fishing on yields. However, production must depend to a certain extent on the amounts of food energy available in the food-chain system. From recent work it appears that,, at least in theory, the relation of this yield per recruit ratio to the amount of fishing is different from that followed by the ecological efficiency, calculated as the ratio of yield to food intake by the fish stock. Both of these efficiency measures appear to differ from the food-chain efficiency, calculated as the ratio of yield to food available to the fish stock. In addition, natural systems seem to consist of such an interwoven network of energy pathways that it is difficult to relate observed yield changes to those predicted from studies of simpler experimental or theoretical systems.

Knowledge of which food-chain relations can be used to predict short and long-term yield is of paramount interest to industry and government for the establishment of guides in fisheries development and management. With the present apparently contradictory results of different methods of analysis, advice on yield trends may be so much in error as to be unreliable for most practical purposes; A resolution of the contradictions must therefore be a primary consideration of any biological production study. Improvements in the accuracy of predictions can certainly be made. But they depend to a large extent on more detailed measurements of the biomasses and energy turnover rates of the organisms in nature. This required information is not yet available for any known marine system.

The program of MEL is designed explicity to study problems of this sort. The research summaries contained in this report describe a combination of laboratory and field studies which are being developed in an effort to provide biomass and production rate estimates for a number of important stages in the trophic systems. The studies also attempt to understand the degree of association of the various stages and the influence of important physical environmental parameters. Present research programs are especially concerned with studies in St. Margaret's Bay and environs, as a model natural system. The new methodologies at which the studies in the Bay are aimed are essential to future attempts to measure similar processes in the open seas. From the results obtained to date it seems clear that useful methods and estimates will soon be developed for at least the pelagic communities. As studies continue it becomes clearer that the benthic community is of particular importance in the overall picture and special problems encountered there deserve increased attention in any expanded laboratory program.

The food-chain analogy is an oversimplification which, if carried too far, tends to

obscure the nature of other important marine production problems. Thus, the beginning of the so-called food-chain consists of the energy load in a multitude of minute particles which are widely distributed in the sea. The biological energy transfers leading to fisheries consist of progressive concentrations of part of this load into larger and fewer particles distributed less and less homogeneously. The final stages consist of the relatively large-bodied fishes which are often very mobile and almost always unevenly distributed. It is increasingly appreciated that changes in the spectrum of sizes, and the patterns of spatial and temporal distributions of the plants and animals, have as great an influence on the amounts and rates of production as do normal changes in their abundance. In a gross way, this has always been obvious, in the sense that the geographical and seasonal distributions of fish determine fishing success. What has not been understood until recently is the importance of sizes and distributions at local levels. In the case of fisheries, for example, fluctuations in the concentration of fish within the area swept by a single tow of a unit of fishing gear appear to be of as great an importance to fishing success as is the average density within the fishing area. Similar inhomogeneities seem to be important when considering all natural predator-prey links in the food chain.

Awareness of the importance of distribution on the productivity of biological systems is reflected in the reports from MEL scientists by a general concern with statistical sampling methods related to seasonal and spatial distributions. This structuring of the system must ultimately be dependent on the nature of the physical characteristics of the environment, and this accounts for our further preoccupation with joint biological and 'physical, chemical and geological studies. It is of particular importance to the development of future studies to identify the relative scales of physical and biological mechanisms which operate at the various levels of the food chains.

Studies of distribution of organisms and their influence on production rates in nature are expensive and dependent on the development of new observational and data-processing equipment. Major expenditures of ship time are also necessary. These studies do not at the moment play as important a role in our programs as we would like. However, since the distribution of fishes is of immediate practical as well as general theoretical importance, as large a proportion of our laboratory budget as practicable has been devoted to development of improved methods for measuring adult fish abundance and distribution. Eventually we hope to spend a greater proportion of our efforts on studies of juvenile fishes, ichthyoplankton, and potential food organisms, as well as on the organisms comprising the primary production links of the food chain.

Studies referred to above deal primarily with natural production systems and ways of taking advantage of them for increasing yields. In shallow bays and estuaries the balance of controlling factors is somewhat different, and the smaller size of these areas offers the possibility of greater mainipulations by man, including culture of selected marine organisms. In early 1968 the responsibility for programs at the biological substation at Ellerslie, P.E.I. was transferred from the Biological Station, St. Andrews, N.B. to MEL. This new arrangement provides a readier opportunity for developing studies to compare production processes in areas having different degrees of isolation from the open sea. The practical importance of the study of these shallow marine areas can be appreciated from the fact that they are thought to be basically as productive as the most highly cultivated farm lands. Better methods of utilizing them to produce the high protein products which are characteristic of marine environments would be of enormous value in food production.

The productivity researches undertaken by MEL also provide important general background and some of the methodology necessary for the examination of marine pollution problems. In a few instances the reports given below refer to surveys which have been undertaken in response to a request for specific information or in situations where there appears to be a potentially hazardous pollution problem. The needs for surveys appear to be increasing faster than our abilities to execute them and analyze the results. Only very limited studies have been possible to date.

Administrative Review

The Marine Ecology Laboratory is into its fourth year of operation and has grown from a nucleus of 15, in 1965, to a total establishment of 56 in 1968. To support the growing program it has been necessary to provide a number of capital facilities. Early in 1968 a new fish-studies laboratory, having

Fig. 16. New Fish Studies Building of MEL at the Bedford Institute.

temperature controlled continuous flows of salt and fresh water, was completed and occupied. (Fig. 16). Associated with it is a complex of five mobile laboratory and office accommodation units. The facilities, which are accommodating 12 of the staff and student associates, have helped to relieve the extreme shortage of accommodation which has developed in the main Institute building. A long-term rental of property on the shore of St. Margaret's Bay, about 25 miles from the Institute, has made it possible to set up a small field station to support our operations there. Facilities include an approach road, a jetty suitable for operating small research vessels, a boat ramp, and a mobile laboratory unit. It is hoped to develop this site to provide an improved field laboratory, equipment servicing, and storage space as funds become available. In late 1968 the *MV Navicula*, a new 65-ft wooden-hull research vessel suitable for handling oceanographic moorings and fishing gear, and capable of year-round inshore operations was completed, (Fig. 17) and began operations in St. Margaret's Bay and vicinity allowing some relief for the overworked *MV Sigma-t*, and the two chartered small boats used during the earlier part of the year. Our large ship requirements continue to be met, as far as possible, by the ships of the Bedford Institute, the Maritime Command of the Canadian Armed Forces, the Department of Fisheries, and the Fisheries Research Board Biological Station at St. Andrew's, N. B. During 1968 it was necessary to supplement these sources by a 3-month charter of the *MV Brandal* from a private Halifax firm. Similar charter arrangements were made in 1967. In addition the laboratory has been fortunate in securing the consulting services of Mr Geoffrey Trout, Ministry of Agriculture, Food and Fisheries, Fisheries Laboratory, Lowestoft, England in the planning of a large ocean-going biological and fisheries research vessel.

The programs undertaken in the laboratory are necessarily wide ranging, and often require the advice and cooperation of experts in areas not covered by our own staff. This has led to the desirable result that a significant number of research projects are developing as joint studies with the staff of other laboratories and institutions. From this point of view, we continue to find that our location in the Halifax-Dartmouth area is particularly advantageous. The day-to-day contact this makes possible

Fig. 17. *MV Navicula*

with scientists of AOL in the Bedford Institute, and of the Institute of Oceanography and Department of Biology at Dalhousie University has led to a number of fruitful collaborations which are already reflected in the joint authorship of papers appearing in our List of Publications. A number of other studies being undertaken jointly with university and research institution staff from outside the Halifax-Dartmouth area are also briefly referred to in some of the investigators' summaries. Special mention should be made of the association of MEL researches with the International Biological Programme (IBP). In many ways our work shares the objectives of the marine production section of this international comparative study. The Canadian IBP Committee has therefore adopted the St. Margaret's Bay study as part of its program and our scientists hope to contribute to the international scientific symposia which will examine the results. In addition, MEL is cooperating with a number of other laboratories in a broadly based study of basic production of the Gulf of St. Lawrence. This study is coordinated by Dr. D. M. Steven, Department of Zoology, McGill University. University participation in it is directly sponsored by the Canadian Committee of IBP. To date the general suitability of particular sampling procedures has been examined. MEL expects to participate in the physical oceanographic program, and to investigate certain biological production mechanisms in the Magdalen Shallows area of the Gulf.

It has been our experience that mutually fruitful associations also develop from contacts with graduate students. During the past 2 years the laboratory has provided field and laboratory facilities for research projects by two graduate students from the Institute of Oceanography, Dalhousie University, one from the Department of Biology, Dalhousie University, one from the Department of Zoology, McGill University, and one from the Marine Sciences Centre, McGill University. The programs of these students are under the joint direction of MEL and university scientific staff. One member of the MEL staff is on educational leave at the Institute of Oceanography, Dalhousie University and others of the staff have availed themselves part time of opportunities afforded by our close relations with the university to advance their level of scientific training. The laboratory has also welcomed the opportunity to provide facilities and general advice and supervision to one NRC Postdoctoral Research Fellow from India and one Canada Council Postdoctoral Fellow from France who is under the general supervision of Dr G. A. Riley, Director of the Institute of Oceanography, Dalhousie University. Three of the senior staff of the laboratory also hold appointments at Dalhousie University and participate in regular lecture courses at the senior undergraduate and graduate level.

Dr D. H. Loring, the senior geologist-geochemist, is at present on Sabbatical Leave at the State University, Wageningen, Holland. During his leave he expects to prepare a major publication on the geology of the Gulf of St. Lawrence in association with Dr D. J. G. Nota of that university.

Scientists specializing in particular research projects often encounter difficulties in keeping abreast of developments outside their own specialty. This is a particular danger in government laboratories isolated from active research centres. The cooperative work with scientists from other institutions and universities outlined above is one important means of minimizing this danger. Further insurance is provided by participation in continuing series of seminars sponsored by Dalhousie University, and by the Bedford Institute or jointly. In addition, in late 1967, MEL organized a major 2-day seminar on marine production studies with particular reference to our developing program in St. Margaret's Bay. Work in the Bay itself was reviewed in the light of experience elsewhere and guests from outside laboratories were asked to comment on the general feasibility of our proposals. We were fortunate in having active discussion and participation from approximately 90 scientists and students in attendance. Particularly valuable were comments from experienced scientists from the Institute of Oceanography and Department of Biology, Dalhousie University ; Atlantic Oceanographic Laboratory, Bedford Institute ; Marine Sciences Centre and Department of Zoology, McGill University ; Fisheries Research Board, Biological Station, St. Andrews, and the Halifax Laboratory; and from Woods Hole Oceanographic Institute, Woods Hole, Mass. Abstracts of presented papers were mimeographed and circulated for further consideration by the participants. A similar review of oceanographic studies in the Gulf of St. Lawrence is being held at the Bedford Institute in late 1968.

L. M. Dickie

Staff List as of September 1, 1968

Director and Administration

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

M. Blaxland

Hilda K. Gamester

K. A. Overton (from Jan. 23 1967)

Sylvia M. Smith

Lis Clarke (from July 8 1968)

Marsha A. Mosher (from April 3 1967)

Vessel and Support Services

C. J. Bayers

H. S. Glover

J. A. Matthews (from May 2 1968)

R, Savoury (from May 6 1968)

D. G. Richardson (from Aug. 12 1968)

Environmental Oceanography

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

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

R. W. Sheldon, Ph.D. (Manchester) (from April 3 1967)

I. W. Duedall, M.Sc. (Oregon State)

G. B. Taylor

C. C. Cunningham

D. P. Krauel, B.Sc. (McMaster)

J. P. Budlong, B.Sc. (Case Institute of Technology)

R. T. T. Rantala (from Dec. 1 1967)

A. E. Swyers (from May 19 1967)

Biological Oceanography

K. H. Mann, B.Sc. (London), Ph.D. (Reading), D.Sc. (London) (from July 28 1967)

W. H. Sutcliffe, Jr., B.A. (Emory), Ph.D. (Duke) (from Sept. 5 1967)

R. J. Conover, B.A. (Oberlin), Ph.D. (Yale)

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

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

D. V. Subba Rao, Ph.D. (Andhra India) (Postdoctoral Fellow from Sept. 11, 1967).

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

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

M, Hodgson, B.Sc. (Dalhousie)

M. A. Paranjape, B.Sc. (Poona), M.Sc. (Bombay), M.Sc. (Washington) (from March 18 1968)

B. D. Irwin

E. I? Anderson, B.A. (Harvard)

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

Fisheries Oceanography

S. Paulowich

R. G. Dowd

W. B. Fraser

Population Dynamics

B. S. Muir, Ph.D. (Toronto) (from April 16 1968)

D. D. Sameoto, M.A. (Sask.), Ph.D. (Queens) (from August 4 1967)

E. Bakken, Cand. real (Bergen)

J. C. Smith, M.Sc. (UBC)

T. C. Lambert, B.Sc. (Victoria), M.Sc. (Dalhousie) (from Nov. 1 1967)

A. D. MacDonald (from Aug. 14, 1967)

J. C. Frost (from Dec. 1 1967)

Oyster and General Estuarine Ecology (Biological Sub-station Ellerslie, P.E.I., from April 1 1968)

R. E. Drinnan, B.Sc. (London)

M. L. H. Thomas, B.Sc. (Durham), M.S.A. (Ont. Agr. College)

P. Woo, B.Sc. (Hong Kong)

Margaret C. Frost, B.Sc. (Acadia,) (from Sept. 15 1967)

Eleanor L. Hutchinson

K. R. Oatway

1967 and 1968 Publications

ANON (prepared by SHELDON, R. W., and P. J. WARREN). 1967. The deep-water shrimp. *Fish. Res. Bd. Canada*. Fish Leaflet, No. 1 Dartmouth

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Investigators' Summaries of Current Research

Productivity Studies in St. Margaret's Bay

The staff of MEL has continued to use St. Margaret's Bay as the site of a multi-disciplinary study of production at all tropic levels. This small body of water, about 10 miles by 6 miles, has a relatively narrow opening to the sea,, about 2 miles across. It is therefore a well-defined study area which nevertheless exchanges with the open sea. Detailed studies of physical oceanography, primary production, zooplankton, benthos, and fish are in progress and are reported in more detail in a number of the following research summaries. The aim is to obtain estimates of production and ecological efficiency at each trophic level, and to understand the underlying regulatory mechanisms, so that the insights obtained may be applied to larger systems which support commercially important fisheries.. This type of study is central to the theme and purpose of the PM (productivity, marine) section of the IBP, with which we have associated ourselves so as to obtain the benefits of discussion and exchange of information with other participants.

It is possible to sketch in broad outlines a tentative pattern of energy flow. These estimates will be progressively refined as more data become available.

From carbon-14 uptake studies, it is estimated that primary production by phytoplankton amounts to 1,700 to 2,000 kcal/m^2/yr. When a correction for production by seaweeds and epiphytic forms is applied, it is likely that total primary production will amount to between 2,000 and 2,500 kcal/m^2/yr.

The standing stock of zooplankton averaged over the year is of the order of 3 kcal,/m^2. In comparable situations it has been shown that copepods turn over their biomass about 10 times per year. Allowing for a higher rate of turnover of bacteria and other small forms it is likely that production by planktonic herbivores and decomposers is of the order of 50 kcal/m^2/yr.

The average calorific value of benthic animals from 17 stations is given as 76 kcal/m^2 and it is probable that this biomass is turned over at least twice per yeas, giving a production of more than 150 kcal/m^2.

Landings of mackerel, averaged over 6 years, amount to 5.9 kcal,/m^2/yr and it is likely that total mackerel production amounts to at least twice this figure. By the same token, production of herring is estimated as 1.6 kcal/m^2/yr. An American Plaice population, resident in the Bay, is unexploited. The average standing stock of fish vulnerable to the net is 4.6 kcal/m^2 and annual production, allowing for those not vulnerable, is of the order of 5 kcal,/m^2. Lobster production, though small (0.25 kcal/m^2/yr) is commercially the most valuable. In taking into account the food requirements of the fish, it must be remembered that mackerel and herring are migratory fish spending only part of the year in the Bay. There are populations of cod and pollock on which no data are available.

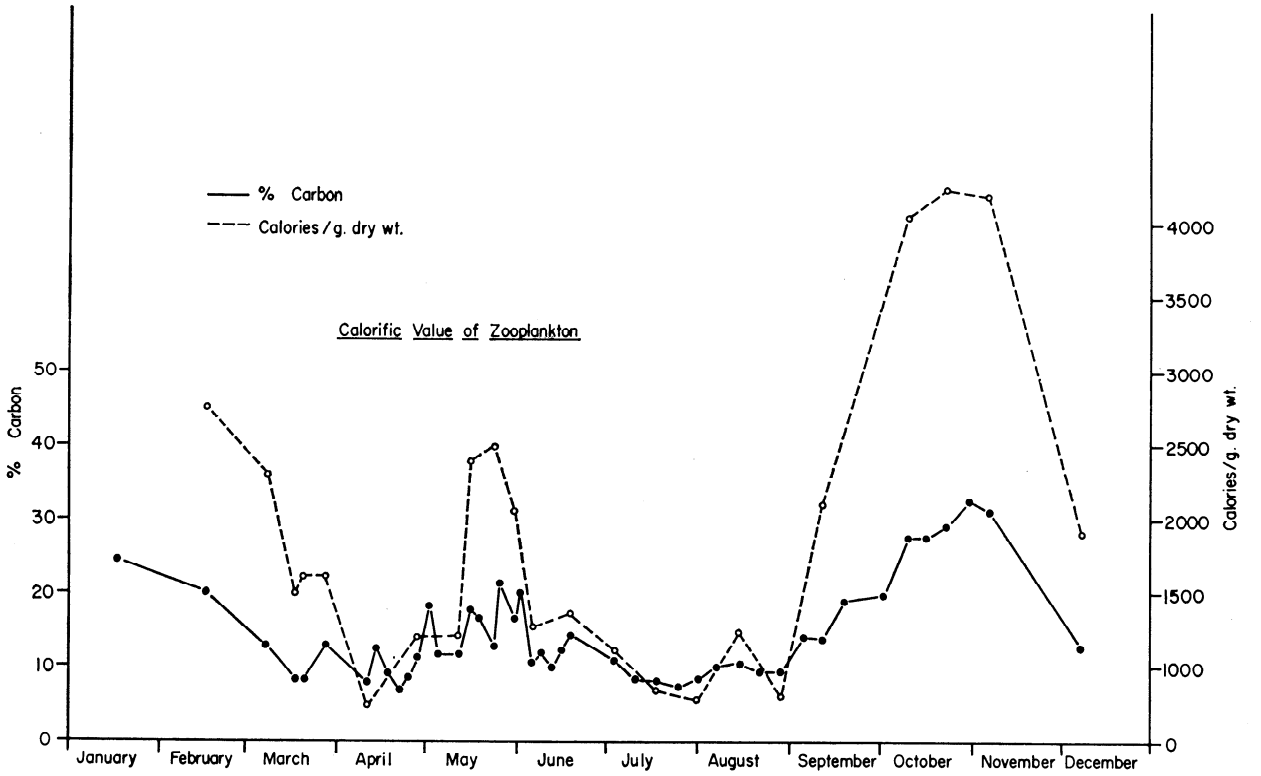
Assuming for the moment that zooplankton and benthos feed mainly on plants and detritus, and that fish are carnivores, we find that annual production in kcal amounts to: primary production 2,000, herbivores 200, and carnivores 20. The ecological efficiency at each trophic level is thus of the order of 10%.

Many predictions of productivity in marine environments have been based on a 10% efficiency of transfer at each trophic level, but there are very few figures to support it. As this study progresses it should be possible to provide well substantiated data for the populations mentioned above, and additional data for populations not yet studied, such as epibenthos, large planktonic forms, and the herbivores of the seaweed zone.

K. H. Mann

Primary and Secondary Productivity Studies in St. Margaret's Bay

To provide information on the amount of energy potentially available to marine food chains, detailed measurements of primary production and related parameters were made at a station in St. Margaret's Bay on 51 occasions throughout 1967. The following parameters were measured: primary production *(in situ)*, chlorophyll, particulate carbon, particulate phosphorus, dissolved silicate, nitrate, ammonia, inorganic phosphorus, total phosphorus, oxygen, temperature, salinity, incident radiation, and water transparency. The annual production by the phytoplankton population was estimated to



Fig, 18. Seasonal variation in calorific value and carbon content of zooplankton at Stn. "A", St. Margaret's Bay, 1967.

be between 125 and 155 $gC/m^2/yr$ or from 1.7 to 2.0 x 10^6 $cal/m^2/yr$. The 1967 data are collected with a preliminary discussion in FRB Technical Report No. 77. Measurements of primary production and certain other para-. meters have been continued in 1968 with the addition of a second station outside the Bay. It is hoped that estimates can be made of the year-to-year variation in annual production, and the difference, if any, in production at the inner and outer stations.

The sampling program has also included replicate vertical hauls for zooplankton which have been analysed in terms of carbon and caloric content per unit dry weight. This series of data probably constitutes the first study of the seasonal variation in caloric content of the standing crop of mixed zooplankton at a single station. Results are shown in Fig. 18. There was a wide variation in the carbon content and calorific value of the zooplankton during the year. These changes appear to be attributable to changes in the species' composition of the zooplankton community, age distribution within species, availability of food, and life history phenomena. It is evident that use of a simple conversion factor to estimate energy content per unit zooplankton biomass is inadequate for any but the crudest models of energy pathways in the sea. The standing crop of zooplankton energy content (cal/m^2) was a relatively stable measure of the amount of zooplankton present at any time.

A study has been started of the population dynamics and production ecology of the cladocera which in summer are an important component of the zooplankton biomass of the upper 20 m layer of St. Margaret's Bay. The program is based on detailed weekly sampling with a Clarke-Bumpus net and weekly 24 hr *in situ* incubation experiments. Measurements will be made of the biomass, size distribution and fecundity. The species present are *Evadne nordmanni, E. spinifera, Podon polyphemoides, P. leukarti* and *P. intermedius.*

Trevor Platt

Studies of Plankton Distributions

Statistical studies of the variation of chlorophyll concentration in St. Margaret's Bay have been aimed at describing the heterogeneity in phytoplankton distribution in the Bay, and establishing the reliability of point

samples taken in the Bay. A sampling design has been set up which allows the overall variance in the chlorophyll concentration to be partitioned into three components; a between-station component, a between-sample component and an analytical-error component. Using this design, it has been possible to study the relation between the magnitude of the between-station variance and the area represented by each sample. The between-station variance appears to increase rapidly to a point where each station represents 0.1 sq miles but thereafter stays relatively constant. The coefficient of variation of a single observation is about 70% compared with 8% due to analytical error alone. Information of this sort is basic to the design of sampling programs which will permit a study of the relation of primary production to the physical and biological environment.

Trevor Platt

Integrating Photometer

Studies on the relationship between photosynthesis and intensity of illumination require an estimate of the light energy available to the phytoplankton at any given depth. This is usually determined indirectly by calculation from the incident radiation at the surface and the water transparency between surface and the given depth. Such a calculation is subject to error because of uncertainities in the spectral distribution of the incident radiation, in the correction for reflection loss at the sea surface, and in the wavelength depen-. dence of the absorption coefficient. To obviate some of these difficulties, a self-contained integrating photometer for use underwater has been designed and constructed, and is being tested. The response is independent of the wavelength over the spectral range useful for photosynthesis. The instrument should allow the total light energy received by the plankton at a given depth during the period of an *in situ* primary productivity experiment to be measured directly in absolute units.

Trevor Platt

Productivity of the Seaweed Zone

The zone extending from the seashore to a depth of 30 m supports massive growths of seaweeds and in St. Margaret's Bay this zone constitutes a significant fraction of the total area, so that the contribution of the seaweeds to total primary production cannot be ignored.

Starting in the summer of 1968 the zonation, biomass, and growth rate of seaweeds were studied on 24 transects, by Scuba diving. Ten zones were recognized, dominated by (1) *Fucus* and *Ascophyllum, (2) Chorda filum,* (3) *Chondrus cripus,* (4) *Zostera, (5) Alaria* (6) *Laminaria digitata, (7) Laminaria longicruris or L. agardhii, (8) Agarum cribrosum with Laminaria* spp., (9) *Agarum cribrosum* with *Ptlota serrata* and (10) *Ptilota serrata*. *Chondrus* was present on rocky shores but in sheltered muddy areas *Zostera* grew at the corresponding depth. *Laminaria digitata* was present only on exposed rocky shores, and was replaced by *L. longicruris* in more sheltered sites. *Agarum* extended below the *Laminaria* to about 20 m depth, and *Ptilota* to about 30 m, provided a hard substrate was available.

Quadrat samples showed that the average biomass in *Laminaria* zones was 10-15 kg wet weight per m^2 while *Fucus* and *Ascophyllum* averaged 6.7 kg/m^2 and the *Chondrus* only 4.4 kg/m^2. Moreover, the *Laminaria* zones were 68-128 m wide, compared with an average of 16 m for the *Fucus* and *Ascophyllum.* The result is that *Laminaria* and *Agarum* contribute over 80% of the total biomass of the seaweed zone, this total being over 1,000 kg per rnetre of shoreline.

The growth of *Laminaria* and *Agarum* is being studied by measuring marked specimens at intervals. In most cases the growth at the base of the blade was offset by erosion at the tip, so that total size was approximately constant. Between early June and late August some plants had replaced almost the entire length of the blade, and many others had replaced at least 50%.

The most important herbivores present were the sea urchins, *Strongylocentrotus droebachiensis*. Although distributed in low densities throughout the seaweed zone, they were also present in certain areas in high densitities, for example 330 per m^2 with a biomass of 7.7 kg/m^2. In such places there were no macrophytes present. One population was observed to eat its way 160 cm into a bed of *Laminaria* during the summer.

K. H. Mann

Physiological Ecology and Production of Marine Phytoplankton

Influence of humic compounds on phytoplankton growth

The ecological importance of biologically active substances in sea water, viz. vitamins, antibiotics, and other extracellular products is fairly well recognized. Other lesser known organic compounds such as humic substances have remained objects of speculation as regards their function. It has been suggested by several workers that humic substances may influence phytoplankton production in the sea; however, no direct experimental evidence has heretofore been provided.

In our earlier studies on *Gonyaulax tamarenis,* it was observed that a marked improvement in growth of this marine dinoflagellate occurred when humic acid was added to the culture medium and that the response was concentration dependent (BIO Annual Report, 1966). To understand the nature of humic substances and their possible influence on the growth of marine phytoplankton, several species of diatoms and dinoflagellates have been grown under varying conditions of humic enrichment. Small concentrations of humic and fulvic acids were found to exert a stimulatory effect on marine phytoplankton which was reflected in increased yield, growth rate, and C^{14} assimilation. Hymatomelonic acid, on the other hand, did not support any growth.

By fractionating humic acids derived from river water, terrestrial and marine soils into different molecular weight fractions using the Sephadex gel-filtration technique and enriching the culture media with these fractions, it has been found that the growth-promoting activity of humic acids lies mostly with the low molecular weight (700-1500), water soluble fraction. It appears that these low molecular components of soil humus act as biological stimulants for marine algae and are associated with the cellular metabolic processes in addition to their assigned role as efficient natural trace-metal chelators. Our results indicate that humic substances do not satisfy an absolute growth requirement for phytoplankton but are definitely stimulatory and act as accessory growth factors. In view of high concentrations of humic substances found in coastal waters, there remains little doubt that they are a significant ecological entity influencing coastal phytoplankton productivity. Further work is being continued to examine the physiological pathways and main functional groups of humic substances which lead to growth enhancement of planktonic algae.

A. Prakash

Factors influencing dark assimilation of ^{14}C by marine phytloplankton

In spite of the prevalence of dark assimilation of CO, in bacterial, animal and plant cells, nonphotosynthetic assimilation of CO, by marine phytoplankton has been looked at with some scepticism. Although the primary organic production in the sea is predominantly due to photosynthetic processes in the euphotic zone, sufficient evidence has accumulated in recent years which shows that even the strictest autotrophs may resort to some degree of heterotrophy under certain conditions.

In routine primary productivity measurements using the Carbon-14 method, the rate of dark fixation of $^{14}CO_2$ as a percentage of light fixation by natural phytoplankton population has been calculated to be mostly between l-3%. These estimates are based on observations carried out in eutrophic temperate waters as well as on algal cutlures maintained in nutrient rich media and have been assumed to apply as well in the oligotrophic waters of the tropics and subtropics. Our recent observations in waters south of 44° N lat, including both the Sargasso and Caribbean Seas, have revealed latitudinal variations in the rate of dark fixation of $^{14}CO_2$,. Dark fixation rates as high as 86% of light fixation have been observed around 19° N lat *(CSS Hudson* cruise, January-February 1968). A similar trend of increased dark fixation in southern waters has been detected by us in other cruise data in the Sargasso Sea.

These observations have led us to the belief that increased dark fixation of $^{14}CO_2$ in subtropical and tropical waters is in some way related to the nutrient deficiency of the water masses. Results of our preliminary experiments on unialgal cultures of marine phytoplankers grown under varying nutrient levels in the laboratory have indicated a tendency towards increased dark fixation under low nutrient conditions. There is also some evidence in our data for diurnal and seasonal

periodicity in the dark fixation particularly in tropical and subtropical waters. Further studies on these aspects are continuing.

A. Prakash
W. H. Sutcliffe, Jr.

Pyrodinium blooms

Sporadic occurrence of monospecific blooms of marine dinoflagellates is a fairly common and widespread phenomenon, yet very little is known of the factors which influence and control the development of such blooms. One of the main reasons for this is the fact that the blooms tend to be too sporadic and of too short a duration to permit a systematic study. However, there are several embayments, particulary in the tropics, which maintain a year-round presistent bloom of dinoflagellates and may be used for a study of growth dynamics of these organisms. One such embayment is the Oyster Bay located in Falmouth on the northern coast of Jamaica, about 20 miles from Montego Bay in the West Indies. This Bay has been the subject of an intensive study by a group from Johns Hopkins University since 1966 mainly from the point of view of bioluminescence of the bloom species *Pyrodinium bahamense* and its possible correlation with physical, chemical and biological factors within the Bay.

During February 1968, an invitation by Dr Howard H. Seliger of the Johns Hopkins University group enabled me to participate in their research program in Jamaica and to cary out investigation on the influence of land-derived organic compounds on the growth of *Pyrodinium bahamense* within Oyster Bay. Several observations on the production rates of natural populations were caried out both in the laboratory and in the field and certain tentative conclusions have been reached. The generation time of this dinoflagellate within the Bay was estimated to be between 60-63 hr; however, towards the mangrove swamps the growth conditions appeared to be good and an average generation time of 59 hr was observed. Growth of *Pyrodinium* in laboratory cultures was substantially improved when yellowish-brown humic water from the mangrove swamps was added to the culture medium. These observations suggest that exudates from mangrove swamps provide a continuous source of efficient chelating and sensitizing agents for dinoflagellates which probably keep the bloom organisms in an exponential state of growth. It appears that the flushing rates and flow patterns in Oyster Bay are in some sort of an equilibrium with the production rates of *Pyrodinium* permitting a perpetual bloom. From our experiments there appears a strong possibility that mangrove exudates form metal-organic complexes and that these complexes are Fe-humate and Fe-fulvate type since large amounts of iron are found in the Bay.

A. Prakash

Bedford Basin studies

A program of weekly monitoring of the phytoplankton population and hydrographic conditions which started in March 1965, was concluded in December 1967. The main objective of this program was to investigate the annual phytoplankton cycle and to evaluate the environmental and biological factors which influence the growth and succession of diatoms, armoured dinoflagellates and tintinnids. A fuller analysis of the data is in progress and will appear elsewhere; however, based on some preliminary treatment of the data certain tentative conclusions can be reported.

Bedford Basin represents a highly eutrophic ecosystem compared with outside coastal waters. The phytoplankton biomass is fairly high throughout the year but species' diversity is low. Although a conspicuous diatom-dinoflagellate succession is evident towa(rds the end of spring, dinoflagellates become an important component of the phytoplankton during the rest of the year. *Ceratium longipes*, *Ceratium tripos* and *Peridinium* sp. are the dominant dinoflagellates, whereas diatoms are represented mostly by *Chaetoceros* sp. Several species of tintinnids appear in rapid succession palrticularly during the summer and autumn and appear to feed predominantly on dinoflagellates and other microflagellates.

A comparison of the hydrographic conditions between Bedford Basin and outside embayments like St. Margaret's Bay reveals that the temperature and salinity regimes in the two regions are generally similar during most of the year, although the surface salinities in Bedford Basin are subject to wide fluctuations mainly due to the influence of run-off from Sackville River. The seasonal surface temperature distribution in Bedford Basin is characteristically sinusoidal in form with maximum and minimum temperatures reached in August and February respectively.

Except at the surface, there appears to be very little seasonal variation in salinity.

The gross features of the seasonal variation of Silicate, Nitrate, Nitrite and Phosphate are similar in Bedford Basin and St. Margaret's Bay waters; however, at any season the levels of these nutrients are at least an order of magnitude higher in Bedford Basin. Generally speaking, the low summer levels of these nutrients in the Bedford Basin are comparable with the "high" winter values recorded for St. Margaret's Bay. There appear to be significant amounts of dissolved organic material in the Basin water as evident from high UV absorbances particularly in the surface and bottom layers.

Mark Hodgson
A. Prakash

ToC

The Formation of Organic Particles in Sea Water

If sea water is passed through a very fine (bacterial) filter and then allowed to stand undisturbed, particles begin to form in it. The number of particles increases for about five days after which no further growth takes place. If the sea water is again filtered another batch of particles will form. This can be repeated many times.

There is no doubt that the particles are organic (published work by Riley and associates; Baylor and Sutcliffe; and others), but there is considerable doubt as to whether they are living. The general opinion at present seems to be that the initial stage is nonliving and that colonization by bacteria then follows. The bacteria may then promote further precipitation of nonliving organic material.

However, careful measurement of these particles, particularly at the earlier stages of growth, has shown that samples of sea Water of different origins produce particles of different sizes to different limiting concentrations. There is some evidence to suggest that in some cases these particles may represent a hitherto unknown type of marine micro-organism.

R. W. Sheldon

Photosynthesis and Respiration of Diatoms and Flagellates

To understand and interpret the factors that govern the primary production in the marine environment, it is desirable to grow phytoplankters under measurable laboratory conditions and study their behavioural response to changes in environmental conditions that are likely to be encountered by them in their habitat. The following phytoplankters common to St. Margaret's Bay, Nova Scotian Shelf waters, and Bedford Basin have been isolated and brought under culture: *Chaetoceros* spp. *Coscinosira* sp., *Cylindrotheca closterium, Dunaliella tertiolecta, Monochrysis lutheri, Fragilaria* sp., *Phaeodactylum tricornutum* and *Thalassiosira nordenskioldii.*

Photosynthesis and respiration rates have been determined by a manometric technique. The influence of light, temperature, pH and nutrients on growth, photosynthesis and respiration of the phytoplankton cultures is being studied.

D. V. Subba Rao

Zooplankton Abundance and Distribution

Very little is known about the seasonal and regional distribution of the zooplankton in coastal embayments along the southern coast of Nova Scotia or along the adjacent Scotian Shelf. Before any serious start can be made toward solving problems pertaining to food chain dynamics and production processes involving the planktonic community, it is necessary to find out when and what organisms are important. Because of its open mouth and shallow sill, St. Margaret's Bay is perhaps not an ideal environment for the study of zooplankton production processes, but it is a rather typical coastal embayment and seemingly highly productive, at least of commercially important fish species. Therefore, a combination plankton-physical oceanography program was initiated in the spring of 1967 designed substantially to "calibrate" St. Margaret's Bay. To do this a series of stations were established within the Bay itself and across the Continental Shelf out to the LeHave Basin. Cruises were carried out in May, September, and December 1967 and monthly beginning in January 1968. Twenty stations in all have been established but because of the limited size and, hence, working range of some of our research vessels, the outer four stations have not been sampled so regularly as the remaining 16.

At each station temperature and salinity measurements were taken and at least one vertical plankton tow from bottom to surface with a metered net (240μ mesh aperture, ¾

metre diam) was carried out. During the May and September 1967 cruises some observations of current movements in the mouth of the St. Margaret's Bay were carried out using parachute drogues. In addition, certain drogues were designated as water mass tags and the populations and physical parameters associated with them sampled daily for a week.

As this phase of the investigation is still in progress, it is not possible to make generalizations with a strong feeling of confidence but several observations seem pertinent to our understanding of the processes controlling the composition and abundance of plankton in the St. Margaret's Bay area.

In early May 1967, our plankton-oceanographic section and the drogue studies immediately following it suggested the existence of a clockwise eddy, which persisted for at least 5 days, lying adjacent to the Bay mouth and inshore from the 50-fathom curve. Further offshore there was a strong westerly flow of very cold water (<l°C). The westerly drift of water on the Continental Shelf in this region would be expected and I have personnally seen this very cold water in the spring in other years around the edges of Brown's Bank.

After the initial phase of the May cruise a series of northeast gales occurred which destroyed the eddy pattern and presumably drove this water offshore. In any event, following these gales a marked shift in the long-shore currents toward the east occurred. Such conditions, if persistent, might cause upwelling and a major exchange of Bay water with offshore water. Indeed, a section run just after the first gale (May 10-11 1967) revealed some upward tilting of isotherms and isohalines near shore although the plankton composition was not significently affected.

The distribution of plankton during the period perhaps illustrates the importance of some presistent pattern of eddies to the maintenance of large populations in the Bay area. Largest population abundance (> 7,900/m^3) was found in the eddy and least in the westerly flowing cold water. Possibly this cold current could be serving as a barrier holding the neritic populations against the coast long enough for sizable populations to develop in the inlets. As evidence that this circulation pattern may be relatively presistent in the spring, we again found a well-developed cold core in April 1968 and a less well-developed but still detectable one in June. Regrettably weather conditions did not permit the sampling at the offshore stations in May 1968 and as yet we have no supporting evidence for some such pattern of eddies from this year's still unanalyzed plankton samples.

In summer, the water structure is apparently largely controlled by thermally-induced stability re-inforced by runoff from the land in the nearshore waters. There seems to be a regular pattern of increasing salinity with isohalines sloping from bottom toward the surface as you move away from the shore. In the absence of a major meteorological disturbance, this pattern would be likely to keep meritic populations close to shore in the somewhat fresher, less dense water most of the summer, and indeed this is what our plankton distributions seem to indicate.

During the summer of 1968 we initiated an experimental program designed to give us information about population growth parameters for some of the important neritic plankton species. With the technical assistance of Miss Judith Caldwell, a student at McGill, we were able to start an apparently persistent culture of *Pseudocalanus ebngatus*, the dominant copepod in most of our tows. Eventually we hope to learn enough about captive populations to compare them with wild ones, probably in a more restricted environment such as Bedford Basin. Still further in the future we hope to extrapolate our observations to more open embayments such as St. Margaretys Bay where the topography and current systems are not so favorable for use of the classic methods of population biology.

R. J. Conover

Productivity and Biomass Estimates for **Zooplankton**

Investigations are being continued in an effort to assess the possible effectiveness of RNA concentration as an indicator of growth in animals; analyses are at present incomplete. Determinations of RNA have been made on a number of zooplankton samples from St. Margaret's Bay and surface tows from a section from Grand Banks to Puerto Rico. In both series, RNA concentration was inversely related to biomass in terms of dry weight. If this correlation proves to be significant, it would indicate an inverse relationship between unit productivity and standing crop.

Attempts are also being made to use DNA as a measure of phytoplankton biomass, utilizing a fluorometric technique. Initial results from determinations on culture material were most encouraging, showing a good relation between DNA and carbon content. However; determinations on collections at sea show more DNA present than can be accounted for by the amount of living material present. Presupposing that the method is not measuring something else in natural sea water, the possibilities are that free DNA is present in the ocean or that some living material high in DNA (such ars viruses) is contributing to high values.

Other methods are being tested, such as growth in bottles measured by particulate carbon and Coulter counter techniques to back extrapolate to biomass by the method recently presented by Cushing.

W. H. Sutcliffe, Jr.

ToC

Sediment and Benthos Survey of St. Margaret's Bay

Geographic distribution

During 1967 an intensive quantitative survey of the benthos of St. Margaret's Bay was carried out. All collections were made between mid-May and mid-June.

At each of 29 locations throughout the Bay 10 samples were taken from an anchored vessel with a 0.1 m^2 Van Veen bottom grab. The samples were screened and stored in formalin immediately. An additional sample for particle size analysis of the sediment was taken at each location. Particle size analyses were done by the Marine Geology Branch of AOL.

Results from 21 stations were analyzed in detail and appear to give an adequate coverage of bottom types encountered. Sixty-five different taxa were separated quantitatively and 75 species' identifications were made. A set of type specimens has been deposited at the Canadian Oceanographic Identification Centre, Ottawa.

A major topographic feature of the bottom of the Bay is a depression which runs parallel to the long axis of the Bay near the western shore. This part of the bottom, about 7 sq miles, is covered entirely with silts and clays and provides the largest single expanse of uniform sediment type.

The eastern part of the Bay contains a number of drumlin islands and submerged drumlins. The tops of the submerged drumlins consist of large boulders and cobbles while the areas between them are covered with silts and clays with variable amounts of sand (15-25%). The seaward facing (westward) slopes consist of sand and gravel with little or no silt-clay material.

The most reliable quantitative data were obtained from the silt-clay (mud) and the sandy mud areas. Differences between these sediments are as follows: sand content, 15-25% for sandy mud and 1-6% in the mud from the western depression. The mud from this basin smells more strongly of decomposing organic matter and has a higher water content (75% vs 55%). Biological oxygen demand measurements on freshly mixed sediment appeared to be slightly higher (on a per volume basis) but the difference is not statistically significant with present information.

The dominant organism by weight in the mud bottom was *Synaptia inhaerens* (Echinodermata) with a biomass of 9.0-18.0 gm/m^2 wet formalin weight. This was followed in most stations by *Yoldia* sp. (Mollusca) and two species of the family Lumbrineridae (Annelida). *Goniada maculata* (Annelida) and *Ponteporteira femorata.* Crustacea were also abundant in terms of biomass and one of these species was always the most numerous. The total biomass was always less than 100 gm and often went as low as 25 gm/m^2.

The fauna of the sandy mud was, like the sediment, more variable. It was also richer. Total biomass of all stations was over 100 gm/m^2 and went as high as 500. At most stations the dominant organisms by weight were *Malpodia oolitica* (Echinodermata) and *Sternaspis fossa* (Annelida) whose abundance was proportional to sand content. Other characteristic organisms were: *Laonice cirrata* (Annelida) *Ctenodiscus crispatus* (Echinodermata), *Pherusa plumosa* (Annelida) *Phascolion strombi* (Sipunculid) several species of the family Maldanidae (Annelida) and *Chaetoderma canadense* (Mollusca). In addition most of the species present on the mud bottom were also present in the sandy mud.

Quantitative data from bottoms of boulders and cobbles were not obtained. Echo-sounding and bottom-grab profiles indicate that at

least 1 sq mile of this type of bottom occurs below the IO-fathom contour in different parts of the Bay.

Sceasonal distribution

Upon completion of the survey of St. Margaret's Bay, showing geographic distributions of the benthos, four locations were selected, each representing a characteristic sediment type. It is intended to sample these stations periodically to observe any seasonal changes in biomass or species' composition.

The station selected to represent mud bottom was found to have an exceptionally large settlement of *Pectinaria hyperborea*. When first sampled in late Ma,y the numerical abundance was 560/m^2 and the specimens taken were all between 4 and 10 mm long. No adult worms were present. This year class could be seen on subsequent samples taken throughout the year during which the modal size increased from 4 mgm to 60 mgm (see Fig. 19). No similar settlement was observed in the spring of 1968. This patch of newly-settled *Pectinaria* extended over an area about 3 miles long by about 1 mile wide.

D. L. Peer

Pictou Harbour Benthic Samples

During October 1967 just prior to the outset of effluent discharge from the holding pond of the new pulp mill at Abercrombie Point a series of quantitative benthic samples was taken in the vicinity of the discharge. It is proposed to repeat this survey in subsequent years in order to evaluate changes that may take place and their possible relation to the effluent. From these samples 21 different taxa were sorted, weighed and identified. Of these, 12 consisted of a single species.

D. L. Peer

Shrimp-Sediment Relationships

Commercial concentrations of shrimp (various Pandalus species) tend to occur over soft mud bottoms. Within the general area of occurrence however variations in density can be predicted on the basis of sediment particle distribution. Before sediment distributions can be used as an index of relative densities it is necessary to have some indication that shrimps are present in the area for many

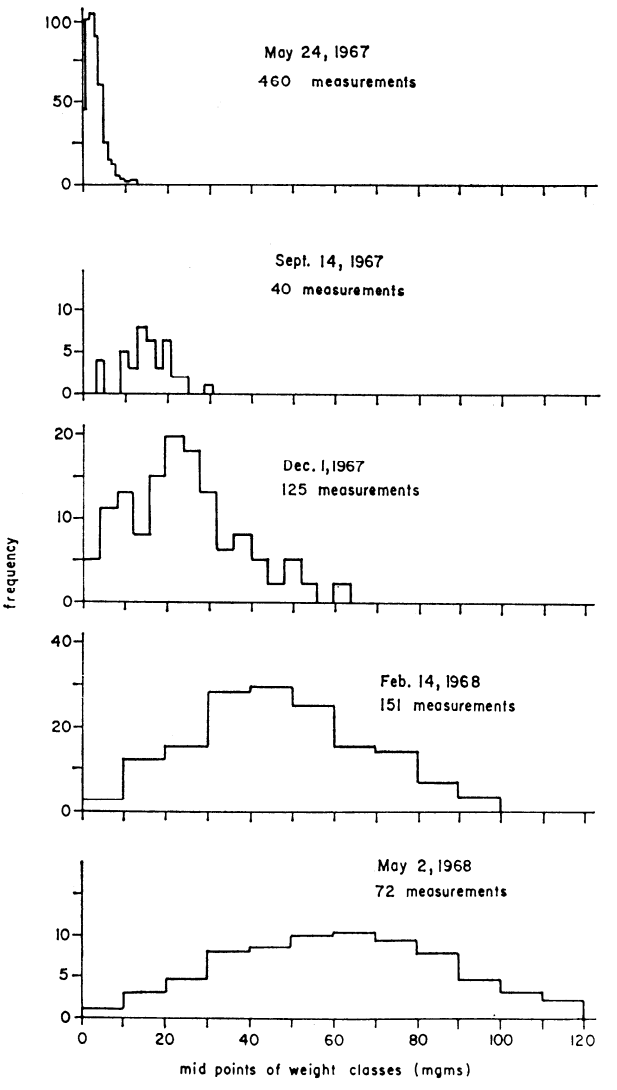


Fig. 19 Weight frequency histograms of population of *Pectinaria hyperborea* takes at approximately 80-day intervals throughout 1 year.

places of the continental shelf with soft bottom do not support shrimps. However, our experience in the North Sea,, off the British Columbia Coast, and the Scotian Shelf has shown that the initial indication need be nothing more than a few shrimp taken in a groundfish trawl or plankton net. Given this indication, the pattern of bottom sediments can be used to define exactly the parts of the area having highest relative density. Population density on bottom also varies with time of day, but studies of the amounts of sediment carried in the stomach make it possible to predict when they will congregate on bottom

and be available for capture. Such observations show one way in which studies of animal-sediment relationships can have a direct application to practical fisheries problems.

R. W. Sheldon

ToC

Life Histories and Production of Polychaetes in St. Margaret's Bay

In May 1967 in order to estimate invertebrate benthic productivity a start was made on a study of the life histories of some of the quantitatively important polychaetes in St. Margaret's Bay. Until this time work on the benthos in the Bay had been concerned with quantitative and qualitative distributions of species.

The polychaete annelids form approximately one third of the total benthic biomass of the Bay and within this group the family Maldanidae often constitutes up to 37% of the polychaete biomass in a "Compacted" or gravelly mud. Consequently the Maldanid species *Praxillella gracilus* which occurs abundantly in a mud-type bottom covering some 3-4 sq miles, was chosen. The species also exhibited some peculiar features in its distribution; notably, only large worms i.e. about 8 cm (contracted live length) have been found.

Females of *P. gracilis* were found, in June 1967, to be packed with yellow eggs, and an examination of egg sizes was made over the ensuing months with the expectation of seeing a significant change in their size prior to spawning. It was postulated that this species might spawn in response to an increase in bottom temperature. According to B.T. data from June to August 1966 there was a rise in temperature of l°C over a 2-week period (July 25-August 8) after a mean of 1.75°C during the preceding two months. Females collected by a 0,.2 m Van Veen grab after August 8 were still heavily laden with eggs.

Sampling was continued approximately biomonthly throughout the autumn of 1967, recording the length and sex of *P. gracilis* individuals in two square meters of mud at one station (No. 34). Samples of gametes were regularly taken from the coelom and stained as smears with Erhlich's acid haematoxylin for examination and analysis at a later date. A refrigerated sea-water tank has also been set up, in which the effects of rising temperature on reproductive activities might be observed directly. Gravid females and ripe males have been collected and paired in six-inch cores of mud from the Bay (Station 34) which had previously been collected and immersed in the refrigerated tank. Approximately 50% of the experimental animals have survived for over 3 months and observations are continuing.

R. J. Bentley

Caloric Content of St. Margaret's Bay Benthos and Zooplankton

The most abundant benthic inverteb-rates of St. Margaret's Bay collected in summer from below the thermocline differed considerably in their caloric contents. The shrimps, amphipods, and the polychaete *Lumbrinereis* containing between 1,000 and 1,300 cal/g wet weight had the highest energy content of the 27 species tested and may be compared with values below 300 cal/g obtained for the three holothurians tested. Seven species collected in the summer and again in March and April at the time of the lowest water temperatures showed seasonal differences in calories/g wet weight varying by - 20% to + 10% of their summer value.

The standing crop of benthic inverterb-rates in the summer at St. Margaret's Bay at depths of 28-62 m determined at 17 locations, contained between 8 and 174 Kcal/m^2 with a mea$_1$n of 76 Kcal/m^2. The highest values were found where sand and silt-clay fractions of the sediment were nearly equal. Annelids and echinoderms together accounted for more than three-quarters of the caloric content of the standing crop when the values for all stations were combined.

Determinations also were made of the caloric content of zooplankton from the Bay throughout the year. These showed a five-fold increase from the low April and July values to the high October value of 4,259 calories/g wet weight.

V. M. Srivastava (Brawn)

Production of Ichthyoplankton in Marine Fish Populations

St. Margaret's Bay studies

There is ample evidence that the strengths of successive year-classes of fish are subject to large fluctuations. However, there is little knowledge of the factors responsible

for these fluctuations. Broad limits on year-class strength are centainly set by total egg production, and certain theories of fish population dynamics make the tacit assumption that in the long term it is the number of parent's which determines the general level of production of young. However, there seem to be few situations in nature where, over time periods of the order of 2 or 3 times the average generation time, any relation between adult abundance and year-class strength can be demonstrated. Environmental circumstances obviously play an important role in the short term. They might equally be expected to control the general level of stock production within which an uneasy balance between growth and reproduction could be established.

If we are to better understand the factors underlying population production, there would appear to be no satisfactory substitute for information on the abundance, distribution, and trophic relations of natural populations. Of particular importance are the early life-history stages in which especially heavy mortalities are known to occur. An intensive sampling program was therefore begun in late 1967 to provide information on the pelagic ichthyoplankton and associated fauna of the St. Margaret's Bay area. Sampling gear adopted initially is the Icelandic high-speed plankton sampler and Isaacs-Kidd midwater trawl. Thirteen 1½ mile transects were set up in the Bay and seven transects in the coastal water adjacent to the mouth. Day and night sampling at two depths has been carried out once a month and provides information on the horizontal and vertical distribution of fish eggs and larvae, and of certain of the micro and macrozooplankton. The results to date give some basic information on the diel and seasonal changes.

There appears to be a seasonal succession of dominant ichthyoplankton. In September the larvae of *Lumpenus lumpretaeformis* (Walbaum) and *Tautogolabrus adspersus* (Walbaum) are the most common. During October newly hatched larvae of *Clupea harengus harengus* Linneaus are by far the most dominant form with *Gadus morhua* Linnaeus being very common. From November to March *Clupea harengus* and *Mallotus villosus* (Muller) dominated the ichthyoplankton. In addition to those listed, 20 other species of pelagic fish larvae were commonly caught.

Differences in the composition of the smaller zooplankton collected inside and outside the Bay were found from May to October, but no consistent species' difference was seen during the winter months. There appears to be only one zooplankton bloom starting in late May and reaching a maximum in October. Large differences in the volume of zooplankton per unit volume of water were found in the different locations of the Bay during the summer bloom which suggests a patchy distribution. Due to the vertical migration of the zooplankton during the night, the samples taken at night provided a more consistent picture of the species' composition and volume of zooplankton in the Bay.

Significant differences in the species' composition of the macroplankton were found during different times of the year and between the stations inside and outside the Bay. The most striking difference is the almost complete lack of *Pandalus* species in the Bay and the abundance of *Pandalus* in the waters a few miles outside the Bay.

The calorific values of the more abundant species of zooplankton and fish eggs will be determined in order to express each as a unit of energy in the total energy budget of the marine community.

Scotian Shelf project

A preliminary herring larvae survey along the Scotian Shelf was made during July 1968, using the Department of Fisheries patrol vessel *Chebucto*. The aim of this survey was to try to locate herring spawning beds on the Shelf. This survey will be continued in 1969.

Gulf of St. Lawrence larval fish study

As part of a combined exercise with physical oceanographic staff of the Institute, plankton samples, pelagic fish samples and hydrographic data were collected within a 70 x 90 mile grid in the Gulf of St. Lawrence. The purpose of the study was to detect the presence of gyres in the Gulf and determine if these circulations had any effect on the biological properties of the water within the gyre. The data on the physical and chemical properties of the water will be examined to detect any relationship between them and the zooplankton collected.

D. D. Sameoto

Fish Population Studies in St. Margaret's Bay

The American plaice *(Hippoglossoides platessoides)* is predominant among the demersal species in St. Margaret's Bay and was therefore selected for a study of distribution, abundance and production as part of a general study of basic production processes and their influence on fish production. St. Margaret's Bay is characterized by a sill at the mouth with water depth less than 30 fathoms while the deepest part is 50 fathoms. The eastern coastline is indented by many shallow coves, and the western side is steep and rocky. The Bay appears to be partially separated from the adjacent open coastal areas, and in this it is typical of a number of inlets on the Nova Scotian coast.

Studies of meristic characters and seasonal variations in catches of plaice in the Bay and from offshore areas, indicate that St. Margaret's Bay supports a local plaice population. More than 8,000 plaice were tagged in the Bay in 1966 and 1967. Only three of these tagged plaice were caught in areas outside the Bay compared to 200 returned by fishermen in the Bay. St. Margaret's Bay has been closed to commercial trawling since 1950. Local fishermen set gill-nets during the winter months. This is the only fishery for groundfish, and the few plaice recaptured are large individuals which become entangled in these gill-nets. The catches of plaice are small, hence the stock is virtually unexploited.

The growth rate of St. Margaret's Bay plaice has been determined from measurements of length and determination of age from otoliths. Plaice of both sexes grow at the same rate until age 5. Thereafter females grow more rapidly, reaching 30 cm (200 g) by age 9, compared to age 10 or 11 for males. The oldest female was 25 years and the oldest male 14 years. The growth curves can be described by the two von Bertalanffy equations:

$$L_t = 85.5\ [1-e^{-0.04\ (t + 1.23)}]\quad \text{females ;}$$

$$L_t = 45.0\ [1-e^{-0.10\ (t +0.98)}]\quad \text{males.}$$

Samples of plaice were obtained with a small otter trawl. Observations made by scuba divers indicated that the net was effective in catching the plaice. The bridles between the otter boards and the net had a herding effect, and only a very small proportion of the flatfish escaped across the bridles. It is therefore possible to calculate an average density of the fish with fair accuracy.

The abundance and distribution were calculated on the basis of catches and from results of the tagging program. The highest population density was found at depths below 30 fathoms with about 700 plaice (>20cm) per hectare. Much lower densities were observed in shallower areas where winter flounder *(Pseadopleuronectes americanus)* replace the plaice as the most common flatfish.

Relatively large variation in the size of the plaice was found within the Bay. In the deeper parts the plaice were, on an average, much smaller than those caught nearer shore, and no seasonal differences could be demonstrated.

The plaice spawn in St. Margaret's Bay: females usually for the first time at 11 years (35 cm) and males at 7 years (23 cm). The spawning takes place in early summer.

Benthic invertebrates are the most important food of the plaice. Young plaice (<35 cm) also feed on epibenthic animals, espically mysids. Larger plaice eat mainly molluscs and echinoderms. The most intensive feeding period is June-October when the temperature at the bottom increases from about 1^{o} to 4°C.

Young plaice have been found in stomachs of cod, ocean pout, monk fish, and sea ravens.

Assembled information on the growth of the plaice, the age structure in the population and the size of the stock will form the basis for estimating biomass and annual production of this stock in the Bay. Such estimates contribute to the understanding of the complete food-web structure and the construction of a biological energy budget for St. Margaret's Bay.

Erling Bakken

The Food of the American Plaice

With growth fishes generally show a progressive pattern of change in the food organisms they eat. While this appears in many cases to represent a change in the food preferences and degrees of selectivity of various diet items this has not often been explicitly demonstrated. The relative importance of

enviornmental and behavioural or physiological mechanisms responsible for these dietary changes is largely unstudied. An analysis of the stomach contents of the American plaice *(Hippoglassoides platessoides)* in St. Margaret's Bay was undertaken with a view to measuring the degree of "electivity" of various items relative to their density on the bottom and their type and size relative to the size and abundance of the predator.

Standardized collecting tows with a small otter trawl were made on two stations in St. Margaret's Bay in the autumn and spring. The total numbers and size compositions of the plaice were determined and subsamples of the gut contents and otoliths stratified into six size categories were preserved. Food species' groups found in the stomachs were later identified, counted and weighed and where possible the major species identified. Initially the size compositions of individual species were also determined, but when it appeared that there was little size variation within species' groups relative to the total size range of foods, this was abandoned and species' group taken as a sufficient index. The results were analyzed for differences in foods between stations, seasons, and sizes of predator. Using information on the natural relative abundance of the food groups, supplied by D. Peer and J. Bentley of MEL from sampling by Van Veen grabs, indices of food electivity were calculated, and the species' diversity of the food arrays was determined.

The results showed that the only seasonal effects on feeding resulted from changes in the frequency of empty stomachs. All fish were actively feeding during the spring, whereas feeding activity was low in the autumn. The stomach contents of feeding fish showed that over both season and station the size of prey relative to size of predator appeared to be the dominant factor determining the type of intake. Electivity indices for particular size groups of prey reached maximumly high positive values at given size of plaice but were generally lower for smaller and larger predator sizes. The preferred particle size of food increased with increase in size of predator. Polychaetes and crustacean were strongly selected by small and intermediate size plaice and molluscs by the larger plaice. The degree of electivity was however also influenced by its abundance, species-type and apparently by interactions of predator-prey behaviour. A tenfold difference in food biomass between stations was inversely correlated with plaice abundance, and was associated with a difference in electivity for the species' groups. Molluscs were strongly positively elected only by the largest fish and only when they were the only food available in the large size range. There was a strong positive election of ophiuroids by larger fish sizes although in total they form a very small proportion of the diet in St. Margaret's Bay. Holothurions were avoided. Differences between food species and stations indicated that while small active crustaceans appeared to be the favoured food, they were not taken preferentially except where they were most abundant on sandy bottom, presumably a reflection of their availability to the actively foraging predator.

In general, it appeared that large plaice have a much larger range of food items available to them than do small plaice. The results form a progressive election of larger and larger food particles with size, apparently as the fish become large enough to handle them. Small food particles still form an important proportion of the total diet of large fish, presumably because the larger items are relatively scarce, but they nevertheless show a negative electivity or tendency to avoid the smallest particles. It would appear that the larger fish have a competitive advantage in cases of food limitation, and that this may be only partially compensated for by the greater activity hence ability of small fish to catch the more pelagic and active small food organisms.

Abstracted by L. M. Dickie from a report by J. D. Ardill

Benthos of Bideford River, P.E.I.

The composition and distribution of benthic fauna and flora in Bideford River, a typical oyster producing estuary in P.E.I. has been intensively investigated using grabs and diver-operated suction dredges. Sediments have also been investigated.

In the area surveyed which comprised 135 hectares, the following species, which are listed by decreasing area of distribution were common, *Yoldia limatula, Zostera marina, Macoma balthica, Mytilus edulis. Crossotrea virginica, Mya arenaria,* and *Volsella demissa* (all but *Z. marina* or eel grass are bivalve mulluscs). If the estuary is divided into areas dominated in terms

of decalcified dry weight by various fauna, it is found that an area dominated by *Y. limatula* covers about 50% of the total ; however, the fauna biomass in that area makes up only about 3.5% of the total. *M. balthica*, *M. arenaria*, and *V. demissa* dominate 19, 8 and 2% of the estuarine area respectively, and the fauna on these areas contributes to the total biomass in similar percentages. *M. edulis* and *C. virginica* dominated areas on the other hand contribute more to the total biomass than the percentage area they occupy. *M. ledulis* dominates only 17% of the area, but it and its associated fauna comprise 44% of the total biomass. Similar data for *C. virginica* are 4% and 9%. Several other species dominated over very limited areas.

Y. limatula predominated where sediments comprised over 70% silt clay and the salinity was high and stable. *M. balthica* replaced Y. *limatula* on similar bottoms in areas of at least seasonally reduced salinity and also predominated in a narrow zone just below extreme low water. The zone dominated by *M. edulis* generally surrounded the main *Yoldia - Macoma* area in a zone of coarser sediment. *M. arenaria* occupied the sandy lower intertidal zone.

Detailed investigations of the abundance and biomass of benthos along enviornmental gradients does not support the widely held theory that marine benthic communities consist of a characteristic assemblage of species and show relatively sharp boundaries. Rather, most of the species appear to be distributed independently of the other species with a large apparently random component to the pattern of occurrence. However, laboratory and field experiments suggest that "oyster beds" may be exceptions to this and be indicative of discrete communities dependent upon the interactions of several species.

Coring has shown that the Bideford River estuary is steadily filling with progressively finer sediments and that the area of oyster beds is declining. Monitoring of sedimentary activity has shown peaks in spring and autumn. The majority of sedimentary activity is considered to be the reworking of estuarine sediments but significant new material is added. It has been demonstrated that the initial trapping and binding of sediment to the substrate is mainly caused by colonial diatoms. Silt trapping on a larger scale is accomplished by hydroids, *M. edulis* and *Z. marina.*

Stomach analyses have shown that the fishes *Pseudopleuronectes americanus, Microgadus tomcod,* and *Fundulus heteroclitus* are major predators on the benthos. *Asterias vulgaris,* the common starfish, and *Lunatia heros,* the moon snail, are important predators of the mulluscs.

Field and laboratory studies of the growth of several common molluscs suggest that in many species, the process is more rapid than is suggested by so-called "annual-rings".

M. L. H. Thomas

Benthos of Ostrea Lake, N. S.

The benthos of Ostrea Lake, a saltwater lagoon off Musquodoboit Harbour, N. S., has been investigated annually in conjunction with an oyster farming experiment being carried out by the Nova Scotia Department of Fisheries. Quantitative samples have been collected using a diver-operated suction dredge. Results have shown that the bottom is usually covered with an algal mat composed of a variety of species but dominated in water over 2 m deep by Cyanophyceae. Periodic decay of the mat results in anaerobic conditions over large areas of bottom and the mass-mortality of much benthos. Only short-lived species are present except in shallow water. The sediments contain extraordinarily high organic content and are composed almost entirely of fecal pellets. Oysters grow very well in suspended culture in this unique area and their trophic relationships are being investigated.

M. L. H. Thomas

Problems in Production of Seed Oysters

The supply of seed oysters has always been an important limitation on the realization of the full potential of the oyster industry of the Maritimes. To the variable severe climate of the area has been added a general ecological deterioration of the key spawning areas in the creeks, resulting in only occasional natural recruitment in many areas. For example, our continued monitoring of natural oyster spatfall in the creeks adjacent to our laboratory showed that in 1968 spatfall was extremely heavy in late July and early August. However, growth and survival in August were extremely poor. The net result was a general failure of recruitment. The warm dry July was undoubtedly important in the heavy settlement observed. The unusually cold wet weather in August appears to have slowed growth to the point

where silting and fouling became major mortality factors. Although weather effects were important the planting of spawning stock in these creeks is thought to have been extremely important in supplying a breeding potential and may well prove to be a powerful and important management tool.

A major part of the Ellerslie program of the past few years has been the investigation of the factors important in seed oyster production under controlled, hatchery conditions and in the field. The Experimental Shellfish Hatchery at Ellerslie has played an important role in such investigation. In the past few years commercially applicable methods have been developed and shown to be biologically feasible in Eastern Canada,. The responsibility for further development and demonstration, and exploration of other potentially suitable locations for hatcheries has been passed to the Resource Development Branch of the Department of Fisheries. As part of our own program we have continued investigation of techniques of mass culture of the flagellates used as food for larval molluscs. A pasteurization technique, rather than the normal autoclaving, has been shown to be satisfactory, and even advantageous, in preparing culture media. Several food species have been adapted, after several generations, to growth in natural sunlight, and a simple, water-cooled, culture apparatus developed. Such culture is now well within the competence of commercial hatchery operators.

The use of scallop shells as a substrate for oysters in the hatchery, because of their inertness and general convenience, has led to the incidental demonstration of the feasibility of suspended scallop shell string culture of oysters to a size suitable for bottom planting. As an alternative to the doubtfully economic alternatives now available, this has great commercial promise for both hatchery and natural production.

R. E. Drinnan

Studies in Oyster Genetics

In the mass transplants of disease-resistant Prince Edward Island oysters to mainland New Brunswick and Nova Scotia to rehabilitate the industry after the disease epidemics in the 1950-60, much of the former genetic diversity of these stocks was lost. In an attempt to retain such diversity, oysters which survived the original epidemics have been collected and are maintained in our experimental hatchery for selective breeding of various known types.

A possible example of a unique stock is that formerly found in Miscou, N. B. Not only were these oysters noted for their excellent shape, flavour and keeping qualities, all of which may be phenotypically rather than genetically determined, but they were shown during the epidemics to be different in their susceptibility to disease, from all other known stocks. It is possible that they will show other, genetically determined, differences also. We have now reared a generation of pure-bred Miscou oysters and their crosses with our native Ellerslie oysters. These will be subjected to selection for growth and disease resistance. We are also selecting fast-growing, disease-resistant oysters from Cape Breton stocks and a number of fast-growing lines from native Ellerslie oysters. With our successfully developed hatchery techniques, it is possible that further experiments could result in commercial production of improved oyster stock suitable for different rearing areas.

R. E. Drinnan

The Feeding of Cod

Cod in aquaria are able to take food in midwater or on the bottom and will dig for food buried below gravel. An attempt to observe this behaviour in nature was made by burying chopped herring and mussel in gravel in 30 ft of water in St. Margaret's Bay and observing the area from the Perry cubmarine. Cod were not seen but the abundant pollock fed eagerly on food falling down from the surface. All pollock ceased feeding when the food was l½ ft above the bottom, and did not feed on pieces of mussel lying on the bottom. This behaviour contrasts strongly with the behaviour of cod in captivity which after taking falling food feed without hesitation on any pieces on the bottom.

The diet of cod changes with age as the fraction of fish in the diet increases. Using the data on the food composition of cod published by Powles (1958), and the caloric contents of invertebrates and fish determined here, it was calculated the average caloric content of the diet varied very little with changes in the size of the cod and changes in the composition of the diet. Cod 11-30 cm

long with 10% of the diet being fish were estimated to take food containing an average of 1,138 cal/g wet weight while 71-100 cm cod eating 69% fish obtained 1,293 cal,/g. The greater food energy obtained when a greater fraction of fish is included in the diet is apparently offset by a decrease in the crustacean fraction, the richest invertebrate food, and an increase in the lower energy-containing molluscs and echinoderms.

Previous work suggested that cod might possess an alarm substance in the skin which would cause other cod to flee from the vicinity of an injured cod. Tests to verify this point revealed cod do not respond by a fright reaction to skin extracts of a strength sufficient to evoke this response in the Ostariophysi. They do, however, frequently reject as food small pieces of cod flesh bearing skin while still feeding on herring.

Vivien M. Srivastava (Brawn)

Production and Food Supply

Production in any biological population ultimately depends on the energy derived from its food supply and long-term yield to a predator is dependent on production. But at any time the predator acts on the standing crop or biomass. Understanding the factors underlying yield to predators and to fisheries thus requires a study of the relation of yield to the biomass, its food intake, food supply and other features of the production system. Earlier studies of population production have attempted to deal with this system in rather simple fashion. In general, the biomass is considered to be in an equilibrium state characterized by particular parameters of change and dependent on a constant food intake per unit biomass. Predictions of yield potential are then based on calculations of the yield per recruit. Our earlier attempts to describe the growth phase of the production processes explicitly in terms of food supply suggested that this formulation may be too simple.

Our recent studies have been concerned with an attempt to express in common terms the simple equilibrium population models and production models, which involve measures of food intake and food abundance. The results continue to indicate that there are substantial differences between yield per recruit and yield per unit food intake, to changes in fishing intensity. That is, they show that if recruitment is constant, then food supply must change markedly with fishing intensity. However, if the food energy flow in the population is constant, recruitment must change in characteristic fashion. Comparisons of the theoretical calculations with the few experimental situations suggest that both factors may be involved although to a rather different extent at different rates of mortality. That is, at low fishing intensities it appears likely that compensations in recruitment are sufficient to permit populations to utilize the entire food supply. At very high fishing intensities reproduction is certainly affected and the populations are eliminated. At intermediate levels, however, additional factors appear to influence production and are apparently related to the relative ability of various-sized animals to graze their food.

The models considered so far also suggest that there may be basic differences in types of population dynamics among animals at different stages in the food chains. Zooplankton organisms appear to have a metabolic and food utilizing system which results in a more rapid compensatory production due to predation than is characteristic of fishes. The differences may be linked with a basically different division of energies for growth and reproduction in the face of changes in food abundance.

J. E. Paloheimo
L. M. Dickie

The Effects of Feeding on Metabolism and Enzyme Activity in Fishes

Attemps to measure the energy flows in a fish population are at present frustrated by the difficulty of measuring the metabolism under natural conditions. To test whether or not this limitation might be overcome, laboratory feeding experiments are being conducted with *Tilapia mossambica* of various sizes fed at several levels and maintained at a number of temperatures. Growth and weight are determined directly. At the end of the experimental feeding period heart, liver, and body muscles samples are taken and analyzed for activities of various enzymes of intermediary metabolism which could be indicators of metabolic rate. At the same time, respirometers are being tested and modified to provide a direct measure of routine metabolism and respiratory quotient under nearly constant conditions by continuous monitoring of oxygen

consumption and carbon dioxide production. Provision is made for collections of faeces and uneaten food for caloric determinations. Slight modifications of the present procedures should permit the writing of a balanced energy equation for the *Tilapia* under a variety of conditions, and studying the relation of enzyme changes to the energy turnover.

Laboratory studies are being supplemented by field studies on the American plaice *(Hippoglossoides platessoides)* in St. Margaret's Bay designed to study seasonal changes in enzyme activity and their relationship with body weight, and sex of the fish, and environmental conditions. Fish are collected about every 6 weeks. Tissue samples are frozen on dry ice in the field and returned to the laboratory for measurement of enzyme activity. It is hoped that combinations of laboratory and field data will make it possible to interpret seasonal changes in the production of the plaice population in terms of total energy exchanges.

J. C. Smith

Cardiac Regulation in Fish

Reflex bradycardia develops in fish in an hypoxic environment. The receptors involved are peripherally located in the mouth or on the gills and their nature and distribution are being studied histologically in a variety of fishes. In order to determine the afferent nervous pathways involved, attempts are made to record activity in the branchial branches of the glossopharyngeal and vagus nerves and to relate the frequency of this activity to the oxygen content of the water passing over the gills of a fish. Dr D. J. Randall of the University of B.C. has collaborated in this work during two visits to MEL.

J. C. Smith

Irrigation of Fish Gills

Ram irrigation - the passing of water over the gills by holding the mouth open while swimming - appears to be used by a wide variety of fish. Our hydrodynamic analysis suggests that energy losses due to drag as the water passes through the gill "sieve" are not likely to be greatly different in ram irrigation than in active pumping. There may be a difference in the external drag, however, and active pumping while swimming may cause unnecessary energy loss. At a cruising speed of 66 cm/sec we calculate the drag resulting from gill irrigation to be 5-10% of the total body drag for a 44 cm skipjack tuna. The cost of swimming is high, however, and it is not likely that respiration is the main function of continuous swimming. Ram irrigation may be an energy-saving device used by fish that are swimming for some other purpose such as hydrostatic equilibrium, migration, and food search.

We have described structural modifications of the gills. Fusions between filaments and between secondary lamellae, are found in tunas and certain other large oceanic fish. Such structure appears to be associated with the large size of the gills in these fish and with their habit of continuous ram irrigation. It is believed that the fusions help support the very long gill filaments and aid in the control of their positioning. This same group of fish shows structural modifications in the branchial blood vessels which initially, at least,, appear to be associated with the distribution of blood through the relatively huge gills.

Our studies on the blood pathway within the secondary lamellae show that the counter-current flow of blood and water is diagonally across the respiratory surface rather than along the long axis. Growth of a lamella increases the number of counter-current exchange units but increases the unit length to only a limited degree. Thus, the ontogenetic increase in the total respiratory surface area is such that the exposure time for each unit of blood is not greatly increased but the total amount of blood exposed is.

Barry S. Muir

Studies of Bathypelagic Fish

The deep sound-scattering layers in the sea have been found to occur with surprising uniformity over the large areas in the North Atlantic. If, as suspected, bathypelalgic fish are largely responsible for the scattering layers, these fish must be among the most abundant of the higher animal forms in the oceans. Even conservative estimates of their abundance, based on hydroacoustic surveys, make it seem likely that they represent an important stage in the biological production processes taking place in the open oceans.

In July 1968 a preliminary study of the scattering layers in the western North Atlantic was undertaken jointly by the Defence Research Establishment-Atlantic, MEL and an

observer from the Royal Ontario Museum. Previous work carried out by DREA revealed strong reverberation from a scattering layer at depths between 900-1,100 m, presumably caused by resonant swimbladders of fish. This layer had not been sampled, and *MV Brandal* was chartered by MEL to carry out fishing at these depths. A large commercial-type mid-water trawl made from small-meshed netting was used. At the same time, the DREA vessel *Fort Francis* used a directional wide-band receiver operating with explosive charges as sound source to determine depth and strength of the scattering layers. A series of eight stations were sampled along the 2,000 m depth contour east and south of Newfoundland. Fishing depths were monitored acoustically from *Fort Francis* which also took hydrographic stations. One 1-hr and one 3-hr tow were made at each location.

A large number of species was encountered on the cruise, many of which had not been recorded for the area before or known only on the basis of a few specimens from predator stomachs. The majority were small and, while catch counts were high, the weight of the catches was generally low, averaging about 50 lb. per hour.

Among the most common species taken were *Cyclothone* sp., *Benthosema glaciale, Bathylagus euryops, Scopelogadus* sp, *h ierops arctica, Lampanyctus crocodilus, Myctophum punctatum, Serrivomer* sp., *Chauliodus* sp., *Stumias boa ferox, Malacosteus niger, Lampadena speculigera, Normichtys operosa.*

Analysis of the data with regard to abundance, size composition, and distribution characteristics of the fish species are being carried out at the laboratory. Collections of several of the species' groups have been presented to ROM, Department of Ichthyology, for continuation of their studies of taxonomy and life-history of these groups.

Erling Bakken

General Studies in Physical Oceanography

Staff of MEL engaged in physical oceanographic studies, together with a rather larger complement of similarly occupied staff of the AOL form- the Applied Oceanography Section of the Institute. The Section's responsibilities include studies aimed at elucidating basic physical mechanisms relevant to marine productivity and pollution, as well as the provision of environmental information required for fisheries' studies and management and by the fishing industry directly.

In addition to our intensive program initiated in St. Margaret's Bay in 1967 (see separate report below), a number of other studies have been carried out that are particularly relevant to fisheries' problems. In the Gulf of St. Lawrence, surveys in 1964 and 1965 indicated that gyres 10-20 miles in diameter were present and moving through the system. In June 1968, a program was undertaken with the aim of locating a gyre and, if one were found, to examine its physical and biological characteristics in relation to the surrounding water. The physical oceanographic results of this survey is summarized in the Atlantic Oceanographic Laboratory section. of this report.

On the Scotian Shelf, a moored buoy project, initiated in 1967, was continued in 1968. Current meters and temperature re-, corders were moored at four sites in order to learn more about variability on the Shelf and thereby provide needed information on the significance of seasonal monitoring of the Halifax Section which continues to be occupied for fisheries purposes.

The needs for quantitative information on flushing of estuaries and coastal embayments in order to predict the capacity of a particular area to accept pollutants and maintain effluent concentrations below specified levels, continue to increase. In some instances, studies of the basic physical processes of circulation and diffusion are undertaken for other purposes and therefore the basic data are available to apply to pollution or potential pollution problems. In most cases, however, no data exists and surveys are required if sound advice is to be provided. Present staff is incapable of meeting all the demands but background studies are attempted in areas where serious problems seem most imminent. In 1968 a brief survey was carried out in the Pictou area complementing the work done earlier (1965) to determine flushing characteristics and predict distribution and concentration of effluent. The 1968 survey was carried out in order to determine the new flow patterns in the area, resulting from the construction of a

causeway in Pictou Harbour and the elimination of tidal exchange in Boat Harbour.

With the industrial development in the Strait of Canso area there is a need for basic oceanographic information there as well. Limited studies were initiated in 1968 as background to an anticipated detailed study to be undertaken in 1969.

Some of the projects referred to above are discussed in more detail elsewhere in this report.

R. W. Trites

Physical Oceanographic Studies in St. Margaret's Bay

Studies were initiated in St. Margaret's Bay in 1966 and continued in 1967-68 in order to provide physical environmental information needed for the study of the basic processes underlying marine production.

In 1966, the program was designed to yield preliminary information about the rate of exchange at the mouth of the Bay. Seven current meters were moored for about 1 month at five stations across the mouth of the Bay. Current speeds at these stations rarely exceeded one knot, and most frequently lay between 0.4-0.6 knots. From frequency diagrams, it is apparent that direction of flow, although frequently showing peaks directed more or less into and out of the Bay, is rather variable. Only near bottom in the deeper part of the channel is the flow nearly rectilinear.

A harmonic analysis was carried out in order to evaluate the tidal constituents and to permit the residual currents to be extracted from the observations. The residual current pattern, when averaged over 15-day periods, indicates a flow out of the Bay on the western side and into the Bay on the eastern side and in the deeper part of the channel. An examination of daily residual pattern shows a marked change from day to day although the most frequent pattern is similar to the 15-day averages. However, the residual flow is found at times to be seaward throughout the section during one day and shoreward the next. The strength of the outflowing residual current reaches nearly 0.5 knots on occasion. From these limited observations, it appears plausible that under certain conditions major flushing could occur in a matter of days.

In April 1967, twice-monthly surveys of temperature and salinity were initiated in order to gain information on the spatial distribution and seasonal variations of properties. Drift bottles and seabed drifters were added to the survey in May. The network consisted of 27 stations which were occupied until June 1968. The network was then reduced to eight stations which have been occupied at approximately weekly intervals during the summer and autumn. From May to September 1967, current meters and temperature recorders, were installed at a number of sites in the Bay and across the mouth. Owing to difficulties experienced in finding a suitable location to measure meteorological parameters that might be representative of a good portion of the Bay, the former hydrographic launch *Merganser* was fitted with instruments to measure wind speed and direction, air temperature, water temperature and solar insolation, and moored in the Bay. However, the measurements were discontinued abruptly in the autumn during a storm when the launch broke her mooring and was driven ashore and destroyed.

The 1968 current measurement program commenced in April and continued until November. Emphasis was placed on maintaining moorings at two stations near the mouth. In June, two moorings were placed well off the mouth of the Bay in order to provide some information on the variability and general features of the offshore waters.

A considerable number of parachute drogues were tracked during 1967 and also rhodamine dye was released on numerous occassions to ascertain both bulk motion and a rough measure of diffusion. Drogue motions were measured mainly at 10 m and 30 m depth. In most instances daily resultant drogue motion was less than 1 mile. The dye patches were usually retained in the near-surface waters and hence generally moved over much greater distances than did the drogues at 10 m depth. At times dye patches had not increased to more than a few hundred feet in several hours whereas at other times the patch increased in size to nearly a mile in diameter in less than 12 hr. Dye concentrations were frequently diluted to less than 1 part in 10^{10} in 12 hr. In 1968, radio beacons were attached to the drogues and positioned from shore based DF stations. Unfortunately, owing to malfunctioning of one of the DF stations, the start of the program

was delayed until autumn. This, combined with insufficient ship time, permitted only limited experiments to be carried out. The method appears promising, but considerable care and effort is required to calibrate the stations properly.

The drift bottle recovery pattern revealed a very close correlation with the prevailing wind direction. During the summer and autumn period, more than 50% of the bottle return occurred within 5 days of their release. Only a very small number of sea-bed drifters have been recovered to date and thus it has not been possible to draw any significant conclusions about the flushing of bottom water within the Bay.

From preliminary examination of the data, it is evident that fairly rapid exchanges take place at times in the upper layers. For example, major flushing action occurred on at least three occasions, between June and September 1967. On two of these occasions, the surface layer thickened from a few meters to nearly 30 m. On the third occasion, the normal surface layer decreased in thickness and was replaced by water 8° to 10C° colder in a matter of a few days. There was good agreement between the thermal data and drift bottle experiments.

A considerable backlog of current measurement data is yet to be analyzed and studied. In 1969 it is planned to place increased emphasis on drogue studies in the approach area of the Bay.

R. W. Trites

Physical Oceanography of Margaree Estuary

The physical oceanographic studies of the Margaree Estuary and approaches which were initiated in 1965 and continued in 1966, were completed in 1968. Field observations in 1968 covered a 7-week period from mid-April to the beginning of June. It was hoped that this period would cover the spring runoff but unfortunately due to the early thaw the bulk of the increased river discharge had passed by the time measurements were commenced.

From tidal calculations, it was predicted that a river discharge of 2,400 cfs would contribute a volume of fresh water equal to the intertidal volume to the mouth of the estuary and hence would be the minimum river discharge required to keep the estuary fresh. The discharge values are based on measurements recorded by two waterstage recorders, one on each of the tributaries. A factor is applied to the total gauged discharge to obtain a value for the total river discharge. From first analysis of data a river discharge of 3,700 ± 500 cfs will maintain a continuous outflow in the surface layer and a discharge of 5,100 ± 500 cfs will maintain a continuous outflow from top to bottom. Therefore, the discharge required to keep the estuary fresh is twice the minimum predicted value, within experimental error.

In 1968, two Plessey current meters were established on the bottom near the harbour mouth. It is hoped that when the data from these is processed and analysed, the critical discharge values will be determined more exactly. Two tide gauges were also installed. One had been operated during the previous surveys and the other was established at the head of the salt penetration. The new gauge was established in order to obtain better measurements of the slope within the estuary and to permit computation of the intertidal volume. The hydrography of the estuary was surveyed with a Ferrogragh 500 Offshore Sounder to aid in the computation of intertidal volume.

Analysis of the current and dye surveys is progressing and completion of the study is anticipated within a few months.

D. Krauel

Sea Water Chemistry

In the past, the physico-chemical nature of sea water has largely been neglected; consequently, many assumptions have been made about its nature which are probably not valid. In our work, we are carrying out some systematic studies to learn about the detailed structure of sea water.

The following studies are in progress : (1) molecular diffusion of sea water; and (2) partial molal volumes of salts of weak electrolytes in sea water. In addition, some work on the extent of $CaCO_3$ saturaltion in coastal waters is being carried out.

In the diffusion studies, we are using a porous-frit method to determine the molecular diffusion coefficient of sea salt. At 25°C and 30.5‰, salinity, our value of the coefficient

is 1.57 X 10^{-5}cm2/sec. The diffusion measurements are being continued at other temperatures and salinities.

The partial molal volumes of the following salts are being measured at various temperatures and salinities, using a dilatometric method : K_2CO_3, Na_2CO_3, KH_2PO_4, NaH_2PO_4, $K_2B_4O_7$, $Na_2B_4O_7$, H_3BO_3 and Na_2SiO_3. From the results of this work, it will be possible to calculate the change in the density of sea water due to variations in the concentrations of these salts in sea water.

Aside from physico-chemical studies, we maintain a limited analytical service which is under the direction of Mr Carl Cunningham. This service includes the following: (1) determination of salinities; (2) training of MEL and IODAL staff in the use of the inductive salinometer; and (3) the preparation of standardized reagents.

I. W. Duedall

Geological Investigations of the Gulf of St. Lawrence

The purpose of geological studies in the Gulf of St. Lawrence is to provide background information for ecological studies by the Board's biologists.

In the Gulf, recent depositional conditions together with Pleistocene glaciations and sea level rises have produced complicated patterns of sediment distribution. In this complex situation an investigation of the sources and dispersal of the sediments has contributed to a better understanding of the glacial and post-glacial history of the area. The investigation was based on the mineralogical (heavy and light minerals) and chemical analyses of sands and sand-size fraction of other sediments and on the beach sands and bedrock bordering most of the Gulf.

Mineralogical and chemical studies of sand and sand-size fractions of other sediments from the Gulf and from adjacent shorelines reveal the pattern of Pleistocene glaciation in the area. Detrital material from the Shield occurs in the Northern half of the Gulf and is dispersed south and east to the shorelines of New Brunswick, Prince Edward Island, and Cape Breton. In the Southern Gulf Magdalen Shelf) this material is intermixed with local material derived from the underlying Paleozoic bedrock. Within this area, mineralogical boundaries are indistinct and it is difficult to assess the contribution of the Shield material to the total mineralogical composition. However, small but significant differences in the chemical composition of the sands clearly depict the dispersal patterns of Shield material on the Shelf. These patterns show that the ice carried Shield material when it invaded the Shelf through the preglacial drainage system and spilled over the entire Shelf. During and after the post-glacial transgression both Shield and local material have been reworked and locally redistributed. Under present conditions, some material is still being added from the shorelines adjacent to the Gulf, such as the North Shore and Anticosti, by ice rafting.

Detailed investigations in the central Gulf and in the Laurentian trough have been undertaken on board *CSS Hudson* providing us with bottom samples (∽ *300)* core samples (- 60) up to 65' in length, and echograms (- 1,000 nautical miles). A study of the data indicates that pelite deposit's of varying thickness cover old glacial deposits in many parts of the area. The pelite is supplied in suspension and derives from the drainage area of the St. Lawrence and the reworking of older glacial deposits. Prelimina,ry measurements indicate that the amount of material carried in suspension is very low (<lppm) in the surface waters. Calculations indicate the annual suspended load supplied by the St. Lawrence River is about 4 x 10^6 tons while the dissolved load amounts to about 78 x 10^6 tons each year. Since the amount of material added each year is so small, most of the pelite appears to be derived from the reworking of the old glacial deposits. In addition, some material is added each year from the adjacent shorelines by ice rafting. The glacial deposits now partially buried have been derived from the adjacent land areas and submarine shelves. The granulometric, mineralogical, and chemical composition of these deposits reflect their source area and the pattern of late Pleistocene glaciation in the Gulf.

A continuous seismic profiling study undertaken with the assistance of Mr Maclean of the Marine Geology Section in the Laurentian trough clarified the statigraphy of the unconsolidated sediments. In addition, the study outlined the distribution of the various types of bedrock and their structure in the trough.

D. H. Loring

Occurrence and Significance of Iron, Manganese, and Titanium in Sediments from the Estuary of the St. Lawrence River

In glacial marine sediments from the St. Lawrence estuary iron varies between 1.32 and 5.42%, manganese between 0.043 and 0.28%, and titanium between 0.31 and 0.64%. The regional distribution of these elements is related to sediment texture. Analyses of individual sediment size-grades shows that Fe, Mn, and Ti concentrations increase with decreasing grain size. Variations in elemental ratios between the different grades suggest that not all of the Fe and Mn is located in detrital silicate minerals. Dithionite extraction of selected sediments resulted in preferential dissolution of 3 to 16% of the total iron, presumably that derived from amphorous and crystalline iron oxides and from sorbed material. Hydroxlamine-hydrochloride removed 5-59 % of the total manganese, presumably that derived from exchangeable Mn, easily reducible Mn oxides, and sorbed Mn material. The soluble fraction is highest in freshly deposited pelites from the center of the estuary. Soluble Fe and Mn occur as oxide films on the particles deposited from suspension and the amount held depends on rate of deposition and on the physico-chemical conditions in the waters and in the sediments. In contrast, Ti occurs in detrital minerals and accumulates at the same rate as detrital sedimentary material. It is unaffected by environmental changes. This investigation shows that despite the derivation of the sedimentary material from the Canadian Shield predominantly by non-chemical erosional processes, small but significant chemical modification of iron and manganese-bearing material is taking place in response to present physico-chemical conditions.

Organic Carbon in Marine Sediments of the Gulf of St. Lawrence

Analyses of easily oxidized organic carbon in about 700 marine sediment samples from the river, estuary, and Gulf of St. Lawrence provide a good picture of its distribution in the region in sediments. Sediments from the narrow shelves along the North Shore, the Gaspe peninsula, the west coast of Newfoundland, and on the Magdalen Shelf contain less than 1% organic carbon. Sediments from the Laurentian, Mingan, Esquiman, Chaleur Bay and Shediac troughs contain 2.6% carbon. This distribution pattern appears to result from recent depositional conditions. Carbon contents generally increase with decreasing grain size of the sediments, the highest values being found in the rimmed depressions on the floors of the troughs where current's action is at its minimum and deposition of material from suspension is at its highest. Preliminary analyses of the suspended matter in surface waters from offshore areas suggest that most of it is organic in nature rather than inorganic. In addition, it was found that the older glacial deposits exposed in favorable locations contain only 1-2% organic carbon.

D. H. Loring

An Acoustic Echo-Counting (AEC) System for Fish Populations

In fish population studies there is a requirement for estimates of abundance of stocks and for detailed information on the distribution of fish aggregations within the size of area swept by individual fishing operations. Such information is provided inadequately and only with great expenditures of time from commercial or research vessel catch records. Modern acoustic systems, in conjunction with experimental fishing, may however be adapted to give the needed information and considerable effort at MEL has been devoted to the design and testing of appropriate equipment.

The initial development phase of this project is progressing favorably. A prototype has been assembled which will count the echoes from each transmission in a vertical column from the bottom of the sea to approximately 20 m above the bottom. This column can be subdivided to give vertical as well as horizontal fish population distributions.

The AEC system has been described in some detail in a paper presented to the Conference on Fish Behaviour in Bergen in 1967. It consists of a number of major parts: the transmitter, receiver, transducer and control unit; the digital data acquisition system; and the towed body handling gear.

The transmitter used is a modified 3 KW Simrad pulse amplifier. A narow beam magnetostrictive transducer is mounted in a 4 ft V-fin towed by a cable with "haired fairing". The receiver is the modified first stage of a Simrad echo sounder and a broad band

amplifier with output coupled to a control unit. This control unit has been constructed using digital computer module cards. The function of the unit is to set the threshold of the echo sizes to be counted, to digitize the echoes, to supply the time delays necessa`ry for using the direct bottom echoes as a reference for the bottom lock feature and for subdividing the isonified column, and to set the counters.

The digital data acquisition system automatically scans up to 12 digital input channels and 4 manual entry channels. These channels are then recorded on either punched paper tape or digital magnetic tape, and/or on a high speed 20-column per second printer.

The handling gear for the towed V-fin is a modified hydraulic telescoping crane of the type commonly seen on trucks in lumber yards. With the boom extended it has a reach of 20 ft and when not in use can be folded to save deck space on the ship. An electric motor and hydraulic pump have been mounted on its base, and the drum for the faired towing cable has been fitted on the main boom. This drum is driven by a hydraulic motor supplied by the same pump used to operate the crane.

The handling gear has been used over the stern of two trawlers to stream, tow, and recover the body under a variety of sea states with great success. With this configuration it is necessary to bring the body out of the water to recover the net. In our next trial the handling will be over the side so the towed body can remain streamed when recovering the net.

Future development of the AEC system will be based on analysis of data obtained from field trials. During this report period, trials were carried out on the Scotian Shelf and in the Gulf of St. Lawrence. The object of these trials was to test the equipment and obtain information on population densities and distribution. The trials consisted of simultaneous echo counting and fishing, and of high speed echo counting surveys. Mathematical consultants at the University of Toronto are analyzing this data and their findings are being used to modify the equipment and develop survey techniques.

S. Paulowich
R. G. Dowd

Instrumentation for Marine Ecology Research

There is a great need in marine ecology for the development of instrument's and measuring systems to enable new projects to be undertaken and to aid existing programs. The following illustrates progress made in developing equipment to assist in solving some of the problems being investigated by this Laboratory:

Bioluminescence measurements

Light measuring apparatus was assembled to measure the bioluminescence of living material in sea water as a means of estimating the biomass.

The apparatus consists of a modified scintillation counter with the scintillation crystal removed from the photomultiplier tube. A special amplifier was designed to amplify the output of the photomultiplier tube and drive a strip recorder. The phototube and special amplifier have a linear response to light quanta.

The amount of light emitted by bioluminescent material is proportional to ATP (Adenosine triphosphate) concentration. The equipment can therefore be used to determine ATP concentration by measuring light emission as the area under the curve on the strip paper record.

Radio buoys

The group was asked to look into the Institute's need for a self-contained radio buoy to be used as a beacon for direction finders. The buoys are to be used at moored stations and attached to parachute drogues. A working range of 50 miles in the 2-3 MHZ frequency band is required.

The characteristics of a number of buoys were studied and three types were tested in the laboratory, and on sea trials with parachute drogues.

A small buoy manufactured by Furuno Electric was recommended and a number of these have been purchased. The buoy, being small in size (about 55 lb. with batteries), produces little drag but has good stability. This unit can be submersed to a depth of 200 m without damage.

Integrating light meter

To assist in the studies of primary production, a self-contained light meter was designed and constructed that can be lowered to the depths required and record the sun's radiation over a 4-hr period.

This unit consists of a small pressure case, a thermopile sensor, an integrated amplifier with a solid state light chopper, and an electro-chemical recorder (see report by Platt).

Underwater television

Field trials were carried out in St. Margaret's Bay to evaluate the use of underwater TV in Biological studies. A Vidicon camera was used and found to be easy to operate and adjust but suffered from a number of inherent disadvantages. One particular disadvantage is the slow speed of response under low light conditions, making it difficult to resolve moving objects.

Contact has been maintained with television manufacturers and new types of camera tubes such as the Plumbicon, which is reputed to have all the advantages of the Vidicon but none of its fundamental disadvantages, and is suitable for applications previously reserved for the more complicated image orthicon, will be tested as soon as they can be obtained.

Deep scattering layer cruise

This was a joint cruise with MEL on the *MV Brandal* doing the mid-water trawling at a mean depth of 1,000 m, and DREA on *CNAV Fort Francis* doing the acoustics to locate the layers of interest.

The Instrumentation Group supplied communication equipment for *MV Brandal,* acted as liason between the ships, and tried out a number of methods for monitoring the depth of the net when trawling and for compiling a family of curves of depth versus speed versus warp length.

Pulse height analysis

The measurement of the particle size distribution of a large number of samples that have a wide size range is a long and tedious procedure. An attempt is being made to match a suitable pulse height analyser with a Coulter Counter to realize the full dynamic range of the aperture with a given current setting.

Towed thermistor cable

To determine the temperature as a function of depth continually over the bulk of the ocean, a towed thermistor chain was considered.

The following specifications for a towed cable were drawn up: the cable to have a center steel stress core with top and bottom stress termination for towing a depressor; 10-12 pairs of cables to be placed around the center core and all enclosed in a molded neoprene jacket ; breakouts suitable for plugging in thermistors to be incorporated. There appeared to be no great problem in having such a cable manufactured at a cost of about $2,000 for 100-m depth cable less thermistors. These thermistors will require potting in a suitable plug.

The cable manufacturer would prefer the buyer to specify the location of the breakouts as the configuration of a towed cable is rather complex especially if close depth tolerance is required,

Fish activity

To assist in the fish physiology studies, it is necessary to measure and record the activity of the fish held in tanks.

An Ultrasonic system for measuring fish activity of fish held in annular tanks has been designed and negotiations with a commercial concern are underway to purchase components for its fabrication. The problem of measuring the activity in a free-swimming tank is also under consideration.

S. Paulowich
W. B. Fraser

In situ salinity (conductivity), temperature, and pressure measurements

A primary requirement in physical oceanography is for an instrument to determine the temperature and salinity as a function of depth which will operate to a depth of at least 1,000 m with accuracies comparable to laboratory measurements. Also, the time constant of the sensors must be short to allow rapid lowering and raising.

The Institute has tow instruments for measuring temperature and electrical conductivity of sea water as a function of depth. The first is the German designed bathysonde, the outputs of which are frequency analogs proportional to the parameters being measured; the other is a unit designed by Dr T. M. Dauphinee of the National Research Council. The outputs of the latter unit are DC voltages. At present the outputs of both these instruments are recorded on XY recorders.

With co-operation from the Metrology Section, and using mostly their hardware, a curve follower was built to read the STP record from the XY recorder paper and put it on punched paper for computer input.

To further expedite the data handling from these STP units, a Data Logging System was designed. This system will be capable of working with either the frequency outputs of bathysonde or DC voltage outputs of the NRC unit and recording these on digital magnetic tape for direct computer input. A printed output is also available and could be used during calibration and trouble shooting. The XY recorder can still be used if an immediate graphical picture is required. Quotations have been received for this system and an order is being processed for purchasing it.

To assist in calibration and maintenance of the STP units an electronic linear interpolation device was designed and constructed to given intermediate points obtained from calibration tables. In addition, a computer program was written to assist in calibration and give salinity values from the conductivity tempera-, ture pressure readings.

An electric winch with slip rings to handle the NRC STP probe was purchased and fitted on the *CNAV Sackville*. A number of unique interlocking bidirectional controls were fitted on the winch to minimize the possibility of damage to the probe in rough weather or by inexperienced operators.

Preliminary work on the design of a self-contained recording STP unit for use in moored stations has been carried out. The unit will use a binary balance bridge to digitize the data and record these on magnetic tape. Initially, it is planned to test and use this unit by raising and lowering it on a cable.

S. Paulowich
J. P. Budlong