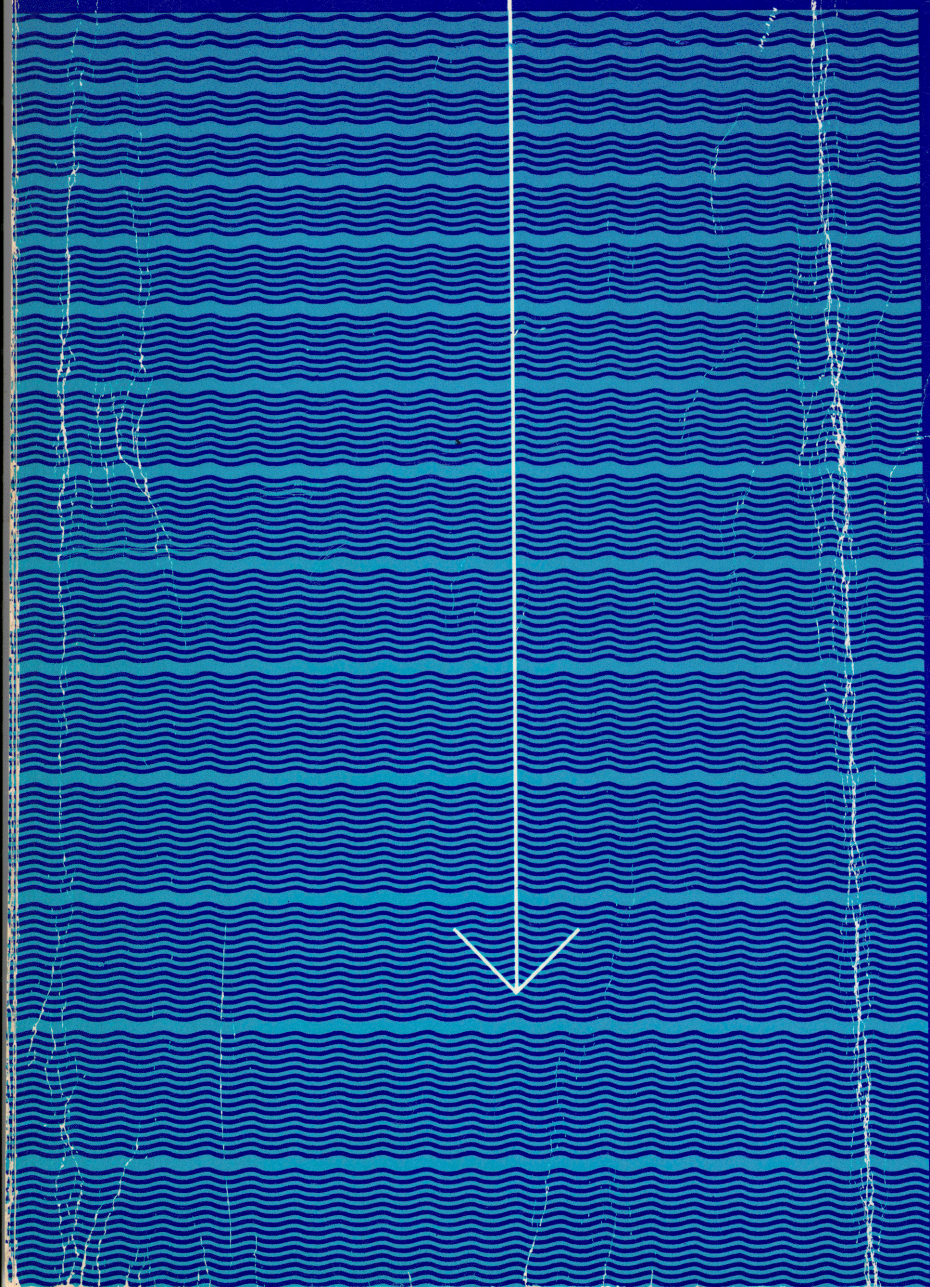
Bedford Institute

Biennial Review 1969/70



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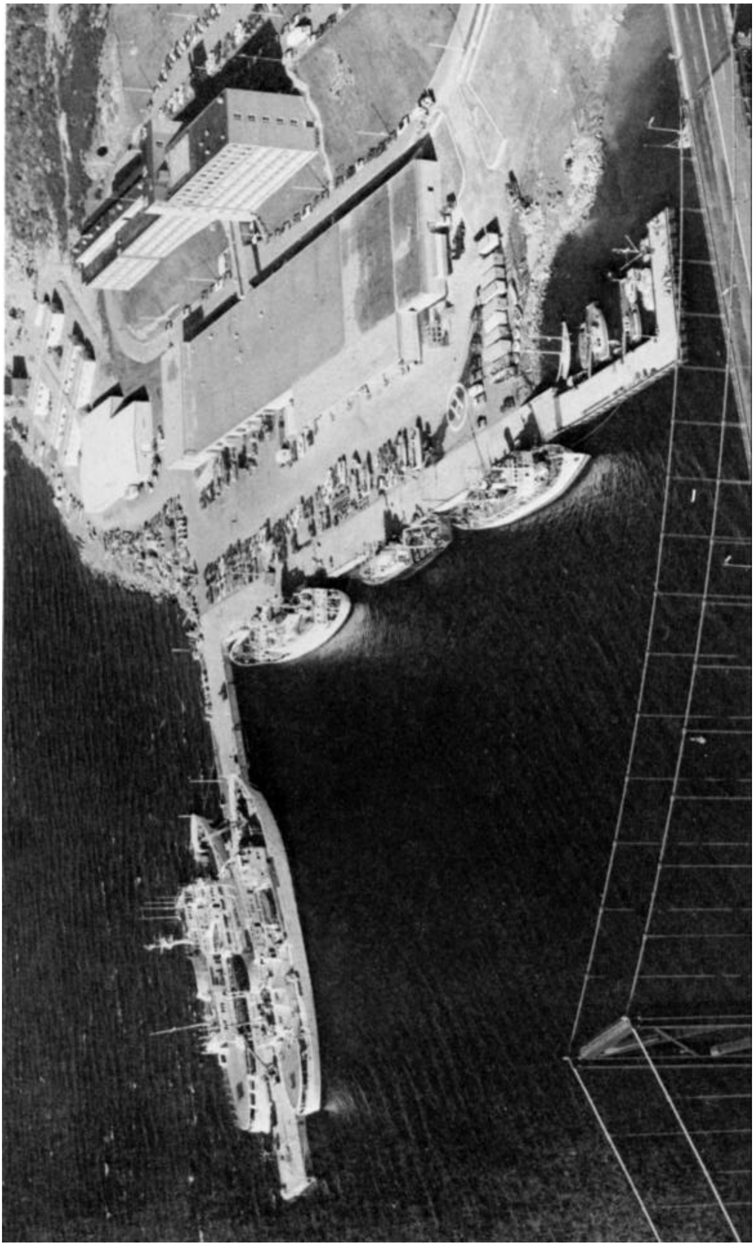

Bedford Institute.

Biennial Review 1969/70
Bedford Institute
Dartmouth, Nova Scotia

Ocean Science Reviews 1969/70

A

Atlantic Oceanographic Laboratory

Marine Sciences Branch

Department of Energy, Mines and Resources'

B

Marine Ecology Laboratory

Fisheries Research Board of Canada

C

***As of June 11, 1971, Department of Environment (see forward),**

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Foreword

This Biennial Review continues our established practice of issuing a single document to report upon the work of the Bedford Institute as a whole.

A new feature introduced in this edition is a section containing four essays:

The HUDSON 70 Expedition by C.R. Mann
Earth Sciences Studies in Arctic Marine Waters, 1970 by B.R. Pelletier
Analysis of Marine Ecosystems by K.H. Mann
Operation Oil by C.S. Mason and Wm. L. Ford

They serve as an overview of the focal interests of the past two years in contrast to the body of the Review, which is basically a series of individual progress reports.

The search for petroleum on the continental shelves of Eastern Canada and Arctic intensified considerably with several drilling rigs and many geophysical exploration teams in the field. To provide a regional depository for the mandatory core samples required from all drilling, the first stage of a core storage and archival laboratory was completed in 1970. This new addition to the Institute is operated by the Resource Administration Division of the Department of Energy, Mines & Resources. In a related move the Geological Survey of Canada undertook to establish at the Institute a new team whose primary function will be the stratigraphic mapping of the continental shelf. The initial staffing of these two units totals 16 persons.

The current awareness of the need to protect our environment by combating pollution has generated a need for more research into the quality of the environment. Although this need arose at a time of general financial stringency, the Fisheries Research Board, by readjustment of priorities and reallocation of resources, was able to approve a new environmental quality program for the Marine Ecology Laboratory. This has involved an increase of 16 in the permanent staff, a complex of 10 new large laboratory trailers, and a doubling of the facilities at the Institute for holding fish and other marine organisms in temperature controlled running water. These new Marine Ecology Laboratory facilities also house a small component of 9 scientists from the Resource Development Branch of the Department of Fisheries and Forestry, who are associated with the pollution studies.

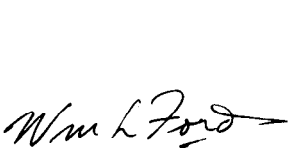
The Institute was host to several thousand visitors - scientific, business, government and general public. It was our privilege to welcome many distinguished visitors including: The Honourable J.J. Greene, Minister of Energy, Mines and Resources who officiated at both the departure and return home of CSS HUDSON on her expedition around the Americas; Mr. Adolph W. Schmidt, Ambassador of the United States of America; His Excellency Boris Miroshnichenko, Ambassador of the Union of Soviet Socialist Republics; Monsieur R. C. Chauvin, Director, Centre Océanolgie de Bretagne, Brest; Rear Admiral G.S. Ritchie, Hydrographer of the Royal Navy; Dr. G. Grasshof, Institute für Meerskunde, Kiel; Dr. Erhhi Polosuv, Institute of Marine Research, Helsinki; Dr. Allan Be, Lamont-Doherty Geological Observatory, New York; Dr. Bostwick H. Ketchum, Associate Director, Woods Hole Oceanographic Institution; Dr. C.C. Bates, Chief Scientist, United States Coast Guard; Dr. Panteleev, Chief Scientist and party on the occasion of the visit to Halifax of the RV AKADEMIK VERNADSKY, March 1970; members of two committees of the House of Commons, the Standing Committee on External Affairs and National Defence, October, 1969 and the Parliamentary Committee on National Resources and Public Works, April, 1970.

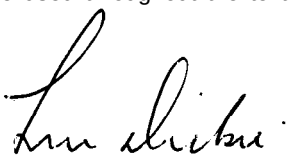
Organizationally the Institute is a loose grouping of laboratories having, as their common focus, scientific research and surveys in the marine environment and sharing such common use facilities as buildings, ships, computers, and scientific information and library services. It has engendered a healthy degree of cooperation and coordination. We anticipate that new opportunities to further strengthen this concept of an inter-agency marine research community will arise out of the creation of a Department of the Environment, legislation for which was under consideration in the House of Commons at the end of 1970.

The proposed legislation became law in due course and was promulgated June 11, 1971. The new Department is a consolidation of a number of elements of the federal service concerned with the management of the air, water, fish, wildlife, and forest resources of the nation. Among the numerous changes brought about by the reorganization is the transfer of the Marine Sciences Branch, and hence the Atlantic Oceanographic Laboratory from the Department of Energy, Mines and Resources to the new Department. However, the Marine Geology and Geophysics sections of Atlantic Oceanographic Laboratory were retained in Energy, Mines and Resources but as part of the Institute. The new designation for AOL is:

Atlantic Oceanographic Laboratory
Marine Sciences Branch
Water Management Service
Department of the Environment.

While the Fisheries Research Board is included in the new Department, its identity as a Board is retained; hence no new designation of the Marine Ecology Laboratory is required. Since the Review deals with a period that precedes the formal establishment of the new Department, the organizational affiliations then in being are used throughout the text.





Wm. L. Ford, Director,
Atlantic Oceanographic Laboratory,
Marine Sciences Branch,
Department of Energy, Mines and
Resources

L.M. Dickie, Director,
Marine Ecology Laboratory,
Fisheries Research Board
of Canada

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Table of Contents

HOME

A

Ocean Science Reviews 1969/70

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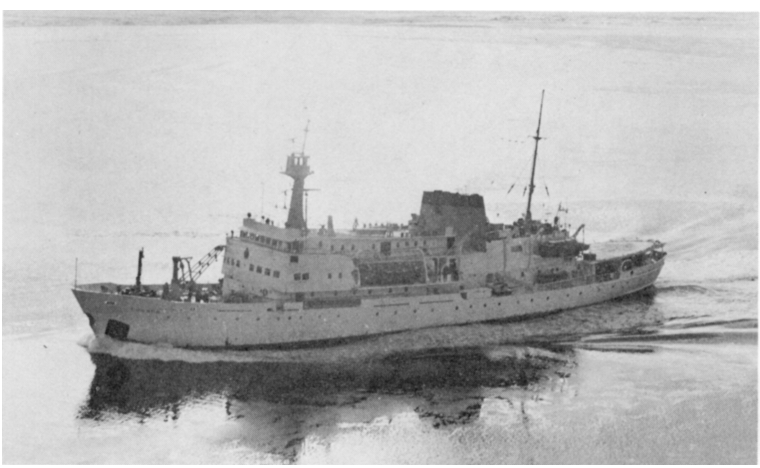
The Hudson 70 Expedition

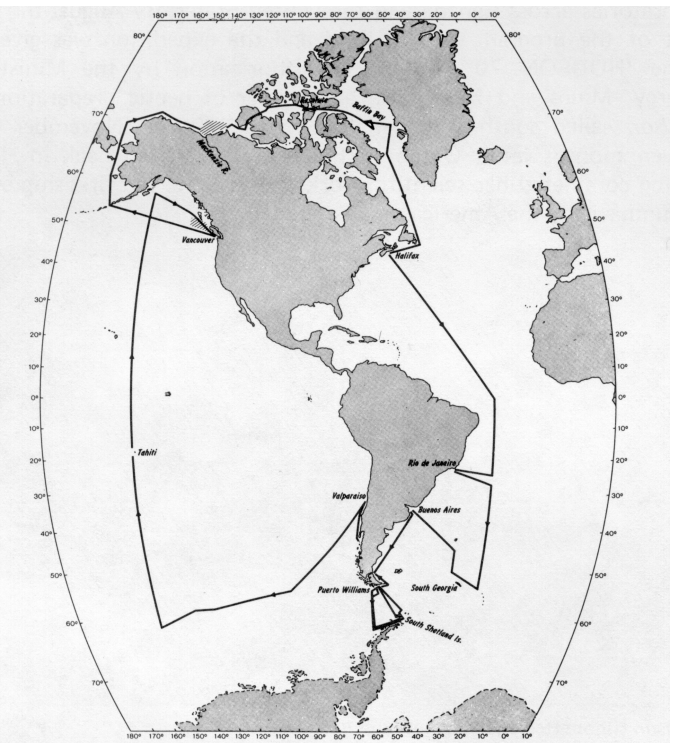
One of the major projects undertaken by the Bedford Institute in 1969 and 1970 was an oceanographic expedition around North and South America on the CSS *Hudson.* The aims of the expedition were to make a significant contribution to the exploration of the world's oceans at the beginning of the international Oceanographic Decade and to continue the exploration of the Canadian continental shelf. A preliminary scientific program was drawn up in January 1968 which was then reviewed and revised during the following summer as requests to take part in the expedition were received from many scientists from laboratories across Canada and the United States. By August the major part of the program was finalized and the expedition was given the name 'HUDSON 70.' Following authorization by the Minister of Energy, Mines and Resources, and a year of hectic preparation, the *Hudson* sailed south from Halifax on the 19th of November 1969. Eleven months later, October 16, 1970, she arrived back in Halifax having completed her scientific work and become the first ship ever to circumnavigate the Americas.



Hudson silhouetted against a low sun in the Beaufort Sea.

The first leg of the voyage took the *Hudson* down the South Atlantic Ocean to the vicinity of South Georgia with a call at Rio de Janeiro enroute. Acousticians, biologists, chemists, geologists and physical oceanographers made up the scientific party, most of whom sought samples for studies of oceanwide distributions. The long transect of the South Atlantic provided the opportunity to collect on this scale. As the ship proceeded south, plankton hauls were made at different depths from the surface to 1500 metres; the acoustic characteristics of the deep scattering layer were mapped and mid-water trawls made to sample the fish in it; sea water samples were collected for chemical

analysis; and measurements were made of the size and distribution of particulate matter at the sea surface. Experiments were conducted on the feeding habits of plankton and on the process of photosynthesis, and the sounds emitted by whales were recorded whenever they were sighted. Altogether the ship was very busy with every square foot of laboratory space occupied and a full 12 hours required at each station to make all the collections and observations. Christmas day was celebrated in the middle of the south Atlantic with Christmas dinner, and a station.



Hudson's track and main ports of call.

From the vicinity of south Georgia, *Hudson* sailed to Buenos Aires, then south to work between South America and Antarctica. Four buoys, each carrying three current meters and three temperature recorders were laid across the Drake Passage and recovered after 11 days. Recovery of the current meters, all of which worked except one, was a major achievement as the recorders contribute the first comprehensive set of direct current measurements across this important passage. A set of mud samples for a study of the emergence of benthic fauna in polar regions was collected in the bays of the South Shetland Islands. Sea water samples for trace element analysis were collected in

the deep waters of Drake Passage. While *Hudson* was laying the current meters and collecting the mud samples a launch party left at Puerto Williams, a Chilean Naval Base, to collect fresh and salt water invertebrates and intertidal algae in the coastal channels of Tierra del Fuego. Of the collection of invertebrates, about one-third are probably new to science. An unexpected discovery was a primitive species of beach flea which has changed little in 100 million years.

Hudson' s deck crew recovering a directional hydrophone in the Atlantic for scientists from the Defence Research Establishment Atlantic: The. hydrophone was used with explosive sources to study scattering from layers of fish at depths up to 1000 metres.

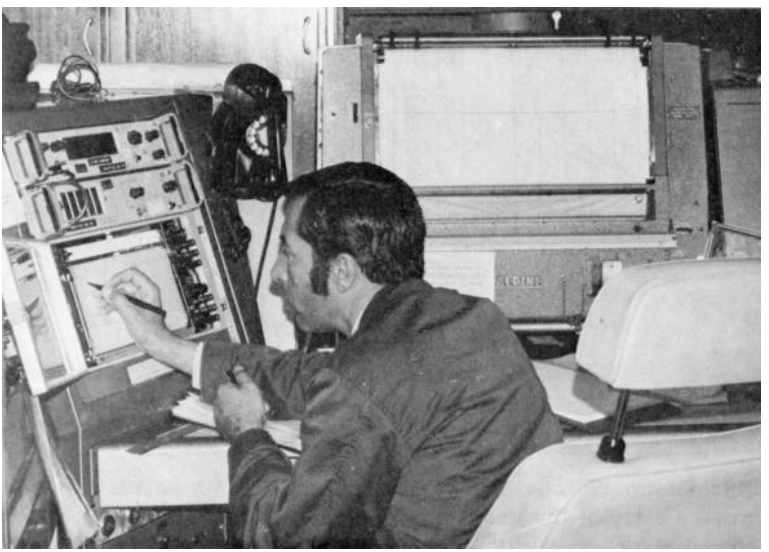
Dr. R.R. Hessler, Scripps Institute of Oceanography, and Dr. E.L. Mills, Institute of Oceanography, Dalhousie University, recovering a benthic sled in the Antarctic. The sled collects a sample of mud for studies of bottom fauna.

From Puerto Williams the *Hudson* sailed to Punta Arenas and then carried a party of Canadian and Chilean scientists to study the physical oceanography, chemistry, and biological life of the Chilean fjords. These fjords whose marine characteristics were unexplored, extend nearly 100 miles along Chile's southern coast. Thirty-three fjords were

visited and it was found they could be classified into three groups: northern, middle and southern. The northern group has clear surface water and high productivity; the middle group has less saline and very silty surface water (due to rock flour from glaciers); and the southern group, opening off the Strait of Magellan, has subsurface water of markedly different characteristics from the others, indicating that it might have its origin in the Atlantic rather than the Pacific. Besides affording the opportunity to study and compare Chilean and west coast Canadian fjords, the expedition provided valuable information that Chilean oceanographers can use to plan further work.

Valparaiso was reached on April 15. Here most of the biologists and chemists who had taken part in the South Atlantic leg of the expedition rejoined the ship to continue their work in the Pacific. Magnetometry and gravimetry were added to the observations, the latter to calculate the slope of the sea surface from Antarctica to Alaska to provide a base measurement for the determination of ocean currents by satellite observations. The track provided the longest continuous gravity line along any meridian. An unexpected deep trench with adjacent peaks was found in the South Pacific; this indicates that the Pacific has not moved as a single block and that more trenches may be found in future surveys.

As the ship approached Vancouver, the only serious setback of the voyage occurred due to fatigue in a cover plate of one of the main engines. Repairs to engines reduced the time available for the



Dr. B.D. Loncarevic, Assistant Director, Atlantic Oceanographic Laboratory, standing watch on the geophysics console in the Beaufort Sea. Gravimetry, magnetometry and bathymetry were recorded automatically.

geophysics program off the coast of British Columbia from six to four weeks. Despite the delay, the *Hudson* with the CNAV *Endeavour* carried out most of the planned two-ship geo-physical survey over the continental shelf and slope between Vancouver Island and the Queen Charlottes. The object of the survey, comprised of gravimetry, magnetometry, bathymetry, seismic profiling, heat flow measurements and coring, was to study Continental Drift; the results support the hypothesis that the ocean floor is drifting away from the mainland. In the Explorer Trench a record high heat flow, measured in cooperation with the University of Washington, showed the trench to be an active zone of rifting, explaining some of the earthquake activity on the west coast.

On August 13 the *Hudson* left Victoria to work in the Beaufort Sea, travel through the Northwest Passage to Baffin Bay, and return to Halifax. Four weeks were spent in the Beaufort Sea as part of a two-ship program of geology and hydrography with the Bedford Institute's other major ship, the CSS *Baffin,* which had come west through the Panama Canal and gone into the Beaufort Sea two weeks earlier. The team of geologists and geophysicists on the *Hudson* obtained an extensive sampling of the sediments on the Beaufort Sea shelf, together with reflection profiles and gravity measurements. The discovery of extensive bands of coarse sands 30 to 60 metres below sea

Dr. G. Vilks, Atlantic Oceanographic Laboratory, recovering a plankton net for the micropaleontology program. The plankton collection for this program was made through all four oceans visited.

level, probably representing relic beaches, and of sediment-filled depressions in the earth's crust will contribute greatly to an understanding of the geological history of the Canadian Arctic. Samples of foraminifera and plankton obtained in the water masses of the Beaufort Sea, and through the Prince of Wales Strait into Baffin Bay form the most comprehensive single collection through the archipelago. A major part of the collection will be retained at the National Museum, Ottawa, as the basis of a description of specimen types and as a national reference. The foraminifera collection is of considerable interest because from it, together with information from cores, much can be learned about the past history of the Arctic Ocean.

The Northwest Passage was traversed between September 22 and September 30. Transcending the rounding of Cape Horn, this was the most exciting part of the voyage, particularly as it had been left so late in the season with the risk of being caught in the ice for the winter. The passage was made through the Prince of Wales Strait, with the *Hudson* and the *Baffin* proceeding independently to its northern end where they were met by the ice-breaker, the *John A. MacDonald.* The three ships sailed in convoy through heavy ice in Viscount Melville Sound to Resolute where a jubilant party celebrated the west-to-east journey and the virtual success of the rounding of the Americas.

It seemed a fitting end that the final major experiment of the voyage, to determine whether the crust beneath Baffin Bay was continental or oceanic, should be successful. The United States Coastguard Cutter, the *Edisto,* with a party from the Bedford Institute aboard, joined the *Hudson* in Baffin Bay to act as shot-ship for a seismic refraction profile of the crust beneath the Bay. This was one of the few experiments where an analysis could be completed quickly on board. The profile proved conclusively that Baffin Bay has an oceanic structure and settled one of the important questions about the geology of the eastern Arctic. From Baffin Bay, the *Hudson* sailed for Halifax arriving home on the 16th of October, 1970.

By any measure, this expedition was a success. The *Hudson* sailed 55,000 miles, carried 122 scientific staff during the course of her voyage, and generated an impressive statistic of samples and observations. All of the scientific program was completed and most of the scientists collected many more samples than they had set out to obtain. Much of the credit goes to the crew of the ship, to Captain D. Butler, who completed the circumnavigation, and to Captain F. Mauger, who was captain during the west coast survey. HUDSON 70 was a collaborative venture and its success was due in large part to the efforts and cooperation of the Chief Scientists each of whom organized their own part of the program. They are listed below:

C.R. Mann*	Halifax to Punta Arenas

G.L. Pickardt†	Punta Arenas to Valparaiso
R.C. Melanson*	Valparaiso to Tahiti
W.M. Cameron[a]	Tahiti to Vancouver
C.D. Maunsell*	West Coast Survey
B.R. Pelletier*	Vancouver to Resolute
D.I. Ross*	Resolute to Halifax

C.R. Mann

Plaque of the commemorative medal for HUDSON 70. Medals were presented to all participants.

• Atlantic Oceanographic Laboratory
† University of British Columbia
[a] Director, Marine Sciences Branch, Energy, Mines and Resources.

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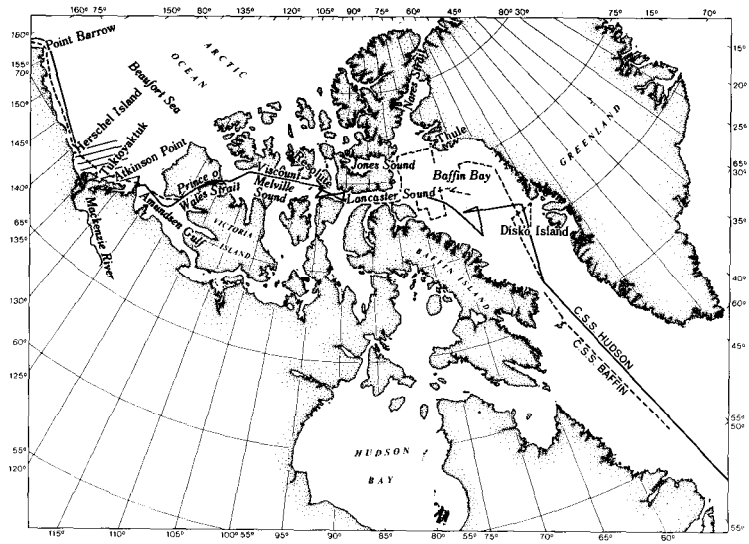
Earth Sciences Studies in Arctic Marine Waters, 1970

During the past decade several multidisciplinary programs in the earth sciences have been carried out in Arctic waters by personnel from the Polar Continental Shelf Project (Earth Physics Branch, formerly the Dominion Observatories), the Geological Survey of Canada, the Fisheries Research Board of Canada, and the federal Atlantic Oceanographic Laboratory of the Bedford Institute, Dartmouth, Nova Scotia. Parties employing dog teams, motor toboggans, helicopters and fixed wing aircraft worked their programs over the ice of the western Arctic, while others in the eastern Arctic worked chiefly from the Canadian Coast Guard icebreakers. In 1968 another dimension was added to Arctic investigations when the research submersible *Pisces I* was used for the first time. In the past two years private companies have carried out geophysical surveying, chiefly seismic and magnetic.

An extensive Arctic marine survey was made in 1970 when vessels of the Department of Transport and the Department of Energy, Mines and Resources - using base facilities of the Polar Continental Shelf Project at Tuktoyaktuk, North West Territories - combined to carry out scientific surveys, experiments and hydrographic charting in both the western and eastern Arctic as well as through the central route of the Northwest Passage. In all, eight vessels and as many helicopters, together with several land-based facilities, were employed. On this program, the *CSS Hudson* completed the Arctic passage of her historic cruise around the Americas (see HUDSON 70 essay).



Tracks of the CSS *Hudson* and the CSS *Baffin* through the Canadian Arctic.

The *Hudson* arrived off Herschel Island (Beaufort Sea) on August 26 and joined the *CSS Parizeau* and the CSL *Richardson* from the west coast (Victoria), and the CSS *Baffin* from the east coast, already working in the Beaufort Sea since mid-summer. In late September when the Beaufort Sea survey ended, the *Parizeau* returned to Victoria, via the Bering Strait, and the *Richardson* remained at Tuktoyaktuk while

CSS Baffin seen from the CSS *Hudson,* Viscount Melville Sound.

the *Baffin* and the *Hudson* steamed easterly to commence their twin attempt of the Northwest Passage. These vessels traversed Amundsen Gulf and then steamed through Prince of Wales Strait where they made moderate speed in new winter ice of 10/10 coverage. They were met in Viscount Melville Sound, at the north end of Prince of Wales Strait, by the icebreaker CCGS *John A. MacDonald,* which escorted them through heavy ice to Resolute Bay. Here a plaque was installed in Silurian-Ordovician limestone, approximately 400 million years old, to commemorate the voyage of HUDSON 70.

On September 30, after an exchange of personnel at Resolute Bay, the *Baffin* made her way to Thule, Greenland, and then south into Baffin Bay to carry out a joint bathymetric-geophysical program with the *Hudson.* Meanwhile the *Hudson* steamed independently from Resolute Bay to take up a line of stations in Lancaster Sound and Baffin Bay, carry out a deep seismic reflection study in Baffin Bay and then resume her geophysical survey with the *Baffin.* Earlier in August the CCGS *Labrador* carried out a geological bottom sampling program in the western portion of Baffin Bay. The CSS *Dawson,* engaged in geological sampling using corers and dredges, spent August and September

carrying out bathymetric, magnetic and heat flow measurements. She also ran continuous seismic reflection profiles in the Bay. Finally, on October 5 the last vessel joined the Arctic earth sciences program; the USCGC *Edisto* made a rendezvous with the *Hudson* in order to carry out a seismic refraction study using conventional explosives in central Baffin Bay. The *Edisto* served as shot-ship and the *Hudson* as listener on this fundamental study of the earth's crust beneath the Bay. After this work the *Baffin* and the *Hudson* continued their joint program of bathymetric, gravimetric and magnetic surveying. In addition, the *Hudson* completed her line of oceanographic stations from the Arctic into the northwest Atlantic.

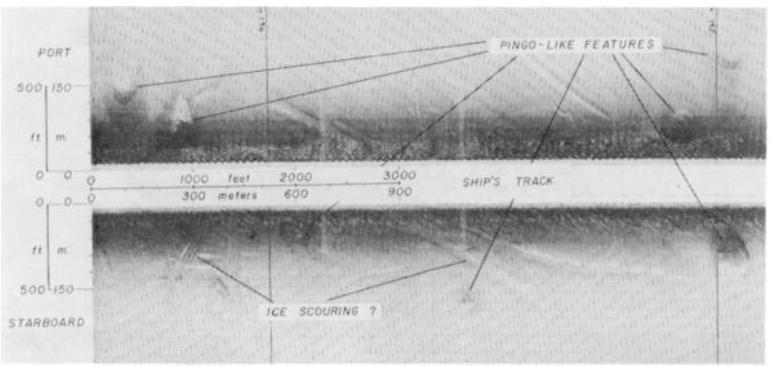
Plaque installed at Resolute Bay.

The work in the Arctic this year was highlighted by several achievements, the most outstanding of which were the following: the successful sailing of both the *Baffin* and the *Hudson* through the Northwest Passage; the first multi-disciplinary survey of the Beaufort Sea and the associated discovery of underwater pingoes and deep ice-scouring in this area; the seismic experiments carried out in Baffin Bay which confirmed the existence of an oceanic crust beneath this sea; and the successful completion of a transect of oceanographic stations studying water properties, plankton foraminifera, and geology, from the Pacific Ocean through the Bering Strait, Arctic Ocean, channels of the Arctic Archipelago, Baffin Bay and terminating in the northwest Atlantic.

The Beaufort Sea Study

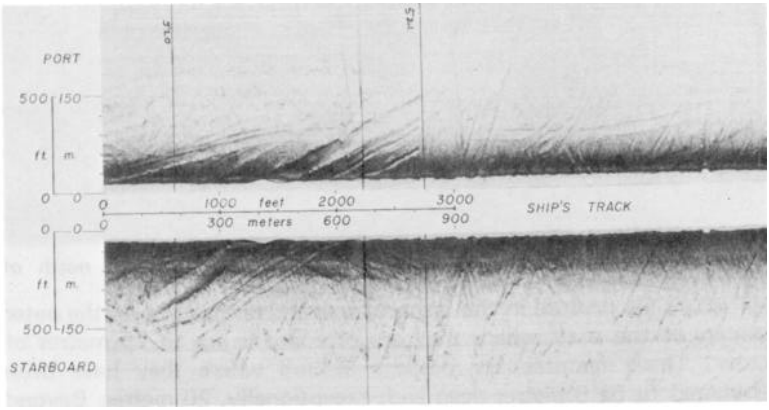
In the Beaufort Sea, an unusually good year for navigation in generally ice-infested waters made it possible for the CSS *Hudson* to carry out geophysical surveys 210 km offshore and to complete both a reconnaissance-type geological sampling program and an underway geophysical survey program that overshot the original plans by 50 percent. In addition to the earth sciences program, standard oceanographic stations were occupied along three main cross-sections and at certain additional locations in support of the biological and micropaleontological work being undertaken.

While the *Hudson* carried out her program, the *Baffin* undertook a hydrographic and magnetic survey, and some geological sampling in the eastern Beaufort Sea, and it was in this area that more than 80 submarine pingoes were located. The *Parizeau* meanwhile carried out a



Side-scan sonar record of sea floor, Beaufort Sea, 100 km north of Tuktoyaktuk Peninsula, showing ice scours and pingoes.

similar program in the western part of the region, where she also discovered numerous pingoes. These features are important to navigation in view of proposed tanker routes that may be established in the future should oil production be a reality in the western Arctic. Also, most of the season the *Richardson* did geological sampling, as well as shallow seismic reflection profiling and side-scan sonar surveying in the inshore area between Tuktoyaktuk and Herschel Island. It was on this survey with the side-scan sonar that deep ice-scour features were discovered on the ocean floor. This has immediate implications to the development of a petroleum field, as new engineering problems are foreseen that will be costly to overcome.

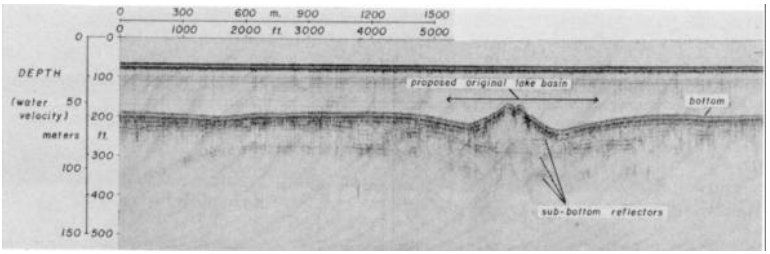


Side-scan sonar record of sea floor beneath Mackenzie Bay, showing ice scours. Water depth about 20 metres.

The station work consisted of bottom sampling by means of dredge, grab and corer and this was complemented by underwater photography and television. Most of the underway work involved measurements with the surface gravimeter and sea magnetometer. About 1600 km of shallow seismic work was completed as well as approximately 1100 km of side-scan sonar surveys. Bathymetric observations were made continuously with positional fixing aided by satellite navigation, Decca, and radar.

The continental shelf appears to be a fairly regular feature sloping gently seaward to the shelf-edge 120 km from shore where it attains a depth of 180 metres. The bathymetric contours trend parallel to the coast except in the vicinity of Mackenzie Bay. There the monotonous relief of the Arctic continental shelf is broken by the Mackenzie Canyon which commences at the marine portion of the Mackenzie Delta and opens seaward just east of Herschel Island in the form of a wide V, dissecting the continental shelf and slope to depths exceeding 1800 metres. This is the most striking submarine feature of the area in terms of size.

Lesser but important physiographic features include the pingoes and ice-scours that abound over most of the inner continental shelf. The former (see figure) are thought to have formed underwater from the expansive force of ice originally locked in sandy aquifers as ground-water which froze against the colder substrate of a marine water mass. Some pingoes are 30 metres in height and rise within 15 metres of sea level, and it is possible that some could occur at shallower depths. They form between 50 and 110 km offshore in the mud belt that parallels the coast. There appears to be an association of the pingoes with the geological formations and the regional physiographic trends, although this has not been established.



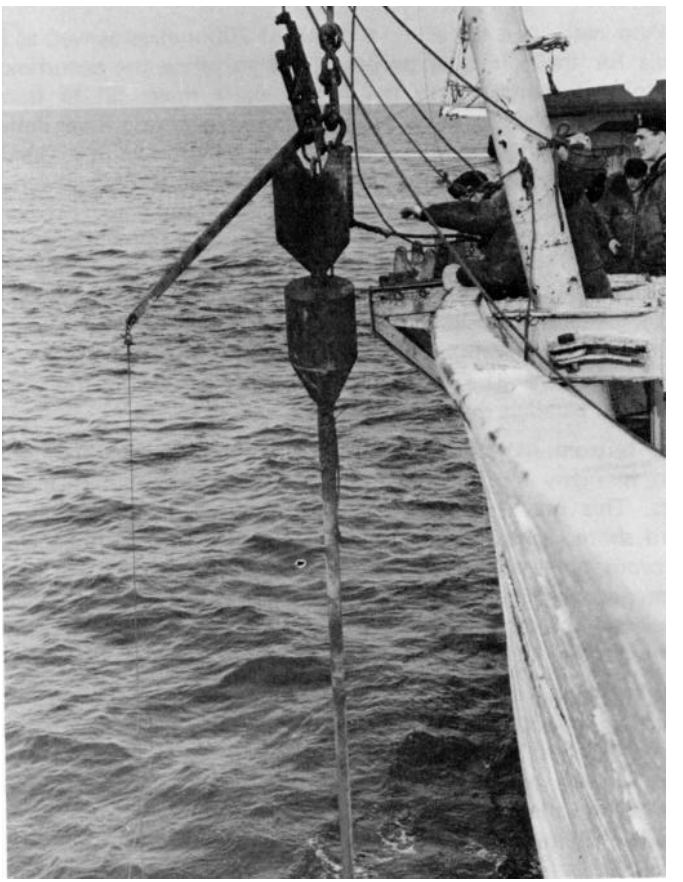
Seismic record of pingoes on floor of Beaufort Sea, 100 km north of Tuktoyaktuk Peninsula.

Ice scours are profuse in the inshore areas and disappear near the outer margin of the shelf where they are recorded in up to 75 metres of water. These features are deepest inshore where they have been estimated to be 5 metres deep and, exceptionally, 20 metres. Beyond the 50-km line from the coast they are 2 to 3 metres deep and occasionally 9 metres. Mostly the scours trend northwesterly but transecting scours show that irregular courses were taken by the ice. Wind apparently drives shelf ice, ice-islands, rafted ice and pressure ridges onto the shallow portions of the continental shelf which is subsequently scoured by this moving ice. In deeper water, where the scouring appears to be older, considerable sedimentation seems to have taken place, and the grooves are less numerous and less sharply defined than those inshore. Of even greater significance is the fact that scours rarely occur in more than 55 metres of water; and that a sedimentary layer occurs beneath the sea floor below which no scouring has taken place. This layer can be traced seaward and is exceptional evidence possibly of a rising sea level that occurred during the past several thousands of years. But most important is the absence of scour before this period suggesting that sea ice was not present and that the Arctic Ocean was truly an open sea.

Evidence of an ancient erosional surface about 90 to 120 metres below the present bottom appears on the acoustical records. Trunk systems once flowed across the present Arctic Continental Shelf beneath the Beaufort Sea and with submergence of the land, the valleys filled with sediment. In some cases such filling amounts to a hundred metres and some of this occurred before the ice age which is thought to have begun approximately three million years ago. The main drainage system was from the Mackenzie River on the west and the Arctic Archipelago on the east. Lesser systems developed along east-west trends paralleling the coast but these are imperfectly delineated by our surveys to date. Generally the sea floor consists of long bands of mud, occurring in topographically low areas, alternating with similar bands of elongated zones of sand. These sandy areas occur on topographic highs and are coarser due to their exposure to the winnowing action of marine currents. Pebbles and coarser sands occur very near shore. In no area

was bedrock exposed, due to the thickness of the sedimentary cover which inshore was greater than 60 metres.

Core recovery was generally good and the resulting samples revealed the presence of a carbonaceous, laminated, muddy layer underlain by coarser sediments. This occurred in the inshore area and is evidence of a rising sea. Offshore, the cores were less carbonaceous and the mud was a typical marine sediment. One core taken 25 km north of Atkinson Point contained lenses of fresh-water ice thus establishing the movement of groundwater through sandy aquifers beneath the sea. Another core from the immediate area contained porous sands saturated with hydrogen carbon compounds. A third interesting core was obtained from a pingo about 100 km offshore. This core contained a vesicular texture which may be attributable to escaping gas.



Piston corer being used from the CSS *Hudson* in Beaufort Sea.

The philosophy behind the planning of this multidisciplinary program was to obtain a spectrum of observations wherein the data from one project, although self-sufficient for its own objectives, could be utilized in support of other projects. For example, as part of the micro-paleontology program Knudsen bottle casts were made to determine temperatures, salinities and dissolved oxygen content at selected stations along three equally spaced lines transecting the Beaufort Shelf. These lines extended from the near-shore area to the ice edge. From the oceanographic observations at these stations the water mass was found to be typical of the Arctic Ocean for that time of year. A two-layer system was present with a positive halocline at about 20 metres, with freshening of the surface waters in the vicinity of ice floes. The oceanographic data then provided valuable environmental information for the biologists and micropaleontologists.

Plankton nets were towed to a depth of 200 metres as well as at the surface for the following purposes: (1) to relate the occurrences of planktonic foraminifera to the Arctic water mass; (2) to trace the extent of coastal water in the vicinity of the Mackenzie River delta; and (3) to follow the net movement of water through the Northwest Passage. The basic criterion for this study is the sensitiveness of planktonic foraminifera to changes in environment; for example, abundance indicates the presence of oceanic water and absence of coastal water. Thus a decrease in the number of these tiny single-celled organisms may indicate the direction in which oceanic waters are passing between the islands. From our studies we found that planktonic foraminifera are present in the Beaufort Sea but are absent in coastal waters. The break occurs approximately at the 50-metre isobath and parallels the coastline.

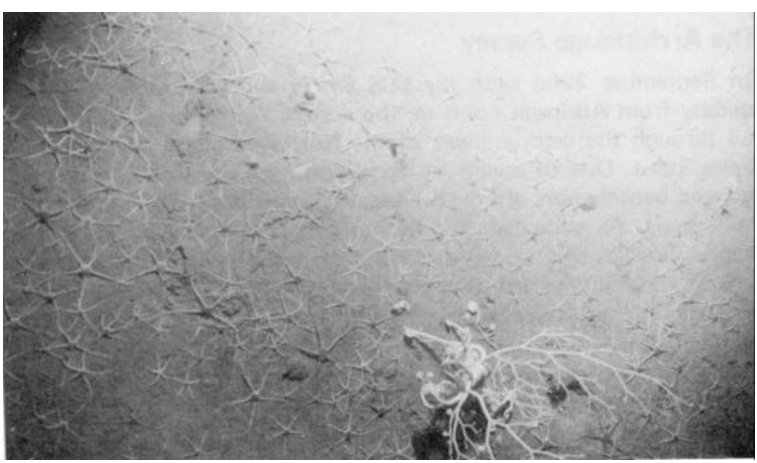
In the bottom sediments planktonic foraminfera are scarce, and are absent in many localities that contain living foraminifera in surface waters. This may indicate a recent transgression of coastal waters toward shore. Seventy-two species were identified and, in general, the arenaceous types are characteristic of the deeper waters, but give way to a preponderance of calcareous species towards shore, This may be an influence of the Mackenzie River discharge of silt-laden waters into the nearshore areas.

Additional faunal studies relating to the mollusca were made on the bottom sediments. Of the 25 species of molluscs (22 pelecypods and 3 gastropods), most were obtained from dredge hauls, with a few of the smaller species being collected in some grab samples. The greatest numbers and varieties were found in the area considerably to the east of Mackenzie Delta where the sand content in the bottom clays was greatest.

Geophysical surveying was carried out on 14 regular traverses which crossed the continental shelf perpendicular to the coast, and which were spaced 25 to 30 km apart. Several tie lines were made, both diagonally to the cross lines as well as parallel to shore. Seismic reflection profiling was carried out on most of these lines and in water depths of less than 180 metres. Some lines extended over a portion of the continental slope.

The seismic records over the shelf break and slope indicate that slumping and/or downslope creep play an important part in shelf progradation. Presumably normal build-up of sediment takes place until a condition of instability is reached and downslope slumping movement with dislocations occurs, which cuts the original foreset and bottomset beds. Generally the structure of the geological formations is gently rolling with a predominant seaward dip toward the Arctic Basin. Along the shelf edge, folding is prominent and many features near the surface appear to reflect very large domal, or intrusive structures at depth.

The dominant feature of the gravity field is a large positive anomaly (maximum amplitude about 80 mgal) which lies subparallel with the shelf edge. Part of the anomaly must be the shelf-edge effect due to the thinning of the crust in the transition zone between the continent and the ocean. This could be indirect evidence that the basin to the north of the Mackenzie Delta shelf is underlain by an oceanic crust. Steep gradients suggest that part of the positive anomaly must be due to a local density excess close to the surface. A qualitative interpretation of the contours suggests that the anomaly could be caused by a prismatic body dipping from east to west. The extension of the anomaly to the



Beaufort Sea floor, 100 km north of Mackenzie Delta in 140 metres of water.

east is not known, and therefore it is not possible to relate this feature to geological structures in the Arctic Archipelago. This positive anomaly is truncated to the west at the Mackenzie Canyon, a situation which is similar to that on the Nova Scotia shelf northeast of Sable Island where the shelf-edge positive anomaly is interrupted by the Gully. In comparison with the Gully, it appears that a much larger and deeper former Mackenzie Canyon has been filled recently by mostly unconsolidated sediments. There are three substantial negative anomalies in the survey area; the largest of the three (maximum amplitude of -56 mgal) is southeast of Herschel Island over the thick sequence of sediments of the Mackenzie Canyon region.

The variability of the gravity anomaly field is similar to that over the Nova Scotia and Grand Banks shelves. In the latter case our area geophysicists suggest that the gravity field was reflecting deepseated ruptures and intrusions formed by the fracturing and faulting which took place during the initiation of continental drift in the area. By analogy, we might speculate that the continental shelf beneath the Beaufort Sea also shows relic signs of the rupturing induced by the process of continental drift. We are not in a position at the present time to speculate on a possible fit of the continents surrounding the Arctic Ocean.

Magnetic data were gathered throughout the survey but were insufficient for the production of a magnetic map. However, magnetograms do show trends that run somewhat obliquely to the regional gravity contours. Over most of the survey area the total magnetic field varied by less than 300 gammas, and was generally smooth and flat.

The Archipelago Survey

On September 22nd both the CSS *Baffin* and *CSS Hudson* steamed easterly from Atkinson Point on the eastern Tuktoyaktuk Peninsula to sail through the central route of the Northwest Passage via Prince of Wales Strait. Due to severe ice conditions, geophysical surveying was reduced considerably although all station work proceeded on the usual daily basis. As expected, the bathymetric data revealed the physiographic profiles of a former drainage system modified by glaciation and subsequently submerged. Since, approximately, 10,000 years ago, the northern islands have been rising continually as evidenced by plant debris in the sedimentary cores, and by the presence of raised marine beaches about 100 metres above sea level. In Amundsen Gulf, a long core revealed evidence of more than one glacial epoch as recorded by interlaying of glacial flour and normal marine sediments. Perhaps 100,000 years of geological history is represented in this core. The sediment cover on the sea floor is thin and gravelly in shallow areas particularly in those localities which are thought to be submerged

watersheds. This is evident in Prince of Wales Strait and again in Barrow Strait.

At the southwestern approaches to the Archipelago, planktonic foraminifera are present in Amundsen Gulf and the southernmost portion of Prince of Wales Strait. In Viscount Melville Sound, planktonic foraminifera are present as far east as longitude 105°W. The water between the islands in Barrow Strait is barren of planktonic foraminifera, but they reappear to the east of Resolute Bay. These results suggest that the net movement of water through the Northwest Passage is as follows: water enters Prince of Wales Strait at the southwest end, and moves slowly toward Viscount Melville Sound. In Viscount Melville Sound and Barrow Strait the general direction of movement is easterly. However, east of Resolute Bay, Baffin water enters and brings planktonic foraminifera with it. Here the Baffin water mixes with the water that flows from the Arctic Ocean and Beaufort Sea through the island channels. Thus the water in Lancaster Sound is a mixture of Baffin Bay water from the east and Arctic Ocean water from the west.

Although ice conditions hampered most of the geophysical surveys, some studies were made around the southwestern Arctic approaches. On lines run from the Beaufort Sea to Prince of Wales Strait, gravity data showed that all free-air anomalies were negative, varying from 0 to -40 mgal and averaging about -20 mgal. A negative gradient exists to the north and a positive one to the east, which might indicate the presence of a tilted sequence of sedimentary rocks of increasing thickness to the northwest. It is also likely that the effects of the mountainous terrain of Banks Island to the north contribute to the decrease in the free-air anomaly in that direction. Free-air gravity anomalies in Prince of Wales Strait are all positive and less than 20 mgal in magnitude. Since most of the surveying in this area was carried out along short lines, very few gravity data were collected. On the lines along which gravity was measured, no major anomalies were observed. The magnetic field varies only slightly and no major magnetic anomalies were recorded in this area.

Many icebreakers in the past have traversed these interisland routes of the Archipelago on their annual voyages of resupply and rescue in the high Arctic. It was on these occasions that our early ideas on the geological structure beneath the eastern marine Arctic evolved. Although we are aware of the recent physiographic development of the island channels and the relationship of this history to concurrent tectonic activity, only recently has evidence of major faulting been ascribed to the configuration of the channels. Lancaster Sound is a graben structure - a block of the earth's crust which has subsided more than 3600 metres on the north side and at least a hundred metres on the south. Some horizontal east-west movement, relatively, seems to

have taken place as well. Jones Sound to the north may have the same history. Both have very steep walls, a feature that was confirmed by direct observation from the submersible *Pices I* in August 1969.

The floors of these channels are covered with mud in the deeper central portion and are coarser in the inshore areas as well as the shallower central areas. These latter areas are thought to be submerged watersheds which may occur only 30 to 60 metres beneath the sea surface. In many areas they lie above sea level where they occur as small islands upon which the water sheds are easily observed. Some islands still contain small ice caps which are remnants of former valley glaciers that once occupied the channels and flowed in a tributary system to the sea at an earlier time when sea level was lower by several hundred feet. All the evidence, particularly that of successively younger raised beaches at progressively lower elevations, suggests that the northern islands are still emerging.

The Baffin Bay Survey

Proceeding easterly from Resolute Bay, both the *Hudson* and the *Baffin* continued their respective programs independently. The *Baffin* steamed to Thule to carry out calibrations on the gravimeter, and then south into the Bay to gather gravimetric, magnetic, and bathymetric data. The *Hudson* continued her geophysical program into Baffin Bay, taking a line of oceanographic stations from Lancaster Sound to the Bay. She was primarily involved in seismic measurements, and obtained additional magnetic, gravimetric and bathymetric data whenever possible. Together with the bottom sampling from the *Labrador,* the geological sampling and geophysical surveying from the *Damon,* and the support from the *Edisto,* an immense fund of information is available for study.

A number of substantial results have already emerged from this work. The bathymetry of Baffin Bay has been fairly well defined, and is characterized by a broad shelf with a width greater than 320 km on the Greenland side and a narrow shelf with a width of 24 km on the Canadian side. The central portion is flat and almost 2500 metres deep. Submerged drainage features and fjords are evident on both shelves. Sediment distribution follows an almost classical pattern of coarse sediments, such as sands and gravels, in the inner portion of the shelf, and very fine sediments in the central deeper portions. Erratic, ice-rafted boulders occur on the shelves where they have been deposited by ice originating mostly from the northern islands adjacent to Nares Strait.

Early magnetic records indicated a very thick sequence of sediments over the whole of the Baffin Bay area. The seismic records show a thickness of 4 to 5 km of sediment. A continuous deep seismic

reflection profile extending from Lancaster Sound to central Baffin Bay shows a sequence of folded sedimentary layers which change abruptly into undistrubed beds to the east along the Canadian continental margin, the latter determined independently from gravity data. Seaward of this margin, the beds are prograding. On the Greenland side, the attitude of the sediments is typically a prograding one, occurring down a topographic slope.

The most significant of the scientific discoveries in Baffin Bay resulted from the successful reverse seismic refraction line along the deep portion of Baffin Bay. This experiment established the fact that Baffin Bay is underlain by oceanic crust with a crustal section about 10 km thick consisting of the following: 2 to 3 km of sediment, 4 km of layer 2 (2 km of vesicular rock and 2 km of mosaic), and 2 km of layer 3. The transition between oceanic and continental material lies landward of the present outer topographical slope in western Baffin Bay, to the west of which sediments are deformed. Thus the Canadian oceanic-continental boundary is well established by both gravimetric and magnetic measurements, and is supported by seismic reflection data. On the Greenland side, evidence of the transition is obscure.

Geophysical evidence based on known seismic velocities of Paleozoic rocks exists to show that the deep basin in the Bay was formed by sea-floor spreading during the Cretaceous period. To estimate an order of magnitude of the time scale involved, sedimentation rates are used which suggest movement commenced about 100 million years ago and ceased 40 million years later. Perhaps as much as 400 km of movement has taken place along Nares Strait.

The seaward extension of the Tertiary basalts cropping out on Disko Island were mapped by means of magnetic field measurements, and the information so obtained was corroborated with selected dredge sampling of basalt on the sea floor.

With reference to possible volcanism in the area, heat flow measurements were made. However, no apparent heat flow anomaly is associated with the central Bay although deep reflection records give an indication of a rugged deep reflector, perhaps a buried ridge, beneath 3 to 4 km of sediments.

Without doubt the year 1970 will be recorded as a landmark in Arctic marine exploration involving the earth sciences, particularly in regard to the broad deployment of a large research and survey fleet, the unique concentration of scientific expertise and its technical support, and the amassed accumulation of new scientific information. The skill in seamanship and navigation of the masters of the Arctic-bound vessels made possible the successful completion of so many difficult voyages: the late Captain W.J. Vieau and Captain M.J.A. Wagner (CSS *Dawson);* Captain P. Tooke (CCGS *Labrador);* Captain V. Dale-Johnson (CSL

Richardson); Captain C. Angus (CSS *Parizeau);* Captain P.M. Brick (CSS *Baffin);* Captain D.W. Butler (CSS *Hudson);* Captain G. Burdock (CCGS *John A. Macdonald);* and Captain W.J. Brasier (USCGS *Edisto).* A film documentary of much of the Arctic Survey in the Beaufort Sea and Northwest Passage is being completed by J.R. Belanger.

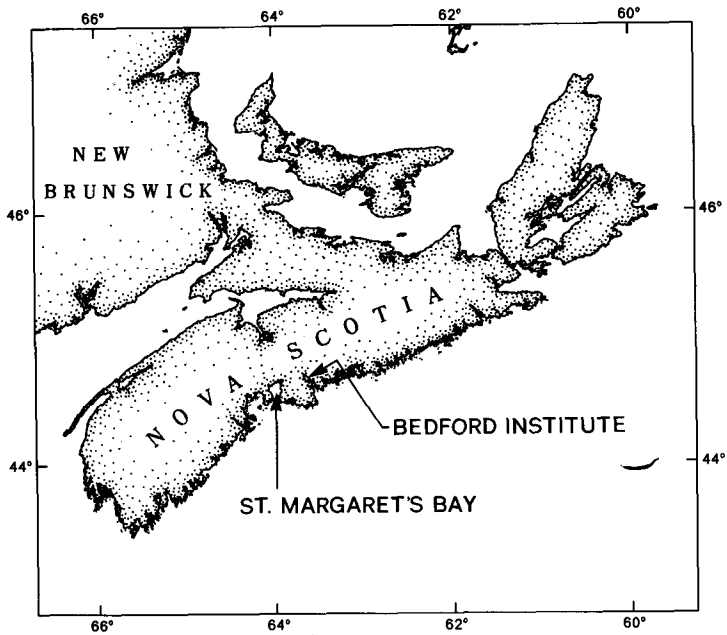
Written contributions were submitted by C.J. Havard, B.D. Loncarevic, R.F. MacNab, C.D. Mann, M.J. Purdy, D.I. Ross, J.M. Shearer, G. Vilks, P. Wadhams, F.J.E. Wagner, J.M. Woodside, and C.J. Yorath.

See also Bedford Institute Contributions 16, 26, 29, 46, 48, 50, 61, 93, 106, 117, 121, 140, 186.

B.R. Pelletier

One of the long range goals of marine ecology is to have sufficient 'understanding' of a situation in nature to be able to make confident quantitative predictions about the consequences of man's interference, whether by harvesting a resource, introducing a pollutant or changing some physical features of the environment. Our 'understanding' of a situation is often expressed in the form of a mathematical model. Several generations of ecologists have modelled species populations but have had very limited success in making good predictions. The reason, as we now begin to realize, is that species populations interact with each other and with the environment in such a complex way that it is impossible to understand the behaviour of one population without considering the whole ecosystem of which it is part.

We must admit at once that we have no usefully predictive models of whole ecosystems, which are so complex that we have to look for ways of simplifying them in order to make them comprehensible. First we have to decide how large a system to study, for the biosphere is a complex of systems within systems. A convenient unit is that system which contains a population of interest to man. An example is a marine bay with a resident population of commercial fish. The Marine Ecology Laboratory has selected St. Margaret's Bay, Nova Scotia, with its resident populations of American plaice and lobsters. Stages in the



Map showing the location of the Bedford Institute and St. Margaret's Bay.

development of a model for this system include a description of its state at a given time and a definition of the boundaries and the fluxes across them. In the case of a marine bay the basic fluxes are of solar energy, of water vapour and gases at the sea surface, of water and dissolved and particulate matter at the mouth of the bay, and of run-off water, with dissolved and particulate matter from the land. The solar energy also generates the winds, which impart kinetic energy to the system in the form of waves and currents.

A technique commonly used to analyze a complex system is to divide it into functionally identifiable parts and study the functioning of each along with the interactions between them. One useful way of dividing living systems is according to trophic function: the primary producers, the herbivores, detritivores, carnivores and finally the decomposers, consuming the dead organic matter and liberating the nutrients for reuse by the plants. The units which are transferred between these compartments are energy-rich organic compounds, so the system may be modelled in terms of either energy or materials.

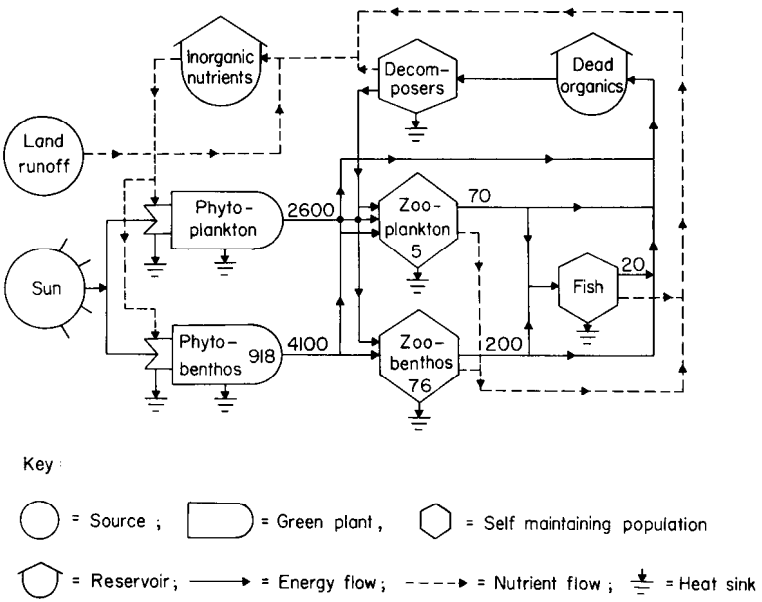
Energy enters the biological system by the fixation of solar energy in photosynthesis, and as it passes from one compartment to another more and more is degraded to heat. Solar energy also exerts controls at various stages of the process by generating currents which transport limiting nutrients, by changing the ambient temperature and so on.

Inorganic materials used as plant nutrients are taken up, released, taken up by other organisms and generally recycled in the system with turnover times ranging from minutes to geological eras. The occurrence of rapid recycling makes it almost impossible to measure the rates of processes in ecosystems from changes in concentration of nutrients, except in a few carefully controlled situations.

Since energy flows in the system always in one direction these complications do not arise and energy flux is a useful general measure of the rates of natural processes. The first figure illustrates a marine ecosystem model with the compartments identified according to trophic habit, using the symbols proposed by Odum (1969). It is easy to see how the amount of energy in each compartment may be measured and averaged over any desired period. It is less easy to determine the fluxes between them.

Considerable insight may be obtained simply by calculating the fluxes for a particular system in a steady state. Numerous practical difficulties are involved, but energy flow diagrams of varying degrees of completeness have now been produced for a variety of ecosystems. They show, for instance, that in some systems energy is transferred to the consumers mainly by a grazing food chain, while in others it is transferred by way of dead organic matter and micro-organisms. They show that some rivers derive almost all their primary production from

terrestrial sources while others have heavy primary production within the river; that the energy of mixing in an estuary is instrumental in the rapid recycling of nutrients so that estuaries are among the most productive of aquatic systems. In St. Margaret's Bay (see figure) the primary production is predominantly the particulate and dissolved matter generated by seaweeds, while in the Strait of Georgia (British Columbia) it has been shown that terrestrial run-off supplies about half the primary input of organic matter.



Compartmental energy flow diagram for the community of St. Margaret's Bay, Nova Scotia. Approximate values for standing stock (kcal/m^2) and energy fluxes (kcal/m^2/yr) are given, where available. Import and export at the mouth of the bay are not represented. Symbols are those proposed by Odum (1969).

These energy flow diagrams serve to summarize analyses of particular situations, defining the organisms present, their numbers, biomasses, interactions and fluxes over a period of, say, one year. They represent an important and difficult first step in constructing a predictive model, but in themselves have no predictive power. One may make educated guesses about the consequences of disturbing the steady state which they represent, but further progress depends on an ability to say how the fluxes will change as a result of changes in conditions. It is rarely possible to carry out a major environmental manipulation in order to test hypotheses about these changes, so small subsystems must be investigated in the laboratory, and the results used to build dynamic

models which may be used to simulate interactions between compartments under a range of environmental conditions.

What are the factors which determine the flow of energy between compartments? Let us consider the simple situation in which one compartment represents a predator population and the other prey. At least six factors may be identified:

(i) The biomass of the donor (prey) compartment. Some models have assumed that the flow from a compartment is proportional to the amount in that compartment, with no other restriction. This is analogous to the flow of electrical energy through a resistance, in proportion to the voltage potential applied. Biologically, it amounts to saying that what is available as food will be eaten by something. This may be true, but it is important to know whether the food is eaten by a fish or a bacterium, and what is the time lag involved. Williams (in press, a) constructed a model on this principle, with linear relationships between biomass and flow, and rejected it in favour of a nonlinear model, since the linear model did not correspond well with reality.

One form of nonlinear relationship is that proposed by Ivlev (1955) for the consumption of food by fish:

$$C=C'(1-e^{-aF})$$

where C is food consumed in a fixed time, C' is the maximum which a predator can ingest, F is the density of the prey population and a is a constant. The amount of food consumed approaches an asymptote at C' as the food density increases. Similar 'saturation' or 'satiation' models have been used to describe the uptake of nutrients by plants, the consumption of phytoplankton by zooplankton, and indeed transfer at all trophic levels in a general model (Smith, 1969).

(ii) The biomass of the receiving compartment (predator). It is reasonable to expect that the larger a predator population becomes, the more food will be consumed. Indeed it is implicit in the application of the non-linear relationship described above that C is food consumed per predator, F is food available per predator. However, Williams (in press, b) experimented with a model in which the flux from prey compartment to predator compartment was proportional to the product of the biomass in each. The implication of such a relationship is that for a fixed amount of prey, the consumption by the predator goes on increasing indefinitely in proportion to the predator biomass. This model, not unexpectedly, was unstable but he controlled it by introducing a self-inhibiting term, with the amount consumed per unit of predator decreasing as the biomass of predator increased. This flux was expressed as $(X_1 \varnothing X_2) \times (1 - aX_2)$ where X_1 and X_2 are the biomasses of prey and predator. Such restraints led to both stability and responsiveness in the model.

(iii) The particle size of the food material. If the biomass in the donor compartment occurs as organisms too large for the predator to tackle, there will be no transfer. Conversely, if the particles are very small, the consumer may find it necessary to expend more energy in collecting them than it obtains from the food. Between these limits there can be large differences in the rate and efficiency of food transfer between predator and prey. Two of the staff of the Marine Ecology Laboratory have explored these relationships (Beamish and Dickie, 1967; Kerr and Martin, 1970). Ardill (1968) documented the relationship between body size and prey size in the American plaice of St. Margaret's Bay.

(iv) The availability of the prey. The prey's ability to hide or escape from the predator, its pattern of spatial distribution, or the timing of its occurrence will markedly influence the rate of energy flux. Such factors are often related to the heterogeneity of the environment. In St. Margaret's Bay, studies have been made on the spatial and temporal distribution of the phytoplankton (Platt, 1970; Platt et *al.,* 1970). Studies are in progress on the spatial distribution of benthic organisms using a diver-operated sampling device and on the distribution patterns of groundfish using sonic counting and a shipboard computer.

Kerr (in press) has modelled the feeding and growth of fishes, taking into account such parameters affecting grazing efficiency as the distance at which the predator perceives the prey and the distance between prey organisms. More comprehensive predator-prey models which take into account the detailed behaviour patterns of predator and prey were pioneered by Holling (1965, 1966) and have recently been applied to fish (Ware, personal communication).

(v) The chemical composition of the food. This may influence the ability of the consumer to take up the stored energy. Animal protein has a carbon: nitrogen (C:N) ratio of about 3.2 to 1, and the C:N ratio of whole animals is commonly between 4:1 and 5:1. Carbohydrates in the diet are used primarily as energy sources while proteins are used for tissue renewal and growth. Carnivores take in food with a C:N ratio close to that of their own bodies, but many herbivores take food with a low protein content, and hence a high C:N ratio. They are faced with the problem of extracting necessary proteins from an excessive amount of carbohydrate, and if the C:N ratio in the diet is greater than about 16.5: 1 they suffer from protein deficiency.

The ruminants, which are the major terrestrial herbivores, harbour micro-organisms in their guts which respire the excess carbon and synthesize essential amino acids. A three-compartment model is needed to represent this situation. In aquatic ecosystems there are two main energy pathways. Phytoplankton cells are grazed by herbivorous zooplankton, but most aquatic macrophytes die and are acted upon by micro-organisms, before they are taken by the animals. The latter situation parallels that found in the guts of ruminants.

In St. Margaret's Bay the phytoplankton had a C:N ratio around 6:1 in spring and summer, but this increased to about 11:1 at the end of winter. Summer phytoplankton is an adequate food for the animals of the zooplankton, but it has been shown elsewhere that as the year progresses the zooplankters supplement their diet by taking considerable quantities of animal food (Marshall, 1924).

Seaweeds in St. Margaret's Bay have a C:N ratio of about 16:1 in summer, rising even higher in the fall; very little of this material is consumed by herbivores. Instead it is colonized by micro-organisms and fed on by bottom-living detritivores. Much of it is also taken up in suspension and consumed by filter feeders. Large quantities appear in the water column more than a mile offshore, after winter storms.

The existence of a two-stage conversion process between aquatic macrophytes and animals greatly complicates the modelling procedures.

(vi) Feedback interactions between the predator and the prey. It is well known to farmers that a grazed pasture may yield more grass in a season than an ungrazed hay field, provided that overgrazing is not allowed to occur. Similar interactions occur between aquatic animals and their food supply. For instance, Hargrave (1970) investigated the grazing effect of a bottom-living amphipod shrimp, and found that increase in shrimp numbers increased production of both plants and bacteria, probably because the shrimps excreted nutrient substances and stirred up the bottom deposits, thus improving the penetration of light, carbon dioxide, oxygen, and nutrients. Above a certain density, the production of food decreased, due to overgrazing, but the optimum predator density was higher for bacteria than for plants. Overgrazing leads to a fall in food biomass often followed by a fall in predator biomass and this leads to cyclical oscillations which are a common feature of predator-prey relationships.

At first sight the obstacles to modelling the interactions of organisms in ecosystems are so great as to appear almost insuperable. However, by looking at whole systems rather than individual species, one discovers evidence of stability of the whole in the face of fluctuations in the parts. In St. Margaret's Bay the population density of each species of phytoplankton changes sharply with the season but the total biomass of phytoplankton, and its productivity, follows a fairly predictable annual cycle (Platt, in press). Similar considerations apply to zooplankton. Moreover, the energy content of the zooplankton shows much less annual fluctuation than either the numbers of dry weight (Platt *et al.* 1969).

Integration over time also leads to greater predictability. When comparing the productivity of phytoplankton at two stations, one inside St. Margaret's Bay and one outside, Platt (in press) found marked fluctuations from day to day at each station, with little correspondence

between them, but the total annual production at the two stations was almost exactly the same.

By grouping, in one compartment of a model, all species feeding directly on phytoplankton we might also expect to find that, in spite of the rise and fall in the productivity of the individual species and the day-to-day variation, the total annual productivity of the consumers bears a relatively constant relationship to the phytoplankton production. Still further along the food chain it is found that the total productivity of fish in an area is much less variable than the productivity of individual species.

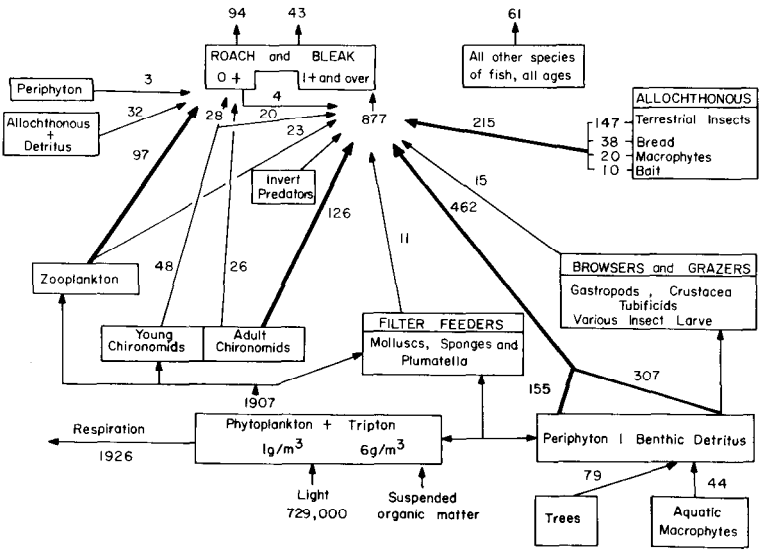
These considerations have led to predictions of a relationship between fish yield and primary productivity based on oversimplified models. Slobodkin (1959, 1962), after operating three-compartment food chains under controlled conditions in the laboratory, postulated that in nature the efficiency of transfer from the input of one compartment to the input of the next (ecological efficiency) is in the range of 5-15%. By taking a mean value of 10%, or a range of values, conclusions have been reached about the productivity of a species in the third or fourth trophic level on the basis of some information about the production of the first. Such procedures are not justified at present because: (a) in most situations we do not have good information on the total input of primary production; (b) a large proportion of organisms cannot be assigned to any one trophic category; and (c) a large proportion of primary production in inland and coastal aquatic systems is channelled to decomposers rather than grazing organisms.

These points are illustrated in the figure, which summarizes about 30 man-years of work on a river ecosystem (Mann *et al.,* 1971).

The productivity of the phytoplankton was measured and found to be very large compared with that of aquatic macrophytes and of overhanging trees. However, the productivity of the periphyton proved very difficult to measure, and there is insufficient information on the fixation of dissolved organic matter by bacteria or on the proportion of imported organic matter utilized by filter feeders. Similar inadequacies exist in our knowledge of the sources of high energy compounds in almost all ecosystems. For most marine situations the only information available is the value for uptake of C^{14} in incubation experiments, and the interpretation of these is still a matter for debate.

At the next trophic level the productivity of the filter feeding benthos was estimated as 110 kcal/m^2/yr, but only 11 kcal could be traced to predators. The fate of much of the benthic production is still in doubt.

As for fish, 70% of their production was realized in the first year of life. The most important energy source for young fish was cladocerans and rotifers, but for the older fish it was organic detritus, followed by terrestrial insects. They also consumed large amounts of benthic



Energy flow diagram for the biological community of the River Thames at Reading, England. All fluxes are in kcal/m^2/yr. The organisms are arranged approximately by trophic levels. At the base of the diagram is shown production by phytoplankton periphyton, trees and macrophytes. There is also an input of suspended organic matter from upstream. All these sources contribute to the tripton and benthic detritus. Invertebrates are shown across the centre of the page; they are mainly herbivores and detritus feeders; the invertebrate carnivores (predators) are leeches and carnivorous insects. The dominant fish species are roach *(Rutilus)* and bleak *(Alburnus),* with other species (perch, *Perca;* gudgeon, *Gobio,* etc.) grouped in the top right-hand corner. To reduce the number of crossed lines, the compartments for periphyton, allochthonous material and detritus are duplicated in the top left corner.

diatoms. Their energy was derived from four trophic levels: (i) plants, (ii) bacteria and fungi feeding on decaying plant material, (iii) detritivores, consuming the bacteria and fungi, and (iv) predatory invertebrates. The allochthonous component in their diet comprises yet another food category. In such a situation it would be ludicrous to relate the fish to one trophic level or attempt to predict fish production from any measurement of photosynthesis. Such a system may be more complex than some open-ocean situations, but estuaries are probably more complex than the river.

Clearly, then, a too-rigid adherence to the concept of trophic levels as a basis for compartmentalizing the system is wrong, but a willingness to subdivide according to one's understanding of the system can lead to workable models.

In considering where effort should be expended to make progress in this difficult field, there is no doubt at all that more and better analytical models of segments of ecosystems should be devised and tested in the laboratory and the field. These will lead to a better understanding of nutrient kinetics, predator-prey relations, competition, species diversity, food conversion efficiency, and so on. However, we delude ourselves if we suppose that by this route we shall soon arrive at detailed models for whole ecosystems which will predict in some detail the consequences of changing some parameters.

The alternative approach is dictated by the need for models with which we can make management decisions soon, and by the potential advantage of dealing with systems which have less variance than their component parts. Smith (1969) has shown by means of a general model that ecosystems have properties distinct from those of their interacting subsystems, and has generated a number of hypotheses which can be tested in nature. Odum (1969). starting from natural systems, has proposed a special energy systems language consisting of a few basic modules each represented by a graphic symbol and a mathematical description of its properties. Using this language, he has shown that nonlinear relationships can often be resolved into two or more linear fluxes interacting by means of a 'work gate' (in much the same way that electrical currents at the base and collector of a transistor can interact in a nonlinear manner). In addition to representing the fluxes of the biological system, he has included in his models the controls exerted by the energy of wind and waves as they recycle limiting nutrients, the feedbacks associated with man's work and the use of fossil fuels, and even the control of such feedbacks by recycling currency in economic transactions.

An important part of this approach (Odum, 1967) is the concept of a relationship between organization and the energy required to produce and maintain it. Many physical processes are seen as destroyers of biological organization, and energy must be diverted to offset this destruction in proportion to the frequency and severity of its occurrence. A system subject to severe stresses of this type will exhibit reduced species diversity. It is abundantly clear that the performance of ecosystems is as much a function of physical energy processes as of biological factors, and for this reason a high proportion of the effort of the Marine Ecology Laboratory in St. Margaret's Bay has been directed to analysis of the physical and chemical oceanography (Sharaf el Din, *et al.,* 1970).

The preparation of energy diagrams is an important step in the construction of workable ecosystems models, and Odum (1969) has claimed that the process of conversion to mathematical expressions which form the basis of a simulation model is relatively simple. Such

general models can only give general predictions, but these are certain to be useful in making management decisions. They can be used to gain insights into the properties of ecosystems without the necessity of waiting for costly environmental manipulations, and validation of the models may be obtained by monitoring the systems under a range of weather patterns, or by following the effects of man-made changes.

Between the extremes of a detailed analytic model of the interactions of a single species with its food and its environment and a simulation model of a whole ecosystem there is a broad spectrum of possibilities. For instance, Menshutkin and coworkers (Menshutkin, 1964; Karpov *et al.,* 1969) have progressed from models of single species fish populations to a model of the community of fishes of Lake Dal'nee, demonstrating the increased stability and decreased variance which results from considering a larger system. It seems likely that by maintaining progress on a number of fronts there will eventually emerge that paradigm which will unite the divergent schools of ecology and give the subject the coherence which is so badly needed for maintaining a viable environment for an exploding human population.

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K.H. Mann

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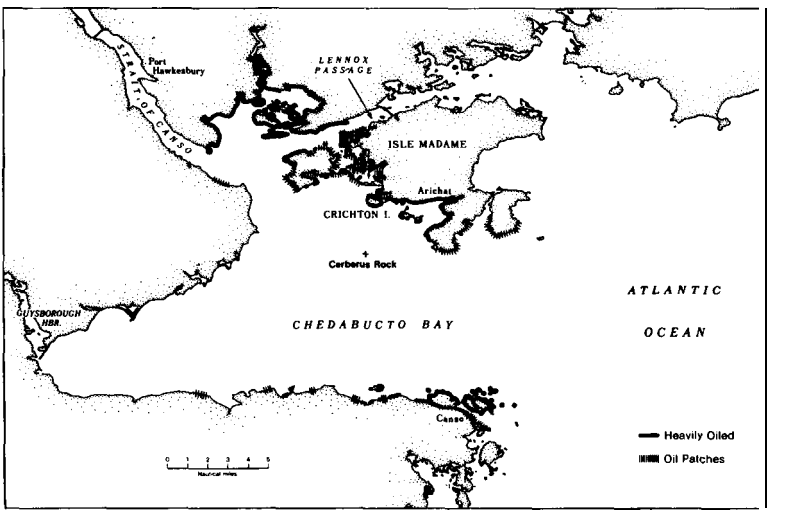
On Wednesday, February 4, 1970, the Liberian tanker *Arrow* ran aground on Cerberus Rock in Chedabucto Bay, Nova Scotia. The cargo of Bunker C residual fuel oil began to escape from the damaged ship and, by February 12, approximately 2.5 million gallons of the viscous black oil had escaped to pollute the waters of the Bay and the surrounding shoreline. Part of the oil escaped to the open sea, some landing on the beaches of Sable Island, 100 miles from the source. Of the 375 statute miles of shoreline in the Bay area, 190 miles were eventually contaminated to various degrees. Canada had experienced its first major oil spill of disastrous proportions. In addition, one-third of the original cargo of oil was trapped in the now submerged aft section of the wreck. Although no further major oil spills occurred after February 12, the amount of oiled shoreline increased as oil trapped beneath ice escaped with the spring thaw and oil moved from contaminated to uncontaminated areas. The extent and degree of oiled shoreline as of July 1970 is shown in the figure.



The extent and degree of oiled shoreline from the sinking of the tanker *Arrow* on Cerberus Rock.

Representatives of the Department of Transport and of Imperial Oil Ltd., owners of the cargo, gathered immediately to recover the vessel and combat the oil spill. Scientific assistance was volunteered quickly by several agencies, including the Bedford Institute; staff from MEL and AOL were on the scene within a few days and, by February 12, the *CSS Dawson* had started the first of three cruises to the Bay. However, by February 20, it became clear that the resources available to combat the disaster were inadequate to cope with a difficult threefold task - the recovery of over one million gallons of oil trapped within the

wreck, the clean-up of the oil-contaminated coast, and a realistic assessment of the damage done to the environment. A three-man task force, headed by Dr. P.D. McTaggart-Cowan, was appointed by the Federal Minister of Transport with authority to gather the resources required to resolve the pollution problem in Chedabucto Bay.

The Task Force decided that substantial scientific and engineering assistance was required and, on February 24, Dr. W.L. Ford, Director, AOL, was seconded to 'OPERATION OIL' as Scientific Coordinator. With the full cooperation of the local and national scientific community, a small management team, based at the Bedford Institute, coordinated an extensive program of support. By the time the team was disbanded, at the end of July, over 100 scientists and engineers, with supporting staff, had been working on a full or part-time basis for the Operation Oil Task Force. In addition, a number of continuing studies had been established. The scientific team hope these studies will assess the long-term effects of the pollution in the Bay and evaluate the threat posed to Canada by the continual accidental and incidental dumping of oil and oily wastes into our environment.

Membership of the central coordinating team illustrates the broad base of university and government support:

Scientific Coordinator	Dr. W.L. Ford Atlantic Oceanographic Laboratory Department of Energy, Mines and Resources
Executive Assistant	Mr. K.B. Yuen Headquarters Marine Sciences Branch Department of Energy, Mines and Resources
Chemical Science	Dr. A.Y. McLean Nova Scotia Technical College
Environmental Sciences (Physical)	Dr. C.S. Mason Atlantic Oceanographic Laboratory Department of Energy, Mines and Resources
Environmental Sciences (Ecological)	Dr. R.W. Trites Marine Ecology Laboratory Fisheries Research Board of Canada
Clean-Up Technology	Dr. W.D. Jamieson Atlantic Regional Laboratory National Research Council of Canada

Steam cleaning jetties (MOT photo).

Dr. F. Payne and Mr. J.R. Brown of the Defence Research Establishment Atlantic and Mr. T.R. Foote of the Atlantic Oceanographic Laboratory served as scientific liaison officers between the Operation Oil Task Force in Port Hawkesbury and the Bedford institute-based scientific support team.

Within a few days of starting their work, the scientific coordination team learnt that the techniques to control and combat oil spills were either primitive or nonexistent. There were a surprising number of products and techniques which did not even function satisfactorily in the specific conditions for which they were supposedly designed! It proved necessary to review and test all the techniques which had been used elsewhere and to invent new ones.

The most desirable way of eliminating oil pollution is to remove the oil from the environment and the team evaluated removal techniques such as booming and pumping, absorbing, burning, and skimming.

There was no commercial boom which would work in open sea conditions. Trials of a seine net boom indicated that a flexible net might contain heavy Bunker C oil, the permeable net allowing the passage of water while retaining the oil. After laboratory trials, a full scale field trial was held in which a 360-metre-long net of 2 cm nylon mesh was deployed and easily retrieved in an hour from two 13-metre boats. It was generally felt that the net would retain Bunker C in cold water successfully but it was not tested on an oil slick.

"Slick-licker" at work in shallow water (MOT photo).

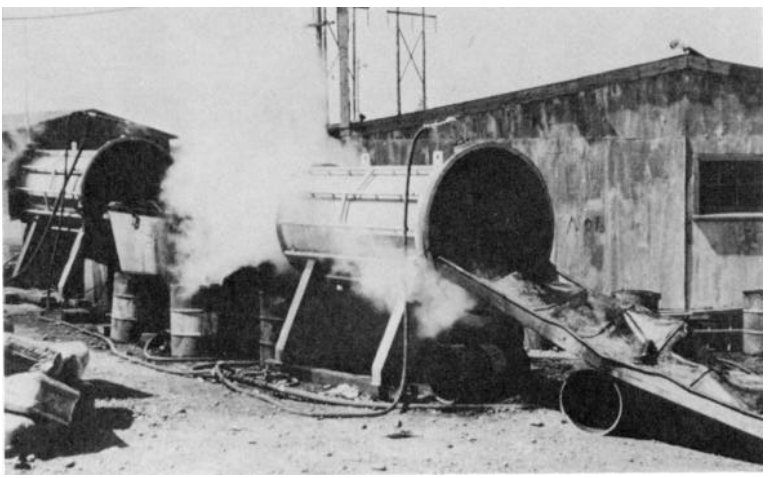
A trial of a wire-mesh peat-moss boom, which takes advantage of the fact that peat moss will absorb fresh Bunker C oil, was successful and it was shown that, in limited circumstances, this device will contain oil slicks on the sea surface. An investigation of pumps to recover oil contained within a boom or trapped beneath ice was carried out. Two field trials were held, without success, and the project was abandoned at the end of March when all the thick pools of oil had disappeared.

It was well known that straw and polyurethane foam would absorb oil and laboratory trials showed peat moss to be an effective absorbent; however, none of these substances will absorb oil which has been in a marine environment for several days. In April, peat moss was used to clean beaches contaminated by a small spill of fresh Bunker C oil after the sinking of the ferry *Patrick Morris* in the Cabot Strait.

Burning of the oil was attempted in the days prior to the establishment of the Task Force and an observer attended U.S. Navy trials in May 1970. In general it was found that if Bunker C oil will burn it will do so without any of the commercially available products and, if it will not burn, none of these products will help. After several days at sea, Bunker C oil is virtually indestructible because it forms an up-to-50% water-in-oil emulsion which will not burn.

Evaluation of techniques which do not remove oil from the environment was also carried out. Despite the disadvantages, the oil at least becomes invisible and does not damage tourist beaches. Techniques for

sinking the oil were reviewed and a number of tests of toxicity of commercial chemical dispersants were done at the Fisheries Research Board of Canada's Biological Station at St. Andrews, New Brunswick. A field trial of one dispersant, BP1100, was held, which proved it capable of removing oil from the surface of rocks without any positive indication of short-term harmful effects upon the adjacent littoral flora and fauna.



Net cleaning equipment devised and built to restore herring seine nets and other gear fouled with oil to a clean, usable condition.

A variety of oil clean-up techniques were tested in addition to chemical dispersants. Steam-cleaning tests were done in the laboratory and in the field and oiled jetties in the Bay were eventually cleaned this way by a commercial firm. A plant for cleaning the herring seine nets which were fouled with oil was designed, built and installed within three weeks. Four of these half-mile-long nets were cleaned, saving at least $75,000 of the alternative replacement cost. A coastal morphologist, advising the Operation Task Force on beach cleaning, also cooperated closely with a study group of geologists evaluating the effectiveness of the mechanical and natural cleaning of the sand, gravel and cobble beaches.

Laboratory experiments showed that ground limestone applied to beached oil could absorb and stabilize it. Field trials, where tonnage quantities were used, were partially successful in warm weather but a technique which would successfully stabilize the oil on the rocks in the Bay was not found. Further research and development was clearly indicated and the technique shows promise.

Along with review and development of control and clean-up techniques a study of the physical and chemical properties of fresh and aged *Arrow* oil was carried out. Bunker C is a remnant of the crude oil refining

process. The composition of Bunker C residual oil will vary even from day to day at the same refinery and, as far as the team could establish, little effort has been made to learn about its properties and chemical composition in relation to its behaviour when loosed in the marine environment.

Fishermen cleaning their own nets by passing them through the net-cleaning plant, under the supervision of the plant foreman.

A start was made on this work and a much clearer understanding was attained of why the oil behaved in the environment as it did. Particularly striking was the rapid increase in viscosity as the water-in-oil emulsion formed. This helped to explain why techniques such as absorbing and burning ceased to work after a few days of marine exposure of the oil. During the period the Operation Oil Task Force was active, at least nine other oil spills occurred in the Canadian Atlantic region. Techniques for identifying the source of the spilt oil became important and there was limited success with techniques based on gas liquid chromatography and vanadium/nickel ratios. Obviously much more work is necessary to establish a positive legal means of identifying the source of spilt oil.

Throughout February and March the mean air temperatures in the Bay were below freezing, ranging between -10°C and 0°C. Gale force winds, snow, freezing rain and rain were frequent occurrences. Sea water temperatures were close to the freezing point and, until March, the ice cover continued to increase. The last area to become ice free, Inhabitants Harbour, was not clear until April 16th. The *Arrow* spill offered a unique opportunity to study the natural behaviour of the spilt oil under these subarctic conditions. A wide ranging program of environmental studies combining the work of coastal geologists,

physical and chemical oceanographers, biologists and microbiologists was established and is still continuing. Of particular interest is a combined study of selected areas of the shoreline of Crichton Island located due north of Cerberus Rock and heavily and repeatedly polluted with oil in early February. Activity on this shoreline has been confined to scientific study and its owners have willingly cooperated in this and allowed free and ready access to the Island. The study is observing the behaviour of the oil in the various types of shoreline represented there and its ecological effects on the biota of the intertidal and littoral zones. Continuation of the Crichton Island program is anticipated for a further one or two years. The oceanographic investigators discovered particulate oil dispersed with water to depths of 70 metres and traced it as far as 180 miles southwest along the Nova Scotia coast.

Geologists considering a section of oil-polluted shoreline, Crichton Island.

Initial results of these scientific programs have been reported in the Task Force report to the Minister of Transport which has been released[1]. Sixteen continuing studies, involving a cooperative program between 20 environmental scientists of the Atlantic Oceanographic Laboratory, Nova Scotia Technical College, National Research Council of Canada, Atlantic Regional Laboratory, Energy, Mines and Resources Fuels Research Centre, Fisheries Research Board, Marine Ecology Laboratory, Halifax Laboratory and St. Andrews Biological Research Station have been established. The results of these programs will be published in the current scientific literature as the work is completed.

As a result of the initial scientific studies, the need for extended scientific programs became abundantly clear. Eleven other oil spills in Canada alone came to the direct attention of the Operation Oil Task Force during its active period between February and September. Estimates of the total amount of oil entering the marine environment annually range as high as 10 million tons[2]. Estimates (made by reputable scientists) of the threat posed by this oil spill range from the statement that "oil and oil products must be recognized as poisons that damage marine ecology and that are dangerous to man"[2] to the statement that "oil is objectionable to all who use the sea for pleasure but it is only directly harmful to diving sea birds"[3].

The scientific support team has strongly recommended that concerted research by interested oceanographers from around the world is required to assess quantitatively the distribution of oil; to understand the physical, chemical, biological and microbiological processes involved in its dispersion and eventual disposition in the oceanic environment; and to estimate the effects on the marine ecosystem. Such work is essential if the ultimate objective of evaluating the true level of this pollution threat is to be attained. Canadian scientists must participate in such an evaluation to ensure that a realistic appraisal is made of Canadian conditions and that our own protective measures are neither inadequate nor unnecessarily restrictive.

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[2] Blumer, M. 1970. Scientific Aspects of the Oil Spill Problem, presented at the NATO Colloquium on Oil Spills, November 1970.

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C.S. Mason, W.L. Ford.

B

Atlantic Oceanographic Laboratory

Marine Sciences Branch

Department of Energy, Mines and Resources

1969/70

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Director's Remarks

In the past two years, our seventh and eighth since the Laboratory opened, we have moved steadily ahead over the broad front of our program and can look back upon a number of significant milestones.

We initiated HUDSON 70 with the warm backing of our Minister, the Honorable J.J. Greene and, in cooperation with many others, carried out this major, 11-month long, multidisciplinary expedition around the western hemisphere. We played a major role in the Beaufort Sea hydrographic/geophysical expedition, 1970, a Branch-wide operation that included one phase of HUDSON 70. In particular, there was the substantial contribution by AOL hydrographers and the CSS BAFFIN which, in the course of the expedition, circumnavigated North America.

* Then there was Operation Oil, the clean-up of the massive spill of Bunker C oil resulting from the grounding of the tanker ARROW. on 4 February, 1970, in Chedabucto Bay, N.S. The staff of the Laboratory, working closely with the many of those involved, contributed heavily to the technological support of the clean-up operations and to a number of scientific investigations designed to learn as much as possible about the behaviour and effects of Bunker C in the relatively cold environment. The general scientific objectives, the program motivations and the main results to date of these major operations may be found in the essays of Part A; investigators' reports in the main body of the Review go into more detail on the various individual projects that comprised these expeditions.

The major shift in program direction has been the greater emphasis given to quality of environment and prevention or abatement of pollution. While the shift was underway early in the period of this review, it was greatly accelerated in 1970 by our involvement in the ARROW spill and by a marked upswing in requests for oceanographic advice and assistance from federal, provincial and civic authorities concerned with various aspects of pollution in marine waters. This process was all part of a nation-wide, indeed a world-wide, trend which at the federal level culminated in the government's decision to consolidate and expand its functions in this field by establishing a Department of the Environment.

It is interesting to observe that, while the program direction has experienced this shift, the scientific or technical objectives of the multitude of research and survey projects that make up our program remain relatively unchanged. At the Laboratory level the implementation of the program is a matter of carrying on with established longer range research studies of the marine environment as the basis of the

* These logos, the backside of the HUDSON 70 medal and the broken arrow, will appear throughout the AOL report indicating articles pertaining to HUDSON 70 and Operation Oil respectively.

program and as support of our competence to adequately provide advice and services for immediate problems of application. For example, the generalized study of estuarine processes along the Canadian eastern seaboard gives us the ability to provide advice and information on specific pollution problems, existing or potential, in inshore waters. Generally speaking, our oceanographic studies have in common the objective of describing and understanding the characteristics and behaviour of the sea. It is perhaps obvious to the point of being redundant to take note of the fact that any assessment of the quality of the environment, in terms of a pollution threat, must have some sort of baseline information on the 'normal' situation. In many cases attempts at such assessments have been frustrated by the inadequate state of oceanographic knowledge and the great gaps in the understanding of the complex physical, chemical and biological pathways through the marine ecosystems along which presumed pollutant substances would pass.

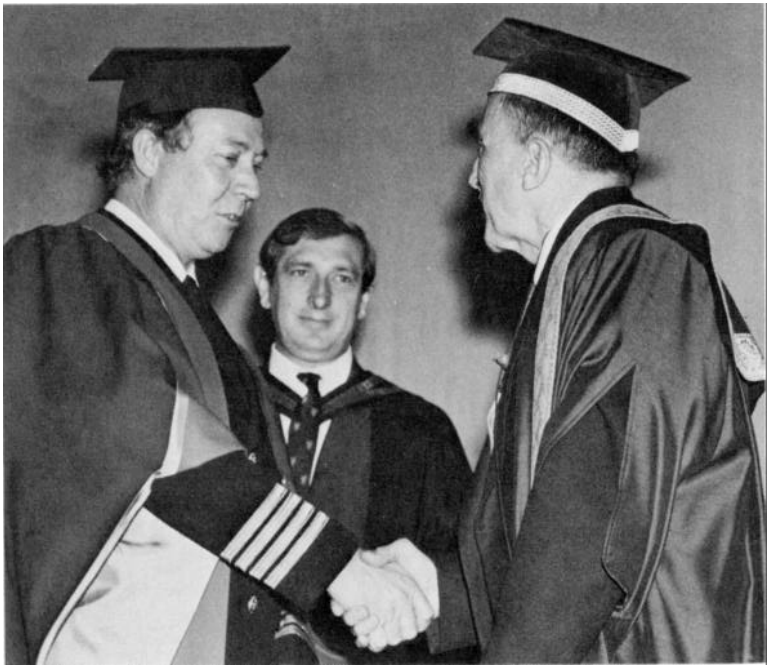
In another kind of example, hydrographic surveys which traditionally have had as their prime objective safe navigation to prevent the loss of life and property, now are more fully recognized as also helping to minimize pollution threats from the spilling of petroleum or other hazardous cargoes resulting from groundings on uncharted or inadequately charted shoals. The growth of tanker traffic and the introduction of very deep draft supertankers has brought the pollution consideration to the fore. The possibility of the use of specially designed supertankers in Arctic waters and the pollution threat they would present to the delicate polar ecology was an important factor in the decision to step up the rate of charting in the Beaufort Sea and Northwest Passage.

By late 1968 the operations of the Laboratory had grown to a size which made it necessary to create a position of Assistant Director (Research). Dr. B.D. Loncarevic, formerly head of the Geophysics group, was appointed to this position in April 1969. He has played a key and innovative role in the formulation of our research programs and in laying the groundwork for the further development of the Laboratory, indeed the Institute as a whole.

It is a privilege and pleasure to report that at its 1971 spring convocation, Brock University, St. Catharines, Ontario, bestowed on Captain David Butler, Master of the CSS HUDSON, the degree of Doctor of Laws (honoris causa) ". . . in witness of his skill and seamanship in commanding CSS HUDSON on a voyage of circumnavigation of the Americas, and his contributions to the sciences of the sea in a great tradition of adventuring."

In closing, I wish to acknowledge with thanks the invaluable work of Dr. Gillian Elliott as editor of this edition of the Biennial Review.

Wm. L. Ford



Captain D.W. Butler being congratulated by Chancellor C.A. Sankey upon receiving the degree of Doctor of Laws (honoris causal from Brock University.

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A Walton[1]

J.M. Bewers
A.R. Coote
C.C. Cunningham[6]
I.W. Duedall[6]
S. Hartling[1]
R.S. Hiltz
H.M Langer
E.M. Levy
I .M.H. Pagden[2]
G.J. Pearson
L.R. Webber[1]
W. Young

The general problem of environmental quality and pollution is one of the major areas of study. The section was heavily committed to 'Project Oil' and studies involving the specific identification and assay of background oil pollution in the marine environment resulting from the *Arrow* and *Whale* incidents. Within the nearshore environment, research has focussed on two of the major industrial activities in the provinces of Newfoundland and Nova Scotia - namely, phosphorus production and the pulp and paper industry. Of particular interest in this latter research is the identification of indicator organisms and their ability to reflect the early stages of chemical modification of the environment.

In common with other sections of the Bedford Institute, Chemical Oceanography had a considerable part to play in HUDSON 70. During the cruise a total of more than 10,000 observations were made of chemical properties of ocean water in the Atlantic and Pacific Oceans, Drake Passage and

12 litre sampling bottle being attached to the hydrographic wire on the CNAV *Sackville.*

[1] Joined AOL [6] FRB staff

[2] Left AOL

the Chilean fjords. A major practical success in this program was the performance and reliability of the Technicon Auto-Analyzer.

With the demand increasing for the measurement of basic chemical oceanographic parameters such as salinity, chloride, nitrate, nitrite, phosphate, silicate, sulphate and sulphide ions, dissolved oxygen, etc., attention has been given to the automation of the analytical procedures and development of *in situ* measurement devices. In addition to the auto-analyzer some experimental work has been performed on the use of selective ion electrodes and evaluation of the MINOS dissolved oxygen monitor.

In spite of the trend toward automation the section has continued to provide considerable laboratory services to other scientists in the Institute.

A. Walton

Environmental Chemistry - Pollution Studies

The sinking of the *Arrow* in Chedabucto Bay and the *Whale* in the Gulf of St. Lawrence, and the accompanying loss of parts of their cargoes of Bunker C fuel OIL, presented several challenging chemical problems. These included the estimation of the extent to which the oil was dispersed throughout the water column and transported to adjacent waters and the identification of the sources of the oil which drifted onto the beaches of Sable Island and the Magdalen Islands soon after the occurrence of these two incidents.

Before either of these problems could be approached, however, analytical procedures and techniques had to be devised, for both shipboard and laboratory application. A successful shipboard technique that was developed consisted of extracting oil from a sample of sea water by filtration or by solvent extraction to provide an estimate of the 'particulate' or 'total' oil concentration. The oil was dissolved in n-hexane and its absorption of UV light at a wavelength of 256 nm was compared with that of standard solutions of the oil. This was a convenient procedure for the estimation of Bunker C, and was suitable for concentrations of 10 ppb or greater. For smaller concentrations, the extracts were analyzed in the laboratory by fluorescence spectrophotometry whereby the sample was excited at 310 nm and the intensity of its fluorescence at 360 nm was compared with those of standard Bunker C solutions. This method was more selective and sensitive than the absorbance method and concentrations as low as 0.5 ppb of residual oil in sea water were readily estimated.

In early May 1970, the concentration of particulate Bunker C oil in Chedabucto Bay, near the wreck of the *Arrow,* was observed to be 16 to 40 ppb. There was conclusive evidence, however, that the concentration of oil not retained by filtration was much greater. At a series of stations extending across the outer reaches of Chedabucto Bay, the concentrations observed for the particulate and dissolved oil were 2 to 16 and 0 to 90 ppb respectively at all depths.

An indication of the residual oil content of the open Atlantic was provided from the analyses of samples collected on the Halifax Section, a series of stations extending southeasterly from Halifax Harbour to beyond the limit of the continental shelf. Concentrations during May 1970 were 2 to 13 ppb; this is considered to be indicative of the background concentration of petroleum residues in these waters following the *Arrow* incident.

A cruise to the Gulf of St. Lawrence during the summer of 1970, in which a series of stations from Cabot Strait to Montreal were sampled, indicated a background oil level of 1 to 6 ppb at all stations and at all depths. Since the concentration of residual petroleum products did not increase upriver, it is suggested that chemical, biological or geological processes must be removing these products from the area. Samples which were collected from the Gulf of St. Lawrence after the sinking of the barge, *Whale,* indicated that this incident had very little impact on the background level in that area, as a relatively small amount of oil was lost.

Shortly after this incident, oil appeared on the beaches of the Magdalen Islands and the question arose whether this oil originated from the *Whale* or from some other source. The absorption spectrum of Bunker C oil has a characteristic flat shoulder at approximately 256 nm and a prominent peak at about 228 nm. Although the general features of the absorption spectra of different batches of Bunker C oil do not differ sufficiently to provide a criterion for distinguishing between them, the ratio of absorbance at 228 nm to that at 256 nm seems to provide a convenient fingerprint of the oil in these restricted circumstances. The values for this ratio for the oils found on Sable Island and on the Magdalen Islands were identical to those for samples taken from the *Arrow* and the *Whale* respectively.

E.M. Levy

In pollution studies the diagnosis of man's impact upon his environment may benefit from the identification of indicator organisms. The identification of such organisms for one or several elements may aid in the tracing of pollutants and facilitate both the monitoring and the establishment of realistic background levels. Bearing this in mind studies have been performed on organisms collected from an area subjected to the input of treated Bleached Kraft Pulp Mill Effluent

(BKME). The results indicate that clams take up more than eight elements, particularly the rare earths which exist in the effluent particulate material. The difficulty of obtaining sufficient quantities of biological species has hampered the satisfactory analyses of other biota, but clams do show significant uptake whereas calcareous forams do not. There is evidence from this work, however, that arenacious forams and ostracods may be sensitive to mercury in treated BKME.

The behaviour of suspended particulate material within the lagoons of a BKME treatment system and also in the receiving saline coastal waters has also been studied. The treatment process was found to be 80% effective in removing coarse particulate matter but fine material was unaffected. The overall efficiency of the procedure for suspended solids removal, therefore, is estimated to be less than 50%. Furthermore, flocculation of fine and colloidal particles occurs when the effluent becomes mixed with sea water.

Since the optical transparency of the receiving waters is controlled largely by the suspended material in those waters, the behaviour of the particulate material is of considerable importance. As a result of flocculation the amount of suspended material admitted to the receiving waters is effectively doubled at the expense of colloidal material. Furthermore, because flocculation causes the particulates to be predominantly in the large particle size range most of this material might be expected to be precipitated into the littoral zone or driven onto adjacent beaches. In laboratory experiments it was found that considerable flocculation occurred within two weeks of the mixing of effluent with sea water to a final salinity of 12‰ . During this period the optical transparency improved by a factor of 7.

An economic method of reducing the amount of discharged solids, and in consequence the effluent transparency, has been suggested, based on artificial flocculation within the treatment system.

J.M. Bewers, G.J. Pearson.

Early in 1969 large numbers of dead herring were observed in Placentia Bay, Newfoundland. In the early stages of this program the section carried out studies of phosphate and fluoride concentrations in the environment. Later, when the phosphorus plant at Long Harbour was suspected as a source of toxic material preliminary tests of wet chemical methods for the analysis of elemental phosphorus in sediment, water and biological material were performed. The analyses consisted of two principal steps: extraction of the phosphorus from its matrix followed by its oxidation and final determination by calorimetry.

It became apparent that benzene extraction was superior to steam distillation as the first step, but the routine wet chemical oxidation procedure for phosphorous was found to be rather lengthy and was replaced by a gas chromatographic procedure for the direct determination of elemental phosphorus in benzene. Wet oxidation was used thereafter to provide an independent analysis of a number of samples to confirm the accuracy of the gas chromatographic method.

A.R. Coote

Chemical services were provided to the Coastal Oceanography Section which has been conducting an oceanographic survey of the Strait of Canso. The purpose of the survey is to establish baseline data on the quality of the water since it is anticipated that in the near future the region will become heavily industrialized. Personnel and equipment for the determinations of dissolved oxygen, alkalinity, and pH were provided. Nine stations were sampled at weekly intervals for a period of seven weeks during the summer of 1969 and the program continued in 1970.

I.W. Duedall

Trace Element and Nuclear Chemistry Research

Until recently the fluoride ion in sea water has been regarded as a conservative ion whose distribution is fairly uniform with location and depth in the major oceans. However, in 1963 the authors (Greenhalgh and Riley, Nature) of a new method for the determination of fluoride in sea water reported increases in fluoride concentration with depth in the China Sea, the North and South Atlantic, and the Mediterranean Sea. These anomalies were most severe west of the Mid-Atlantic Ridge and since this area was one of intense interest to the Atlantic Oceanographic Laboratory, it was felt that study of fluoride behaviour was necessary.

Subsequently, high density fluoride/depth profiles were obtained for five stations at 46°N in the Mid-Atlantic Ridge and two stations at 33°N in the Cape Verde Basin south of the Azores. The results show no significant variation in fluoride concentration with position or depth down to 3500 metres. The mean fluoride concentration obtained from 153 determinations was 1.35 ± 0.03 mg/l. Recently, however, high density sampling has been carried out in an area previously reported as anomalous. Preliminary analysis of these samples, using a method similar to that used by previous workers, show a very structured fluoride concentration with depth. Layers of elevated fluoride concentrations occur at 200, 400, 1300, 1600, 2400 and 2800 metres depth, the increases being between 20% and 35%. In view of the

unusual nature of these results it appears necessary to substantiate them with determinations by an independent method. Since the mechanisms responsible for such a fluoride distribution could be geological and biological as well as oceanographic it is important that further research on this problem be performed if the preliminary results are confirmed.

J.M. Bewers

Chemical traces, such as mercury and chromium, appearing in aquatic systems have recently received much attention due to their inherent toxicity and subsequent effects on fisheries and recreation. Conversely, other trace constituents in water have been found to be essential to life through their roles in metabolism and food chains. To study and monitor these marine trace elements, neutron activation analysis has been used to measure simultaneously the concentrations of several species in the same sample. In this method samples are irradiated in a high neutron flux nuclear reactor which transmutes many of the isotopes present into radio-active forms. The resulting activities are measured and identified with the original elements to yield absolute or relative elemental concentrations in the sample.

The acquired data must be related to actual situations by a method of standardization which can be either total analysis of known quantities of elements, or a reference compilation of all parameters of radio-active species. The latter was chosen in order to hasten analyses and reduce overall cost. Information on radio-active nuclides was compiled from a number of reference sources up to December 1969, and reproduced on punched computer cards. Parameters included for identification are Z, A, chemical symbol, nuclear isomeric state, decay half-life, neutron capture cross-section, chemical abundance and Q-values. Also included are the characteristic gamma-ray energies and intensities emitted by each active species in the decay process. Magnetic tape and disc versions of the catalogue were also compiled for use with a set of eight computer programs which analyze, semi-automatically, the data obtained from each irradiated sample.

Some of the nuclear parameters and especially the capture cross-sections are not yet accurately known for many isotopes. This precludes the possibility of absolute determination of some trace elements but, nevertheless, provides data on relative abundances and concentration changes as a function of sample location or time. For this reason neutron activation analysis is a useful technique for monitoring trace element concentration changes in locations likely to be affected by other than natural processes.

J.H. Bewers, I.M.H. Pagden, G.J. Pearson

Contamination is a serious hazard to accurate determinations of trace constituents in samples. Neutron activation analysis requires the sample to be placed in a sealed container for reactor irradiation. Encapsulation procedure and contact between the sample and its container enhance the probability of sample contamination while removal of the sample after irradiation can involve loss of material and thereby introduce further inaccuracies. The merits of double-walled graphite capsules versus conventional silica vials have been investigated. Eight graphite vials were irradiated in a high neutron flux at AECL, Chalk River and returned to AOL for gamma-ray analysis by the above technique. The resulting activity was predominantly 24-hour W^{187} at a mean concentration in each vial of 249 parts per billion. Mo^{99} was also present at a mean concentration of 486 parts per billion but resulted in a lower activity due to its lower neutron capture cross-section. Very minor contributions resulted from the activities assigned to Co^{60}, As^{76}, Br^{82}, Ru^{103}, and Hf^{181}.

The activities associated with these graphite capsules are sufficiently uniform and minor to permit the direct analysis of the sample without removal from the capsule. Thus, direct analysis is possible for the majority of biological, geological and standard materials whose active species are longer-lived than 12 hours. For analysis of shorter-lived isotopes, however, the W^{187} activity causes significant interference and sample transfer is necessary. The capsules are presently being used routinely for analysis of trace elements in marine organisms and sediments.

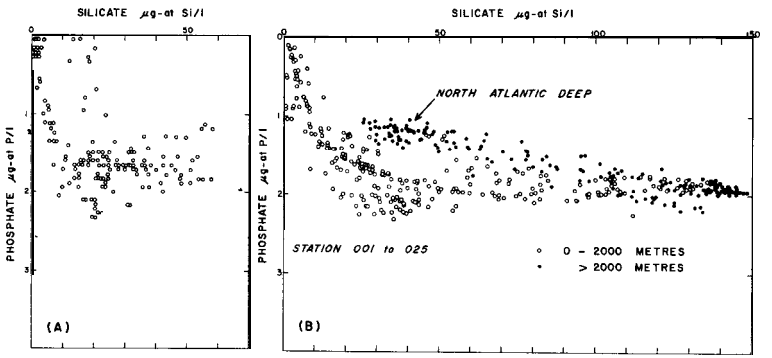
J.M. Bewers, G.J. Pearson

ToC

HUDSON 70 and Gulf of St. Lawrence Chemical Oceanographic Cruises

Three members of the Chemical Oceanography Section participated in the HUDSON 70 expedition during the Atlantic, Drake Passage, Chilean Fjord and Pacific phases. Measurements were made of the concentrations of several basic chemical parameters: oxygen, pH, alkalinity, silicate, nitrate and phosphate, About 10,000 individual determinations were made. Plots showing distributions of oxygen and the nutrients have been drawn using data gathered in the South Atlantic and further analyses of the results are underway.

An interesting method for relating nutrient data to water masses is to examine the relationship between phosphate and silicate concentrations in each water sample. Figure A is taken from the work of Chow and Mantylla (1965) using data from the *Discovery II* IGY cruises in the North Atlantic. By way of comparison figure B shows the same type of plot using HUDSON 70 data for the South Atlantic. It is noticeable

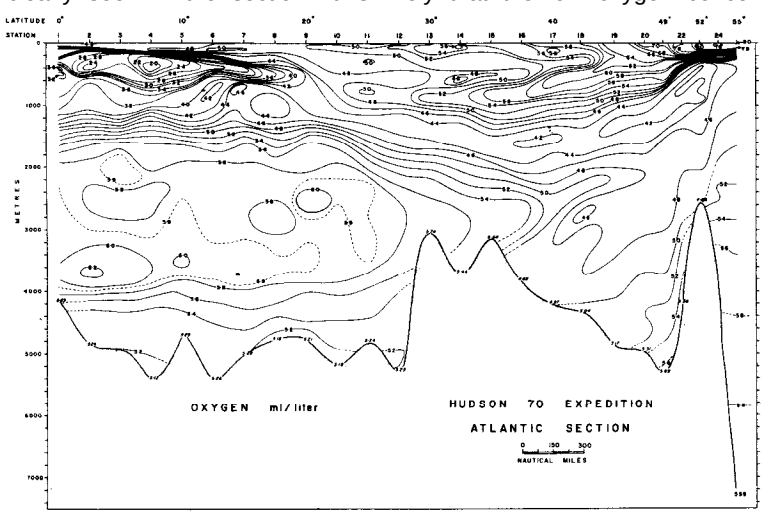


Phosphate-silicate ratios.

that the silicate concentrations reach much higher levels in the South Atlantic and that the North Atlantic Deep water possesses a lower phosphate content than water formed in the Southern Ocean.

A.R. Coote

Dissolved oxygen was routinely measured via the Carpenter modification to the Winkler technique during the HUDSON 70 expedition. The oxygen section for the Atlantic phase of the expedition shows the main water masses of the South Atlantic Ocean (see figure). A strong oxygen minimum situated between stations 2 and 4 and at a depth of about 350 metres is clearly seen in the section. It is likely that the low oxygen concen-



Oxygen section from the South Atlantic phase of HUDSON 70.

tration was acquired off the west coast of Africa where the oxidative processes are apparently high. Sections showing oxygen saturation and apparent oxygen utilization are also being drawn.

Alkalinity was determined at 12 of the 25 Atlantic stations using the Dryssen-Sillen-Gran technique.

I.W. Duedall

The chemical program carried out in the Chilean fjords, as part of HUDSON 70, consisted of the determinations of dissolved oxygen and the nutrients: nitrate, phosphate, and silicate. About 50 nutrient stations were occupied. These were the first chemical studies of the fjords, and the program was carried out as a joint effort with the Chilean chemical oceanographers. In general, nitrate and phosphate showed depletion in the surface water and regeneration in the deep water. Slopes of plots of nitrate versus phosphate are in the ratio of 16: 1 (by atoms) as predicted by Redfield's consumption-production model. Silicate was correlated with nitrate and phosphate but at some stations surface silicates were very high owing to the presence of glacial run-off.

I.W. Duedall

ToC

Physical Chemistry

In the research into partial molal volumes eight salts have been examined, viz. Na_2CO_3, K_2CC_3, Na_2HPO_4, K_2HPO_4, $Na_2B_4O_7$, $K_2B_4O_7$, H_3BO_3 and Na_2SiO_3. The dilatometric method was used and the measurements were first made using sea water of 35‰ salinity. The measurements were then repeated using 0.725 molal NaCl having the same ionic strength as sea water. The purpose of making measurements in NaCl solutions was to determine the effect of saline solutions of the same ionic strength but differing ionic composition on the partial molal volumes of the various salts. This type of information should improve our knowledge of the relative roles played by electrostriction and ion-pairs in sea water. The first set of measurements was made at 20°C, repeat measurements are to be performed at lower temperatures.

Until recently the chemical oceanography of the Gulf of St. Lawrence has been virtually ignored. In July 1970, phosphate, silicate, nitrate and dissolved oxygen concentrations were determined for a series of stations extending from Cabot Strait to Montreal. Significantly, higher nutrient and lower dissolved oxygen concentrations were observed in the St. Lawrence River than in the estuary and gulf. An interesting feature apparent in all four sections is the influence of water from the north shore entering the estuary.

E.M. Levy

Studies are also in progress to determine the effect of hydrostatic pressure on the compressibility of salts in sea water and to provide the fundamental data for investigations into the extent of the hydration of ions in sea water and the effect of pressure on the solubility of salts in sea water. The technique used is to measure, using a back-to-back bellows apparatus, the difference in compressibility of two sea water solutions whose compositions are identical except for the addition of a small amount of a particular salt to one of the solutions. One side of the bellows apparatus is filled with the unaltered sea water while the other side is filled with the spiked sea water. The apparatus. is placed inside a pressure bomb, and, as pressure is applied, the difference between the linear displacements of the two bellows provides a measure of compressibility of the particular salt in the spiked sea water. The assembly of the apparatus is now complete.

I.W. Duedall

A number of fundamental investigations into the factors which affect the accuracy and precision of salinity data was performed during 1969-1970. The entire procedure, including the collection of samples at sea, their storage and analysis, and the processing of results was examined. It is important that sampling equipment be maintained in good working order and that particular care be devoted to the procedures used if a representative sample is to be obtained. By careful sampling techniques, it is possible to observe differences of ± 0.002‰ in the salinities of closely spaced samples even in such homogeneous waters as the deep Sargasso Sea. An evaluation of various sample bottles and closures indicated that U.G.B. Type ESR-324 glass bottles and Poly-Seal caps were the most satisfactory of those tested. The salinity of samples of sea water stored in these containers has not changed during almost two years.

A second phase of this work attempted to resolve a common argument whether salinity sample bottles should be aged by exposure to sea water for a period of time, or whether the bottles should be thoroughly cleaned before use. No significant difference in salinity could be detected between groups of samples stored in aged and other samples of the same water stored in cleaned bottles,

An experiment was carried out to determine what effect, if any, freezing of the IAPSO Standard Sea Water might have on its electrical conductivity and therefore its reliability as a salinity standard. Samples frozen at -20°C for one month with one, two and four cycles of freezing and thawing showed no indication of a change in electrical conductivity as measured by an inductive salinometer provided that the ice had melted completely and that the sample was thoroughly mixed before the measurements were made. The greatest danger in freezing the standard sea water is that of cracking the glass vials.

As an independent check on the accuracy of inductive salinometers, a high precision chlorinity titration was developed. This consists of reacting a weighed amount of sea water with a weighed, and just slightly less than equivalent, amount of accurately standardized silver nitrate solution. The excess chloride in the sample is then titrated potentiometrically with a standardized dilute silver nitrate solution and the exact equivalence point is determined by a differential technique. With a skilled analyst the precision and accuracy of the method is about ±0.002‰ for chlorinities of 11 to 22 ‰ .

E.M. Levy

ToC

Instrument Development for the Measurement of Chemical Parameters

A Technicon Auto-Analyzer was used for seven months of the HUDSON 70 cruise to obtain simultaneous determinations of the major chemical nutrients (phosphate, nitrate and silicate) contained in various water masses of the Atlantic, Antarctic and Pacific Oceans. This instrument automatically carries out the operations of sample aspiration, addition of reagents, mixing, colour development and the reading and recording on a chart of an electrical signal which is proportional to the concentration of the constituent being determined.

Except for a brief period when it was operated in a continuous mode in the Atlantic, the instrument was operated sequentially on discrete water samples. During the oceanic portions of the cruise the analyzer was in use about ten hours per day and in the Chilean fjords it was running continuously. Some difficulties were experienced with methods; also, growth of moulds produced short periods of interference with the nitrate and phosphate determinations. Electrical and mechanical breakdowns were rare; no more than a day's down-time in all during the seven months. No silicate determinations were missed at any station. The analyzer has demonstrated its ability to work long hours in rough weather with probably better precision and accuracy than was formerly obtainable at sea using manual methods. However, the most important oceanographic use of this type of equipment may derive from operating it in a continuous mode, to obtain continuous profiles of smaller scale horizontal or vertical distributions of chemical parameters.

A.R. Coote

A preliminary investigation of the potential applicability of ion-selective electrodes for the determination of chloride, nitrate, and sulfide in sea water has been performed. Both the liquid membrane and the solid state types of chloride electrodes show considerable potential as sensors for *in situ* instruments in environmental studies where relatively large changes in chlorinity may be encountered.

Both the nitrate and the sulfide electrodes were subject to such large interferences from other ions present in the sea water that they were of little value for direct measurements on sea water.

In an evaluation of the Beckman Minos' dissolved oxygen monitor, continuous profiles were obtained for the stations on the Halifax Section and for several stations in the Gulf of St. Lawrence and the St. Lawrence River. An intercomparison was made between the values obtained with this instrument and those for samples collected at various depths and analyzed by the Carpenter modification of the Winkler method. The average difference between these values for the Halifax Section was 0.05 ml/l and for the Gulf cruise 0.85 ml/l. The maximum depth to which the sensor was tested was 798 metres.

E.M. Levy

Chemical Services

During this period a salinity service laboratory was established. Chemical services have since been extended to include a limited number of oxygen, silicate, phosphate, nitrate, pH, alkalinity and fluoride analyses.

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G.B. Taylor[6]
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The Coastal Oceanography Section is jointly supported and manned by the Marine Sciences Branch, Department of Energy, Mines and Resources, and the Fisheries Research Board of Canada.* It is engaged in studies to clarify and understand physical processes in the nearshore region. This is arbitrarily defined to extend from the coast to the edge of the continental shelf and includes all inlets, estuaries and gulfs on the Canadian eastern seaboard. Because of limitations of manpower and facilities only a limited number of problems in a limited number of areas are actively investigated at any one time. These investigations are, most of the time, in response to a felt or anticipated need for greater knowledge of an area to allow intelligent planning for utilization and conservation or to remedy a deteriorating situation. As the nearshore region is the first part of the ocean to feel the impact of the rapidly increasing human activity, need for such studies is increasing in order to serve requirements in fisheries, defense, coastal engineering and pollution abatement. However, some of the studies are initiated to investigate points of basic fundamental importance in the nearshore processes.

The nature of the section's responsibilities necessitates extensive field studies. In turn, this requires having adequate facilities for specialized servicing and calibration as well as for data reduction and analysis. For some of these services, the section depends on facilities provided by other sections; for example, the Standards Laboratory of Metrology

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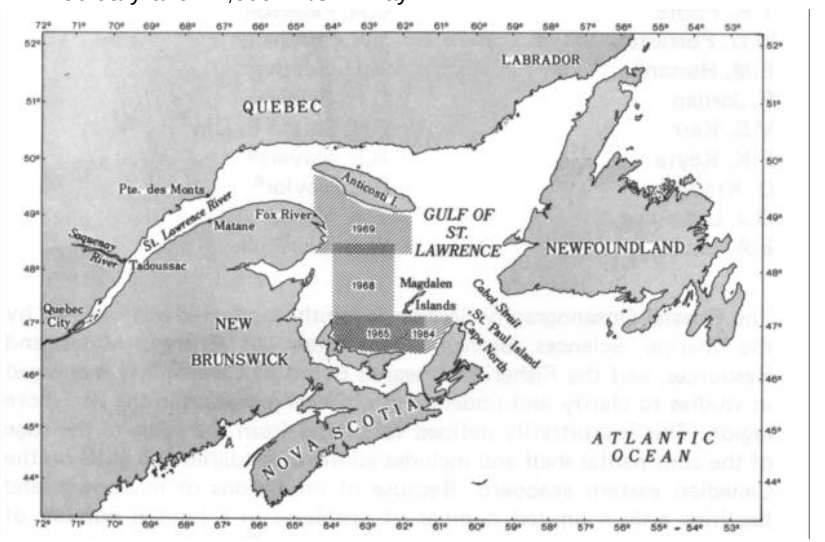
* Part of the work of this section is covered in the Marine Ecology Laboratory (MEL) portion of this Biennial Review.

and the Computing Services group of Scientific Services and Special Projects.

The Gulf of St. Lawrence

In order to evaluate the effects of man-made fresh water regulations (e.g., hydro-power developments and water diversions) in the St. Lawrence estuary, an analysis was made of the 1963 salinity and temperature distributions during a fresh water run-off of 11,000 m^3/s in February and 17,000 m^3/s in May.



The Gulf of St. Lawrence including areas surveyed in the central Gulf by years.

The mixing character in both instances varied from being well mixed at the head of the estuary (Quebec City) to moderately mixed in the section from below the head to Tadoussac. In the deep section below the mouth of the Saguenay River, stratified conditions prevailed. The primary motion in the system is a longitudinal two-layer circulation in which the surface layer deviates to the south shore and the deep layer toward the north shore. There is a net seaward flow of lower-salinity water on the south side and a compensatory flow of higher-salinity water on the north side and in the deeper layer. The Gaspé Current is the high velocity region of the upper layer. Applying the geostrophic approximation, it was estimated that the outward directed velocities in the surface layer were, for a fresh water flow of 17,000 m^3/s, approximately twice that for 11,000 m^3/s.

From this it follows that modifications to the run-off alter the flow regime and with it the salinity and temperature structure of the system. The regulations applied to the St. Lawrence since the turn of the century quite probably have, during the summer, decreased the circulation and increased the water temperature in the surface layer. This most certainly has had consequences likened to large-scale heat pollution, with the corresponding ecological implications.

H.J.A. Neu

In May of 1969 seven strings of current meters were moored for one month in the channel of the St. Lawrence Estuary between the Saguenay River and Matane to help describe internal tides suspected, from earlier work, to exist in the estuary. The measurements were repeated again during the last half of September and the first half of October to investigate the internal tides under different stratification conditions. Tidal stream harmonic constants have been calculated for various cross-sections between Lake St. Peter and Pointe des Monts using tide gauge records and the principle of continuity. Good agreement was obtained with current meter results.

W.D. Forrester

Two winter cruises into the Gulf of St. Lawrence were undertaken to monitor oceanographic conditions in the presence of ice cover. Ice cover was, however, almost totally lacking in the Gulf in the winter of 1968-69, so the cruises (in January and March 1969) served to provide winter temperature and salinity information for an extremely light ice year. The Marine Sciences Centre of McGill University participated in the January cruise in the Gulf of St. Lawrence, carrying out a plankton sampling program.

A McGill University manuscript report summarizing past work on the physical oceanography of the Gulf of St. Lawrence has been prepared (El Sabh, Forrester, and Johannessen, 1969).

W.D. Forrester

In order to study the response to meteorological conditions, current and temperature recorders were moored during the summer of 1967 at eight sites in the Gulf, from Cabot Strait to the St. Lawrence River at the surface and at the subsurface levels. During June-July 1967, 151 hydrographic stations were taken over the Magdalen Shallows. Using the Kieler Howaldtswerke bathysonde, eight lines were taken between the Saguenay River and Gaspé Passage for a total of 260 stations. Each line was occupied three times.

The analyses of these data give the daily variation during one month of the net water movement at the surface and subsurface levels and its

relation to the pressure system surrounding the Gulf. Also, the temperature and salinity structure over the Magdalen Shallows and the oceanographic features of the Gaspé Current have been described in detail.

S.H. Sharaf El Din, R.W. Trites

In 1969 a survey was carried out in the central Gulf of St. Lawrence to measure nontidal currents, continuing the work done in 1964, 1965 and 1968. In 1969 the field party aboard the *CSS Dawson* had the use of a computer-calculator by which geopotential anomalies were contoured as the survey grid was being traversed. In this way the trajectories of parachute-drogues could be compared immediately with the geostrophic flow obtained from the contours. The drogues moved almost exactly where predicted; one beaching up on the rocky shore of Anticosti Island.

The results of the two surveys, 1968 and 1969, seem to indicate that the time-scale of the gyres is sufficiently long (2-3 days) to allow a grid traverse of 1-2 days to be taken as a synoptic sampling of gyre movement.

R.W. Trites, F.K. Keyte

In 1964 a program was initiated to investigate the oceanographic variability (mainly in salinity and temperature) on a network of closely spaced stations in the southern Gulf. Sampling cruises were carried out during the summers of 1964, 1965 and 1968 and during the late fall of 1969 and 1970. Data from the 1965 and 1970 cruises (a total of over 400 stations) will be utilized to study the spectrum of variability over distances between 10 and 250 km and mixing processes over the Magdalen Shallows. Observations during the 1969 cruise show that the Gaspé Current tends to be narrower than previously believed - being less than two miles wide off Fox River, with a counter current on the inside edge of the stream.

G.H. Seibert

Although tidal fluctuations at coastal stations surrounding the Gulf of St. Lawrence are well documented, information on tides and tidal currents in the interior of the Gulf are scarce. In order to remedy this defect and institute a proper sampling program, a numerical model has been developed. The vertically integrated primitive equations are solved over a staggered rectangular net (mesh width of 8.5 km) by time stepping using the explicit scheme developed by Hansen. Although the model may be applied in studying free and forced modes of oscillation in the Gulf, attempts have been confined to the M_2 tide.

G.H. Seibert

In order to understand the large-scale patterns of currents in the Gulf a three-dimensional, steady-state numerical model of the circulation has been developed. The fundamental forcing function in this model is the surface wind stress.

Monthly charts of sea surface atmospheric pressure for the years 1960 to 1969 inclusive have been prepared. The derivation of surface winds from these pressure distributions (via the geostrophic assumption) presents a problem in terms of choosing the proper vector deviation of the surface wind from the geostrophic. We have chosen to calibrate our pressure-derived winds against observed winds at Grindstone Island.

Meridional and zonal stress values are evaluated at ten-minute by ten-minute grid points and then smoothed by a nine-point symmetrical filter. Current meter data will be utilized in specifying proper boundary conditions.

G.H. Seibert, E.M. Hassan

Any study of the large scale circulation pattern within the Gulf of St. Lawrence requires a knowledge of the flows through the various entrances. In 1966, a two-ship survey was carried out in the major entrance - Cabot Strait. The moored current meter data from this survey and from a smaller one in 1959 have been extensively analyzed. The nontidal portion seems to have different characteristics in the upper and lower layers.

In the main part of the channel and below about 75 metres, there is a counterclockwise gyre. Velocities can reach 20 cm/s near the upper boundary and towards the sides of the Strait. The position of the centre of this gyre is not much affected by the temporary disturbances due to the passage of a depression across the Gulf of St. Lawrence. Rather, it seems to undergo only fairly long period changes of the order of weeks, possibly due to the passage of major storms at some considerable distance away. Slight changes in the position of the centre of the gyre have a strong effect on the direction of the current in the centre of the Strait.

In the near-surface depths of the main part of the Strait, and at all depths in the channel between Cape North and St. Paul Island, the nontidal flows are greatly affected by depressions travelling across the Gulf. In particular, a depression over the southwestern portion of the Gulf can cause the normal outflow to be replaced by a strong inflow across the entire Strait.

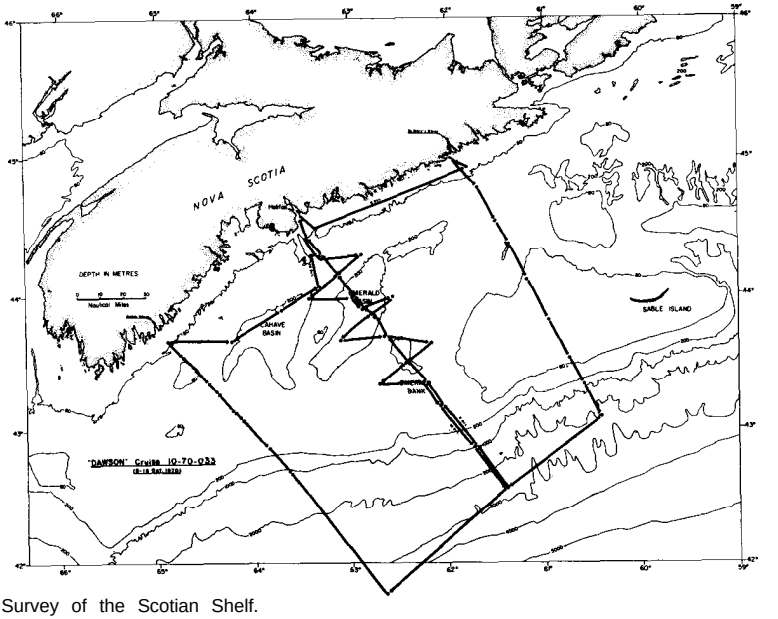
D.J. Lawrence

ToC

Scotian Shelf and Nova Scotian Inlets

The 'Halifax Section' across the Scotian Shelf consists of a number of oceanographic stations on a line normal to the coast from the mouth of Halifax inlet to beyond the edge of the Continental Shelf and has been one of the most extensively surveyed areas of the Atlantic seaboard. A review of the data in 1968 revealed that the slope of the mass-field varies greatly with the season, being nearly horizontal in summer and having the largest inclination at the beginning of January. It oscillates each year in exactly the same way, with little or no variation in the monthly mean. This infers a strong seasonal variation in the residual motion of the coastal current which is unidirectional from northeast to southwest. Applying the geostrophic approximation, the strength of the current in the upper layer is estimated to be 5 to 10 cm/s in the summer, 10 to 25 cm/s in the spring and fall, and about 30 to 40 cm/s at its peak in the beginning of January.

To verify these preliminary results, the survey was continued on a quarterly basis, but in order to also obtain information on the components of this current, the survey was extended to include two extra lines (see figure).



Survey of the Scotian Shelf.

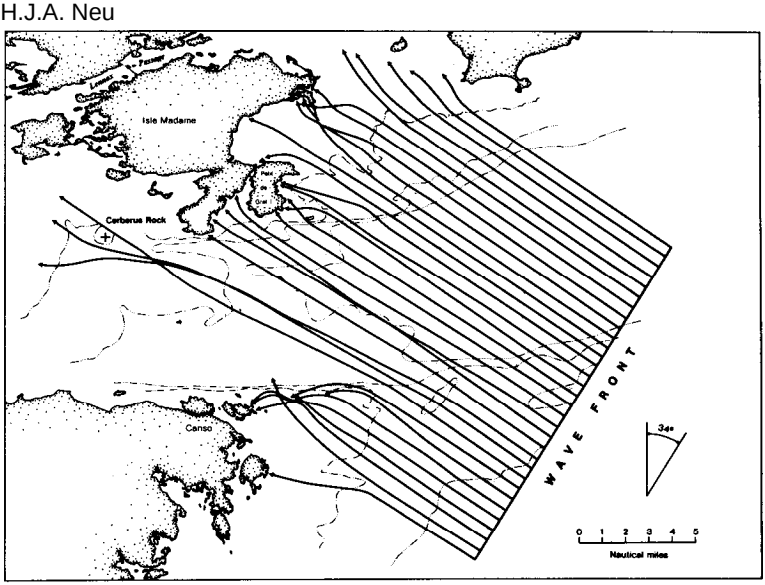
As was demonstrated by the *Arrow* disaster in February 1970, this type of information is essential in forecasting oil movements. Mineral and oil explorations over the Shelf and Grand Banks intensify its need.

H.J.A. Neu

During Operation Oil, early in 1970, a team was formed to assist the Task Force in problems of coastal engineering and to review the hydrodynamic factors which may have contributed to the grounding and destruction of the tanker *Arrow.* Wind, wave, salinity, temperature and current data were obtained for Chedabucto Bay and related inlets and channels, in order to gain a more comprehensive picture of the hydrodynamics of the system. Thus, it was possible to make predictions as to the movement of oil in general and of oil spills in particular; to give advice on the closing of the dam in Lennox Passage and on the installation of oil-retaining structures such as brush-booms; to provide wave data for the salvage operation; and etc.

By applying systematic interpretations based on observations and theoretical principles, it was concluded that the factors contributing to the grounding of the *Arrow* were a storm, which prevailed over the Atlantic seaboard on 4 February 1970, relatively large waves from the southeast (with heights in the open sea to 25 to 27 feet and at Cerberus Rock of 12 to 14 feet) and wind-driven surface currents toward the north. Excessively low Low-Waters during the days following the grounding hastened the destruction of the ship. The oil which escaped during grounding and break-up of the ship was largely contained in Chedabucto Bay by the prevailing winds.

H.J.A. Neu



Wave refraction diagram, Chedabucto Bay, for a wave of 10-second period with wave front at 34° azimuth.

While taking oceanographic observations in Chedabucto Bay following the February 4, 1970, wreck of the tanker *Arrow,* small oil particles were found to be suspended in the water column to depths as great as 80 metres. During February and March 1970 these particles were sampled with plankton nets and water bottles to investigate their origin, abundance, size range, vertical distribution, and their rate of spreading and drift. They were tracked out of Chedabucto Bay into the ocean and along the Nova Scotia coast to beyond Halifax, revealing a coastal flow of about 8 km per day.

W.D. Forrester

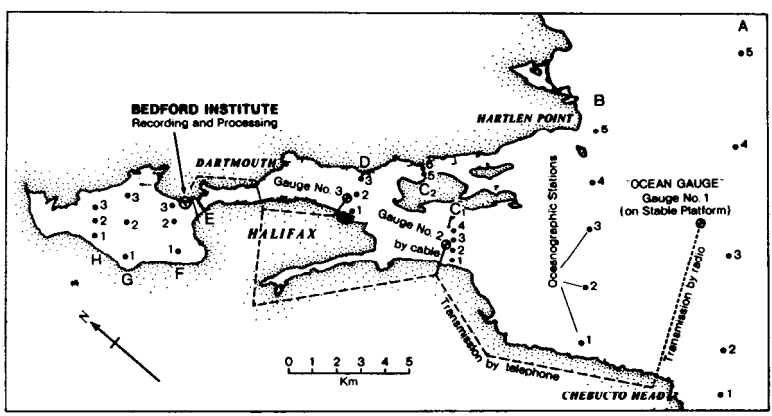
The construction of a causeway across the Strait of Canso in 1955 has reduced the formerly hazardous currents in the Strait and has kept the winter ice from the Gulf of St. Lawrence from reaching east of the causeway, thus creating one of the finest and deepest year-round harbours on the North American continent. Industrialization began in 1962 and is continuing at an accelerating pace today. The investment in the area will exceed $250 million by the end of 1971. Surveys have been carried out in the Strait in 1968, 1969 and 1970 with the twofold aim of measuring water quality and determining the patterns of water movement.

The water does not move with uniform velocity through any given cross section of the Strait. Instead, measurements from an anchored vessel have shown that one can have simultaneously an outflow in the upper and lower layers and an inflow in the middle layer, with the flow pattern persisting over an entire tidal cycle. What is, then, the driving force for this motion? There is virtually no fresh water entering the Strait, and wind-driven circulation does not seem to fit the measurements too well. Examination of one of the records from a current meter moored at 13 metres depth at the entrance to the Strait during July 1969 showed that there was an oscillation with a period of about four days and an amplitudetwice that of the tidal motion (10 cm/s versus 5 cm/s). It appears too regular to have been caused by meteorological conditions over the Continental Shelf although this possibility remains to be investigated. This phenomenon may have been an internal seiche. Using the measured density gradient, 0.001 g cm^{-3}/14m, and the dimensions of the Strait, the theory predicts that an internal wave would have a period of several days. It is hoped that data from the more extensive array of moored current meters of the 1970 survey will reveal more clearly the nature of the oscillation. Dye diffusion experiments have shown that the upper layer is influenced by the local wind, while parachute drogues released in the middle layer during various stages of the tide have suggested that there is a counterclockwise residual motion.

D.J. Lawrence

Halifax Inlet, which consists of the ocean approaches, the harbour and Bedford Basin, has in the past been only sporadically surveyed and then primarily for the purpose of relating the temperature of its water to the seasonal changes of the Shelf. The industrial growth of the city of Halifax and its neighbouring communities, their need for better harbour facilities, particularly with respect to containerization, and the increasing danger of pollution necessitate a comprehensive study of the hydrodynamics of the system. For this purpose, two types of investigations were implemented, a wave study and a circulation study.

The objective of the wave study is to determine the ocean wave energy which enters the harbour. To achieve this a wave survey system was installed in the summer of 1969, consisting of three wave measuring stations - dual gauges comprised of a wave staff and pressure sensor. The first station was located on the Stable Platform of the Air-Sea Interaction group, ten miles off the coast, the second near Maugher's Beach at the entrance to the harbour and the third in the centre of the harbour (see figure). The data were transmitted by radio or underwater



Wave survey system and oceanographic stations of Halifax Inlet.

cable and then by telephone line to the Bedford Institute, where they were recorded on strip charts and magnetic tape. The recorded data were analyzed both manually and by computer. In the computer application, the data were subjected to power and cross-spectrum analysis and to wave height versus wave period analysis. The results indicate that the energy transfer from the sea into the harbour is influenced largely by the direction of the local wind. With significant winds from the north, the wave heights arriving in the harbour are 5 to 10% of those measured outside. This information is necessary in assessing the harbour for the loading of containers.

The purpose of the circulation study is to evaluate the seasonal exchange of water. Salinity and temperature measurements are made

monthly on stations from the open ocean into Bedford Basin. From this data, supplemented by current meter observations, it should be possible to estimate the seasonal water and heat transport.

From the results, ways must be sought to increase flushing and thus decrease pollution. This might be achieved by encouraging an increased interchange with unpolluted seawater. Modifying Eastern Passage could be a step in this direction.

Careful consideration must also be given to any proposal which might further reduce the circulation and flushing; for example, breakwaters, wharf extensions, etc. Their effect must be studied in advance in order to avoid further adverse effects on the existing (still far from satisfactory) heat and pollution balance.

H.J.A. Neu

As part of the study of water quality fluxes in inlets, field work has been undertaken in Halifax and Petpeswick Inlets. Both of these inlets have basins; that is, a deep portion separated from the open ocean by a shallower sill. Therefore, the objective becomes twofold: to understand the fluxes in the upper layer of the inlet which is usually continuously exchanging with the ocean, and in the lower layer (in the basin) which is exchanging with the ocean only intermittently. The two inlets have been classified and fluxes of fresh water have been measured both directly and indirectly. In Petpeswick Inlet, the flushing of dye has been measured; in Halifax Inlet, fluxes of phytoplankton biomass, heat and biomass have been measured directly at the Narrows. Also, current measurements using six moored instruments have been maintained in the Narrows for six months - with recording scheduled for six more months. These current and flux measurements provide calibration for the budget equation models which are being developed. In addition, individual values for dilution factors and residence times have been calculated. Statistical analysis giving probabilities for extreme values or zero values of fluxes, envisaged for application in the upper layer models, is being applied first to give probabilities for exchange of the isolated deep water in the basins.

R.H. Loucks

ToC

Numerical Analysis and Data Processing

The Data Analysis group continued the reading and processing of Braincon and Hydrowerkstatten current meter films; digital magnetic tapes from Plessey and Geodyne meters are also analyzed. 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 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. Each film or tape represents the immersion of one current meter for a period of between 30 and 60 days.

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.

Data from the salinity/temperature/depth (STD) probes are currently stored on magnetic tape. We will shortly be able to send this data to the Canadian Oceanographic Data Centre, Ottawa, in a format that is acceptable to them on standard magnetic tape reels. A computer program has been written to effect this transmission of STD data gathered by Institute cruises.

F.K. Keyte

Short Studies

A brief physical oceanographic survey was carried out in November 1969 in the Conception Bay-Holyrood area, Newfoundland. The measurements of currents, temperature and salinity were used in an internal report on the probable dispersion of heated cooling water from the Holyrood Thermal Generating Station.

Limited oceanographic studies were initiated in the St. George's Bay-Stephenville, Newfoundland, area in November 1970. The program consisted of temperature, salinity and oxygen measurements, the release and tracking of dye spots and parachute drogues and measurement of currents with self-recording moored and portable current meters. In addition, a tide gauge and automatic weather station were operated during the survey. The data are presently being analyzed.

Current meter and tide gauge records for Petit Passage were analyzed to study the dynamics of the flow. Currents in the Passage are caused by differences in tidal amplitude and phase at either end of the channel. A one-dimensional mathematical model was developed and was able to predict currents in agreement with those observed.

G.H. Seibert

Support Activities

Technical field capability from the section supported the field activity for the section and assisted in field activities of other sections and universities. During this period more than 600 current meter and 250 temperature recorders were moored and recovered with a loss rate of less than 5%. The moorings ranged in geographical position from the Gulf of St. Lawrence to Drake Passage and the water depth at the mooring site ranged from a few meters to 3500 metres.

D.D. Dobson, T.R. Foote

Oceanographic Services for Defence

Established in 1960, Oceanographic Services for Defence has the role of developing techniques to provide a forecasting service in military oceanography and tactical indices for Canadian Maritime Defence Forces. It has been necessary to ensure that receipts of synoptic data are maintained, that specialized research projects are undertaken to provide further understanding of the oceanic environment, that a training program is maintained for the personnel who are primary users of the products, and that new methods of data acquisition are investigated and adopted when suitable. In the provision of a service it is equally important to monitor the applicability of the products as it is to develop techniques to produce them.

Cooperation in military oceanography has been a noteworthy development within NATO over the past several years. This cooperation has taken the form of increased data and information exchanges, standardization of techniques, and comprehensive oceanographic research programs. A seminar on training practices and content was held in Halifax in 1969. Under the auspices of the NATO group on Military Oceanography a code for the handling of biological observations from ships and aircraft has been developed by Oceanographic Services for Defence. This code has been received enthusiastically and is expected to make valuable contributions to studies of the distributions and movements of marine biological organisms.

In the production of oceanographic charts based on data collected synoptically, note has been taken of the appearance of anomalous features in the physical oceanographic structure of the waters between Nova Scotia and Bermuda. An investigation of these features to gain an understanding of changes taking place was undertaken by a series of four seasonal cruises with a network of closely spaced observations. The final cruise in the series was completed in 1969. The waters are extremely complex and the so-called anomalous features are in part small eddies that constitute the Gulf Stream system and in part observational errors. Small features are not capable of being depicted

on charts in current use because of the scale size of the charts and the paucity of data. Investigation has been undertaken in the use of infrared satellite photographs received by automatic photo transmission. Results to date show that this method has great potential for use in the production of charts of synoptic oceanographic conditions. Unfortunately, at present both the scale and the geographical location techniques are inferior to the methods of describing the oceanic features currently in use. Work is continuing in this promising field.

Since 1962 a daily series of oceanographic chart broadcasts via radio facsimile for the northwestern Atlantic Ocean has been available. Although the broadcast content is designed to meet the needs of Canadian Defence Forces this particular series of charts has been of use to meteorological offices ashore and afloat, to transatlantic shipping and to marine interest engaged in fishing and whaling. Files of these charts have also proven a boon to fisheries researchers as an environmental data source.

As a back-up to the radio facsimile broadcasts, copies are distributed weekly by mail to interested organizations who do not have the radio receiving equipment. A brief check of the mailing list shows a widening sphere of interest; the number of recipients has doubled since 1967.

The realization of the importance of oceanographic conditions in human activities by marine interests has been reflected in the number and diversity of 'in depth' studies of the ocean environment that have been requested. The range of requests embodies conditions for the selection of military exercise areas as well as the conditions in prescribed areas, geophysical prospecting, commercial plant construction, marine vehicle procurement, and equipment testing.

W.B. Bailey

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B.R. Pelletier

V. Asthana[4]
R. Banerji[4]
G.A. Bartlett[2]
L.C. Brown
D.E. Buckley
D.F. Clark
D.A. Clattenburg
V.F. Coady
R.E. Cranston[1]
G. Drapeau
G.B. Fader[1]
R.A. Fitzgerald[1]
F.E. Frape[1]
C.A. Godden
M.E. Gorveatt
A.C. Grant
I. McK. Harris[1]
W.H. Josenhans
L.H. King
K.M. Kranck
B. MacLean
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M.A. Rashid
K.R. Robertson
C.T. Schafer
G. Vilks
F.J.E. Wagner
D.A. Walker

With the completion of the HUDSON 70 cruise another major portion of Canada's 3.6 million square km of continental shelf had been surveyed. Marine geologists charged with the exploration and inventorying of this vast area have carried out reconnaissance studies off the British Columbia coast, the northwest Pacific and Arctic Oceans adjacent to Alaska, the Beaufort Sea, much of the Arctic Archipelago and Baffin Bay, Hudson Bay and approaches, the Labrador Sea, the western Atlantic Ocean over the Grand Banks of Newfoundland and Scotian Shelf, the Gulf of St. Lawrence and the Bay of Fundy and its embranchments.

Marine Geology carries out its assignments under a traditional fourfold division of effort involving physical geology (sedimentology, physiography, and bedrock studies), regional geology (a special geological project over the entire Scotian Shelf), geochemistry and micropaleontology. These disciplines are not always included on each cruise due to the nature of the project or the size and scope of the operation at sea. However, two major multi-disciplinary cruises, each of ten weeks duration, took place involving physical oceanography, biology, micropaleontology, sedimentology and seismology, magnetometry, and gravimetry. One cruise was the trans-Atlantic voyage in 1969 to Lisbon which was highlighted by the following: a transect of the various water masses between the Grand Banks, Sargasso Sea, northwest Africa, southwestern Europe, and the eastern Canadian seaboard; plankton studies in these waters; obtaining sediment cores from the major ocean basins in the North Atlantic; obtaining numerous rock cores of coralline

[1] Joined AOL

[2] Left AOL

[4] Postdoctoral Fellow

limestone and basalt from the Mid-Atlantic Ridge by means of the hydrostatic drill; carrying out a seismic survey of the Flemish Cap 500 km east of St. John's, Newfoundland, at the edge of the continent; and obtaining a rock core of granite from the Flemish Cap thereby establishing unequivocally the continental nature of the crust in that area. Our other major multi-disciplinary cruise was aboard the CSS *Hudson* on her voyage from Victoria, B.C., to Halifax, N.S., via the Northwest Passage through the Arctic Islands as part of HUDSON 70 (see "Earth Sciences Studies in Arctic Marine Waters, 1970").

Our diving and submersible programs have continued and with the use of lock-out diving from the submersibles, many of these underwater activities have been combined into a single program. The unhappy accident of the *Arrow* disaster in Chedabucto Bay has given rise to a renewed effort in coastal geodynamics involving ocean dynamics as well as coastal processes of erosion, sedimentary transport, and deposition.

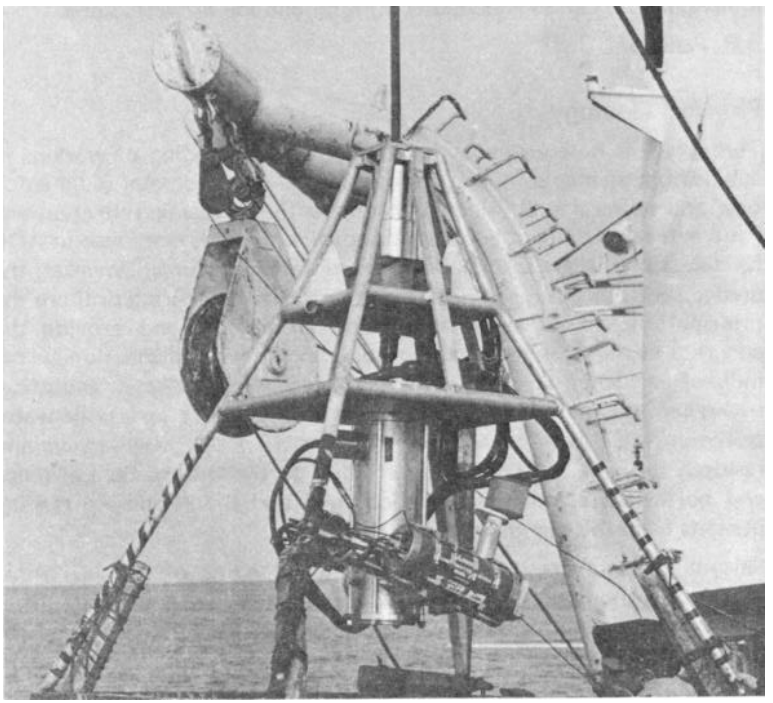
Great strides have been made in our regional geology program with the mapping of the Scotian Shelf in which geophysical as well as geological information has been fairly well utilized. On the Labrador Shelf and on the shelf adjacent to northeastern Newfoundland, another geological mapping project is nearing completion. Northumberland Strait and parts of the Gulf of St. Lawrence are finished and now the program is moving to include Bay of Fundy, the Grand Banks, and the Laurentian trough area.

Regional problems on sedimentation involving the relationship between textural distributions and hydrodynamic environments are being undertaken for Hudson Bay, Beaufort Sea, Baffin Bay and Bay of Fundy. Also carried out at sea is the on-going regional study of foraminiferal ecology based on seasonal variations at given latitudes.

Closer to home, ecological studies are being made in the inshore areas of the Atlantic provinces with a definite emphasis on aspects related to monitoring pollution. All information is extrapolated to the ancient sediments in an attempt to reconstruct the environment of deposition, interpret the ancient geography and climatology, and attempt to gain clues to the complex of problems involving ecology, evolution, speciation, zonation, and taxonomy. In the laboratory these studies are complemented by experiments in aquaria where living foraminifera are being cultured.

The geochemistry program is now operating under two main sub-divisions of organicand inorganic geochemistry. Again some emphasis is placed on the environment with respect to pollution, but generally the problems involved the precipitation of metallics in organo-clay complexes, the exchange of ionic material between sea water and particulates in suspension, the tracing of elemental transport, the

relationship of organic acids and marine sediments with a view to relating chemical structural changes to changing geological conditions over long periods of time, and the laboratory investigation into the structure of layered silicates as well as organo-metallic complexes.



Underwater television camera being lowered from the CSS Hudson, Beaufort Sea.

In our shops, the underwater rock-coring drills have been improved so that both a short- and long-masted version are available. Because these drills are operated by means of the ship's electrical power, it is possible to install various monitoring devices such as underwater television, acoustic links, and indicators of rotary speed and rate of penetration. Special plankton sampling gear is being renovated in hopes of obtaining a successful multiple-type tow, as well as a remotely controlled deep-water sediment trap.

One of our busiest installations is the Jeolco scanning electron microscope which has been made available to a great many outside laboratories and individuals. At present, peripheral equipment is being selected such as a non-dispersive, non-destructive x-ray attachment that will be used to obtain additional information of the spectral variety from the secondary random x-rays generated by the primary electron

beam on the sample. Several reports have been enhanced by the exceptional quality of the SEM micrographs, and many of these illustrations are being used for display purposes and filming. But the real highlight of the instrument is the valuable insight it has provided to mineral identification and studies on foraminiferal infrastructures.

B.R. Pelletier

Physical Geology

This group is heterogeneous in composition, consisting of workers in sub-bottom stratigraphy and structure, marine and coastal sedimentology, and submarine physiography. Conventional seismic reflection and bathymetric profiling are the chief indirect methods employed at AOL for the study of the sea floor and its subjacent features. However, the dredge, bottom grab, sediment corer and the rock-coring drill are the principal means for obtaining geological material and provide the concrete evidence needed for extrapolating known information to the indirect evidence of the graphical records. Side-scan acoustical surveying together with both bottom photography and underwater television are providing additional information. All our surveys and research projects from the Scotian Shelf to the Gulf of St. Lawrence and northward across the Labrador Shelf and the Arctic are reaping benefits from this combined methodology.

Several projects are devoted to an understanding of hydrodynamic conditions and their effect on sedimentational patterns. Data from ocean dynamics is constantly being utilized so that the framework of marine sedimentation can be examined critically and be applied to ancient regimes of sedimentation. In this manner ancient oceanic conditions can be interpreted in part.

B.R. Pelletier

A seismic profiler survey was carried out in the region of Flemish Cap. Total coverage amounted to approximately 100 km of profiling over Flemish Cap and the eastern Grand Banks. The seismic equipment employed for this survey comprised a single channel recording system with a 10 cubic inch air-gun energy source. Flemish Cap is a continental structure, physiographically isolated from the Grand Banks by Flemish Pass. The relatively smooth, erosional surface of Flemish Cap is cut on a central zone of seismically 'hard' basement, which is encircled by outward-dipping layered rocks. These layered rocks are also truncated at the flanks of Flemish Cap. Flemish Pass is underlain by a thick accumulation of sediments, which is at least in part a continuation of prograding beds underlying the slope off the eastern Grand Banks.

A.C. Grant

A reconnaissance seismic profiler study of the Canadian continental margin east of Newfoundland, from Hudson Strait south to the Grand Banks, has been in progress since 1965. The seventh cruise in this program yielded approximately 6150 km of concurrent reflection seismic and magnetic coverage in the region from southern Labrador Shelf to southern Grand Banks. The survey track passed over the locations of seven test holes drilled on the Grand Banks in 1965 by Amoco (formerly Pan American) and Imperial Oil, as well as the sites of the 'Tors Cove' and 'Grand Falls' wells. A number of zones of exceptional gravity and magnetic anomaly in the Grand Banks region were also investigated, and several presumed diaperic structures were traversed. A 900-km survey loop was run eastward off the continental shelf to obtain coverage over Orphan Knoll, which forms a prominent rise at the foot of the continental slope about 350 km north of Flemish Cap. Seismic reflection records show a strong acoustic basement at shallow depth beneath the surface of this feature, and the absence of magnetic relief suggests that this acoustic basement is probably composed of continental material. This feature was later selected as a JOIDES drilling site, and cores recovered there by the *Glomar Challenger* in June 1970 confirmed its continental origin.

A.C. Grant

The role of tidal currents in the residual transport of sediments in Northumberland Strait was examined and used to explain features in the sediment distribution in Northumberland Strait. Suspended sediment sampling, light extinction measurements and current measurements are being carried out in the Strait. Work has progressed on a study of the sediment distribution and Pleistocene history, including the formation of a preglacial drainage system, glaciation, postglacial transgression of the sea and the assumption of present day conditions.

K.M. Kranck

The surficial sediments covering the sea floor form the lower boundary of the ocean. The mechanisms of sedimentation are then directly related to the hydrodynamics of the ocean. However, because of Pleistocene glaciation, it is in many instances difficult to determine whether the distribution of bottom sediments, as found today, resulted from the combined action of waves and currents or not. Hence a study is being made of the geodynamics of surficial sediments in the littoral and sublittoral environment.

Grab sampling, interpretation of echograms, underwater photography, underwater television, and visual observations from submersibles permit analysis of the nature of bottom sediments (texture, slope, settling velocity) as well as of the dynamic sedimentary structures (ripples, sand waves, channelling, etc.).

Since hydrodynamic data are difficult to obtain, observations concerning bottom sediments are concentrated in areas, such as the Strait of Belle Isle and the Scotian Shelf, where data on bottom currents are available. Wave statistics are also used to estimate the amount of wave energy transferred to the unconsolidated sediments. The results obtained so far indicate that the hydrodynamic energy at the ocean sea floor interface is often underestimated. At the upper edge of the continental slope, for instance, upslope current ripples clearly indicate that the bottom currents in that area are much stronger than what is anticipated from the present knowledge of ocean circulation.

G. Drapeau

The wreckage of the tanker *Arrow* in Chedabucto Bay has resulted in heavy contamination of the seashore. Within the framework of

"Operation Oil", polluted seashores were surveyed in order to estimate the damage done and particularly to find out what the principal geodynamic mechanisms are that enhanced the natural cleaning of seashores.

Time lapse photographic studies of an oil-contaminated beach being conducted on Crichton Island, Chedabucto Bay.

Crichton Island was designated as a protected area in which long term scientific projects could be carried out. The geodynamics of a heavily polluted beach is being monitored in order to determine how oil will eventually disappear and what processes are responsible for the eventual disappearance of oil from the seashore. Among the most interesting data to correlate with the sedimentological surveys are the wave

refraction patterns, the geostrophic winds computed for the area, the energy spectra of the waves generated inside and outside Chedabucto Bay, and the nearshore current measurements. The results obtained so far indicate that long period waves generated outside the Bay are responsible for the major changes observed on the seashore.

G. Drapeau

Russian, American and Canadian biologists are engaged in a cooperative program to study herring spawning in the western Atlantic. The types of sediments and the geodynamic conditions that prevail on spawning grounds are being analyzed to help biologists gain a better understanding of this phenomenon. Herring are known to congregate in specific locations to spawn, although the factors that control herring spawning are not clearly understood. A survey on Georges Bank indicated, for instance, that in that area herring spawned exclusively on fine gravel swept by strong currents. Repeated surveys in the same area as well as comparative surveys on other spawning grounds will provide the data necessary to confirm the present hypotheses.

G. Drapeau

Mathematical models such as trend surface analysis and factor analysis (correlation studies) are used to analyze sedimentological problems; the former to differentiate dominant trends from local variations. It is particularly useful in sedimentology to recognize sedimentary trends that are partly obliterated. Investigations carried out so far have served to compare factor analyses of the distribution of surficial sediments on the Scotian Shelf with detailed geological surveys of the area.

Wave refraction diagrams are used to estimate the amount of energy and the angle of approach of waves of different wave length approaching monitored seashores. Although wave refraction diagrams are based on relatively simple wave models, they were used with much success, particularly in Chedabucto Bay where regions of efficient natural cleaning of the shore could be associated with wave action.

G. Drapeau

The distribution of marine sediments may be partly explained by means of various models of sediment transport (from their source on land to their ultimate repository in the sea). Because the study deals with elastic or granular sediments, the models can be constructed on the data derived from a mechanical analysis of the sedimentary particles. Such properties as size, roundness, shape, and the gross aspects of overall texture which involve lithologic ratios, population studies and the attendant statistical analyses are considered in the synthesis of the model. These models utilize various aspects of topography such as position of the sediment in the depositional site with respect to slope

and depth. Finally the models are interpreted on the basis of hydrodynamic vigour.

Several studies are presently underway. In Hudson Bay the models demonstrated the threefold influence of ice-rafting, marine currents and deposition from suspension. In the Minas Basin, the models showed that the sediments are in equilibrium with the minimal energy conditions present and that sedimentation is taking place in an environment of excessive hydrodynamic vigour. In the adjacent Bay of Fundy, sedimentation based on the models of sedimentary transport appears to be occurring in a very high energy regime, although in many areas the model demonstrated normal sedimentation for an open-ocean environment such as that over the nearby continental shelf.

This study will eventually include the development of these models for the Beaufort Sea, Arctic Archipelago and Baffin Bay and will entail a literature review on work previously carried by other workers in marine areas not investigated personally. From these studies certain unifying principles of sedimentation will be sought.

(See B.I. Contribution No. 77, 117, 121)

B.R. Pelletier

ToC

Regional Geology

The Regional Geology group is presently undertaking the study of the geology on and beneath the seafloor across the Scotian Shelf and adjacent areas, and plans to extend its area of responsibility to the Grand Banks. The work is of practical value to fishermen, oil companies, various engineering construction groups, mining engineers, cable companies, environmental scientists, and other scientific disciplines involved in the area of study.

In 1970 the group released its first surficial geology map of the Scotian Shelf, overprinted in colour on Fisheries Chart 4040 at a scale of 1:300,000 (B.I. Contribution No. 153). The chart covers the area from Halifax to Sable Island and was accompanied by a paper describing the stratigraphic sequences and geological history of the Quaternary map-units. Field and laboratory studies have been completed for two further charts (40396 and 4041G) and these will provide complete coverage of the Scotian Shelf.

Further study has been devoted to the Scotian Shelf end-moraine complex (see B.I. Contribution No. 112) and it is now known to extend from the Laurentian Channel to the central part of the Gulf of Maine. It probably correlates with the New England system and is of value in interpreting the regional, glacial history of the region.

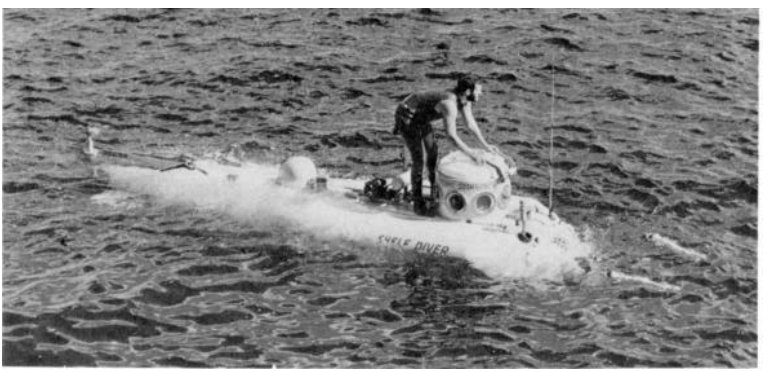
Pockmarks or cone-shaped depressions have been noted to occur in profusion across some mud bottoms on the Scotian Shelf. They were possibly formed by ascending gas or subsurface water leakage from underlying coastal plain sediments. Their distribution might be useful as a prospecting tool.

Bedrock studies are contributing to an entirely new chapter in the geologic history of the Atlantic provinces dealing with mid-late Mesozoic and Cenozoic marine rocks which do not occur on land. The geology is interpreted on the basis of structural and stratigraphic relationships and acoustical reflectivity as revealed by a study of continuous seismic-reflection profiles, geomorphic aspects, bedrock control from adjacent shore geology, a few dredged samples and offshore well data, and gravity, magnetic, and seismic refraction data. (See B.I. Contribution No. 60, 80, 170,204.)

The geology of the offshore falls into four major divisions: a Triassic Basin which occurs in the Bay of Fundy and northern Gulf of Maine; an area of acoustical basement and sedimentary outliers which underlie the eastern and central part of the Gulf of Maine; a Coastal Plain Province of Tertiary and Cretaceous strata which underlies Georges Bank, the Scotian Shelf, and the outer part of the Laurentian Channel; and an area of pre-Pennsylvanian acoustical basement and Pennsylvania strata which extends south and east of Cape Breton Island beneath the Laurentian Channel. A geological map of the Scotian Shelf and adjacent areas on a 1: 1,000,000 scale is in preparation and will be the subject of a departmental publication. (See B.I. Contribution No. 206.)

Geological sampling was carried out from the CSS *Kapuskasing* on the Scotian Shelf and adjacent areas. Approximately 300 bottom samples, 5000 km of echogram profiles, and 2160 km of continuous seismic-reflection profiles were obtained. Underwater photography was successfully carried out at 23 stations.

In 1969 the group used the submersible, *Shelf Diver,* to complete four



Shelf Diver, diver lock-out submarine in Bay of Fundy.

successful dives on the Scotian Shelf. The main objectives of the dives were to check areas that were thought to be well known through the use of remote sensing techniques. The dives confirmed previous indirect observations and permitted the investigators to take many selected photographs, procure bedrock samples, and visit several pockmarks.

L.H. King, B. MacLean, G. Fader

ToC

Geochemistry Group

The organic geochemistry subgroup attempts to characterize the chemical nature of organic matter associated with marine sediments and to correlate the structural changes that occur in these compounds as they are subjected to diagenetic and metamorphic changes leading to the formation of oil shales, crude oils and other petroleum-like compounds; to ascertain the geochemical role that such compounds play in the zone of sedimentation especially in the phenomenon of solubilization, transportation, precipitation and accumulation of various metals; to determine the nature of organo-clay complexes and the catalytic effect of clay minerals in conversion of organic molecules to hydrocarbons; and to determine the significance of dissolved organic matter as an ecological factor governing the primary productivity of coastal waters.

The phenomenon of migration and accumulation of metals in all natural environments is largely associated with humic compounds. Our studies indicated that each gram of humic acid is capable of complexing 20-65 and 95-205 mg of tri- and di-valent metals respectively. The low molecular weight fractions (<700) complex 2-6 times more metal than any high (>700) molecular weight fraction. The infrared spectroscopic studies suggest that the carboxyl groups of humic acid participate in a metal chelation phenomenon. The complexed metals could not be extracted with 1.0 N ammonium acetate solution.

In order to understand the catalytic effect of clay minerals in the conversion of organic molecules, studies were initiated to determine the nature of the association of organic matter with various clays. The infrared analysis, differential thermal analysis, and thermogravimetric analysis of the organo-clay complexes indicated that the reaction occurs through the carboxyl group of organic matter. In addition to chemical reaction. physical adsorption is also important. The physical adsorption is facilitated by the presence of electrolytes and low pH conditions which probably change the electro-kinetic properties of reacting colloids.

The ratio of aromatic to aliphatic components of humic acid determines its solubility, resistance to degradation, coagulation by electrolytes and many other properties. A study of several humic acids of marine origin suggests that these compounds are predominantly aliphatic (and are thus less soluble, have a higher resistance to degradation and are very susceptible to coagulation). Only about 30-35% of the total carbon was found in aromatic form, the rest being aliphatic. The aromatic components may play an important role in post-depositional changes of organic matter.

In determining the chemical nature and characteristics of humic compounds it is essential to investigate the nature of functional groups such as quinones, present on organic molecules. The biological activity of humic acids is associated with their quinone structures because they serve as catalysts in oxidation reduction reactions which pass through the stage of free radical formation. These groups are also responsible for condensation reactions and for the formation of complexes with the transfer of charge. The chemical and infrared spectroscopic studies indicate the presence of quinone groups in concentrations ranging from 1.8 to 2.8 meq/g of organic matter.

Various amino acids are believed to be an integral part of humic acid. A quantitative and qualitative estimate of amino acids elucidates not only the structural details of humic compounds but will also be helpful in determining the age of sediments and rate of sedimentation. Our studies suggest the presence of 16 different acidic, neutral and basic amino acids in varying quantities; the predominant amino acids are aspartic acid, glutamic acid, arginine, glycine, leucine and phenylalanine.

The coastal waters are rich in dissolved organic matter which eventually gets incorporated into the bottom sediments. It is also an important ecological factor enhancing the fertility of coastal waters. The chemical and spectroscopic characteristics of humic compounds isolated from seaweed exudate, their decomposed thalli, and the dissolved organic matter in river water show that in spite of several differences the gross structural features of these compounds are similar to those of humic acids isolated from sediments.

In addition to the projects listed above, more research is underway on organo-metal and organo-clay complexes.

M.A. Rashid

In inorganic geochemistry the overall objectives are to determine the chemical activity of dissolved elements in sea water which includes the distribution and transportation of major elements such as Na, Ca, Mg, Li, Sr, and K and trace elements like Mn, Fe, Co, Ni, Cu and Zn; to determine the chemical interaction of sea water with solids including

the various clay minerals; and to ascertain the geochemical history of sea water and marine sediments. These studies are carried out with a view to constructing a scientific model which may be useful in predicting the cycle or eventual site of deposition of chemical species in the marine environment. The information gathered under various research projects of organic and inorganic geochemistry will also be helpful in tackling problems in pollution of the environment.

Preliminary analyses of metals were conducted on several samples collected from Boat Harbour, N.S., Restigouche River, N.B., Annapolis and Cornwallis Rivers, N.S., and Bedford Basin in association with pollution studies.

Geochemical techniques are now available for elemental analysis of fresh water, salt water and layered silicates. In addition to suitable modifications introduced into several existing techniques, new techniques for the determination of 16 major and trace elements in fresh and salt waters by atomic absorption spectroscopy and a method for a single digestion of silicates for the analysis of 19 different elements have been developed. A new technique for the analysis of mercury in sediments and waters employs flameless atomic absorption spectroscopy. This method allows determination of Hg to 0.03 ppb in sea water and 0.05 ppm in sediments. Our laboratory was also involved in the analysis of 11 trace metals in sea water for the purpose of an inter-laboratory calibration study in collaboration with the Woods Hole Oceanographic Institution.

D.E. Buckley, R.E. Cranston

ToC

Micropaleontology Group

The Micropaleontology group is presently investigating the distribution and ecology of northern and temperate species of planktonic and benthonic foraminifera, molluscs and coccolithophores that live in today's oceanic and coastal marine environments and their associated fossil remains which are preserved in bottom sediments. The study of living species provides the required baseline information for high resolution paleoclimatic and paleo-oceanographic studies of the Quaternary history of North American coastal waters and the North Atlantic and Arctic oceans. The field and laboratory investigations of living benthonic foraminifera in locally polluted nearshore environments is receiving special attention in order to relate the distribution of these protozoans to other invertebrate zonations that have developed in response to the discharge of industrial effluents and sewage into the marine environment. The monitoring of recovery rates for the coastal zone is an especially important benefit of these investigations. Attempts are also being made to describe quantitatively the complicated seasonal and spatial distribution of planktonic and benthonic foraminifera by

means of specialized sampling methods and statistical treatment of data. These quantitative investigations are being integrated with descriptive studies of minute variations in test morphology with the use of the scanning electron microscope.

The present condition of the Restigouche estuary offers a unique opportunity to investigate the distribution of benthonic foraminifera living in locally altered environments. Most of the pollutants entering this estuary are discharged primarily along the New Brunswick shore while relatively unpolluted areas are available for comparative study on the Quebec side. Analysis of the local distribution of foraminifera indicate that *Elphidium incertum/clavatum* and *E. orbiculare* are the most pollution tolerant forms and that they occupy the perimeter of the 'azoic' zone which develops near most effluent sources.
C.T. Schafer

During the summer of 1969 the submersible *Shelf Diver* and a team of Canadian Navy divers were employed to sample quantitatively the benthonic foraminifera population in the Gulf of St. Lawrence. Sampling techniques were designed specifically so that divers, who were 'locked-out' of the submarine at water depths ranging from 16.5 to 53 metres, could collect undisturbed, replicate short cores of bottom sediment. The analysis of these samples showed that, in the Gulf of St. Lawrence, the living foraminifera population have a pronounced patchy geographic distribution in waters less than 20 metres deep. Species proportions in replicate samples were most variable in waters less than 20 metres deep and live specimens were commonly encountered to a depth of 9 cm in the bottom sediments.

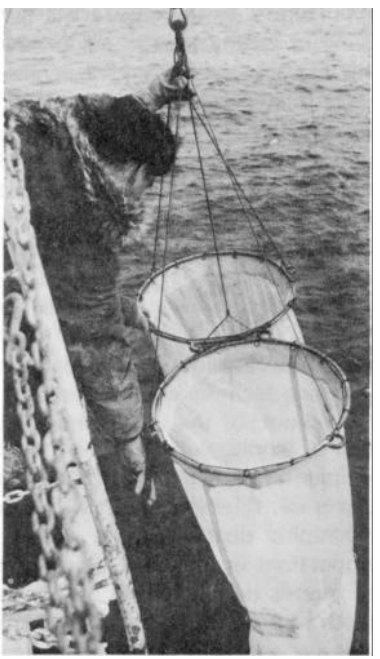
C.T. Schafer

Monthly foraminiferal sampling procedures were carried out from November 1969 to December 1970 in Clam Bay, Nova Scotia. The construction of a large fish farm in 1969 afforded the opportunity to monitor variation in the distribution of foraminiferal species caused by the introduction of warm, low saline, nutrient-enriched water discharged from a newly installed outfall. Sampling was performed by SCUBA divers who collected the top 5 cm of sediment at each station both before and after the discharges from the outfall were initiated. Preliminary results suggest that the warm, low saline water introduced into the study area was not detectable at the control stations. However, nutrient-enriched water, introduced into the Bay on a six-hour periodic basis, appears to be related to a reduction in species and Foraminiferal Number.

D.F. Clark

During the HUDSON 70 expedition benthonic foraminifera and Mollusca from the bottom sediments in the Beaufort Sea of the southern Arctic Ocean (between approximately 69°10' and 71°35' north latitude and 128°20' and 140°40' west longitude) were sampled.

Dredge haul coming aboard the CSS *Hudson,* Beaufort Sea.



Biological tow coming aboard the CSS *Hudson,* Beaufort Sea.

Ninety-eight grab samples and 12 dredge hauls were taken in water depths that ranged between 15 and 1426 metres. Preliminary investigation has shown a paucity of molluscs throughout most of this area. They were present in greatest numbers and variety in the shallow waters east of the Mackenzie Delta. The distribution is apparently related to the texture of the bottom sediments. Arenaceous foraminifers are the dominant forms in the deeper waters (generally deeper than 500 or 600 metres), with calcareous species dominant in the shallow waters.

F.J.E. Wagner

In July 1970 nanoplankton studies, with emphasis on geological applications, were initiated in the Beaufort Sea. Efforts are being focused on the calcite-secreting Coccolithophoridae, which serve as excellent chronostratigraphic indicators in sediments of Jurassic to Recent age. Little is known about the paleo-environments of nanofossil

species, but with new emphasis on the study of this particular phytoplankton group this gap in our knowledge should continue to fill.

A nanoplankton survey was conducted in a part of the Arctic Ocean where previous reports had suggested that the genus *Discoasteromonas,* an 'extinct' Tertiary nanoplankton, was living under frozen sea conditions. To date, collected samples do not substantiate this claim; however, small numbers of other coccolithophores have been observed. This find demonstrates that coccoliths can be used to investigate paleo-environmental changes ranging from arctic to tropical conditions.

D.F. Clark

In conjunction with other station work of HUDSON 70, planktonic foraminifera were collected from surface waters in the Arctic.

Globigerina pachyderma was found in abundance at all offshore stations including those in the Beaufort Sea and most of the Northwest Passage. This species was absent in the inshore waters of Beaufort Sea and in the central part of the Parry Channel system. The relative abundances of the species living in the surface waters will be used to determine the present oceanic influence in the Mackenzie River delta area and in the Parry Channel system. The occurrence of G. *pachyderma* in subsurface layers of sediment cores collected in the area will be used as a criterion to determine any changes in the marine environment in the western Canadian Archipelago during Holocene time.

Two field parties based at Tuktoyaktuk, N.W.T., continued the investigation of inshore marine environments in the Canadian Arctic Archipelago. Samples of bottom sediment were collected in the area which encompasses the westernmost extension of the region investigated since 1960 and represents a transitional zone from the interisland areas to the east and the epicontinental environment with its associative extensive runoff to the west. In a preliminary study of the bottom sediment samples, benthonic foraminifera such as *Ammotium cassis* and *Elphidiella groenlandica* were observed in the western, epicontinental environment but not in the sediments of the Arctic Archipelago to the east.

G. Vilks

During 1969 and 1970 planktonic foraminifera were collected in the surface waters at numerous localities in the Atlantic. In most localities the tows were taken in conjunction with salinity and temperature measurements. The project is designed to accumulate information on the seasonal and spatial changes in distribution of planktonic foraminifera and to associate foraminiferal faunas with water-masses recognized by physical methods. These data will be used to support a

general study in paleo-oceanography and paleoclimates in the North Atlantic.

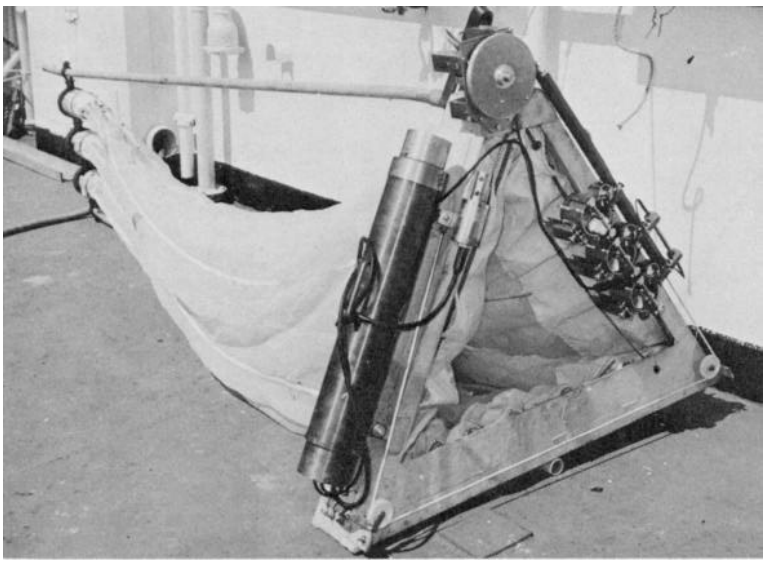
G. Vilks

A series of rock cores was drilled on the crest of the Mid-Atlantic Ridge near 45°N using a hydrostatic drill developed at AOL. Samples were collected from various peaks, in water depths ranging from 715 to 1682 metres. A detailed description of the area and the cores was reported in the March 1970 issue of *Geotimes* and in volume 5 of *Maritime Sediments.* The crest of the Ridge between 40° and 55°N seems to be ideally suited to study variations in the rate of Quaternary carbonate deposition. This situation is enhanced by certain planktonic organisms living in the overlying waters because these calcite-secreting plants and animals have adjusted their northern limit of distribution over approximately the same latitudes depending on climatic conditions. The Quaternary paleoclimatic history of this part of the North Atlantic is recorded therefore in unconsolidated sediments by the presence and absence as well as changes in the relative abundances of microfossil species. In the limestones that have formed on the Ridge crest, long term variations in climate appear to be reflected by precipitation of carbonate (during warm periods) and solution and unconformities (during cold periods). The area appears, consequently, to be characterized by sediments having an inter-tonguing stratigraphic framework which, when finally mapped in detail, should delimit both the number and intensity of the aforementioned climatic variations. Radiocarbon dates of coralline limestone cores determined thus far are in good agreement with this hypothesis.

C.T. Schafer

During HUDSON 70 (May and June), 29 plankton tows were taken in the Pacific along longitude 150°W between Tahiti and latitude 55°N. The stations were located at intervals of approximately five to seven degrees of latitude; three oblique tows were made at each station using a specially modified Benthos telemetering plankton net system. The sampler was set to open and close its three nets at depths of about 150, 450 and 900 metres, thus providing subsamples from three distinct layers. Efforts will be made to correlate the distributional pattern of the observed species with chemical and hydrological parameters measured simultaneously and to determine various ecological factors responsible for the distribution and morpho-structural changes in these organisms.

In all, more than 30 species have been identified of which 20 are receiving detailed study. For certain species the smaller forms appear in



Benthos Multiple Plankton Sampler and associated acoustic telemetry equipment used during Tahiti-Vancouver leg of HUDSON 70 cruise.

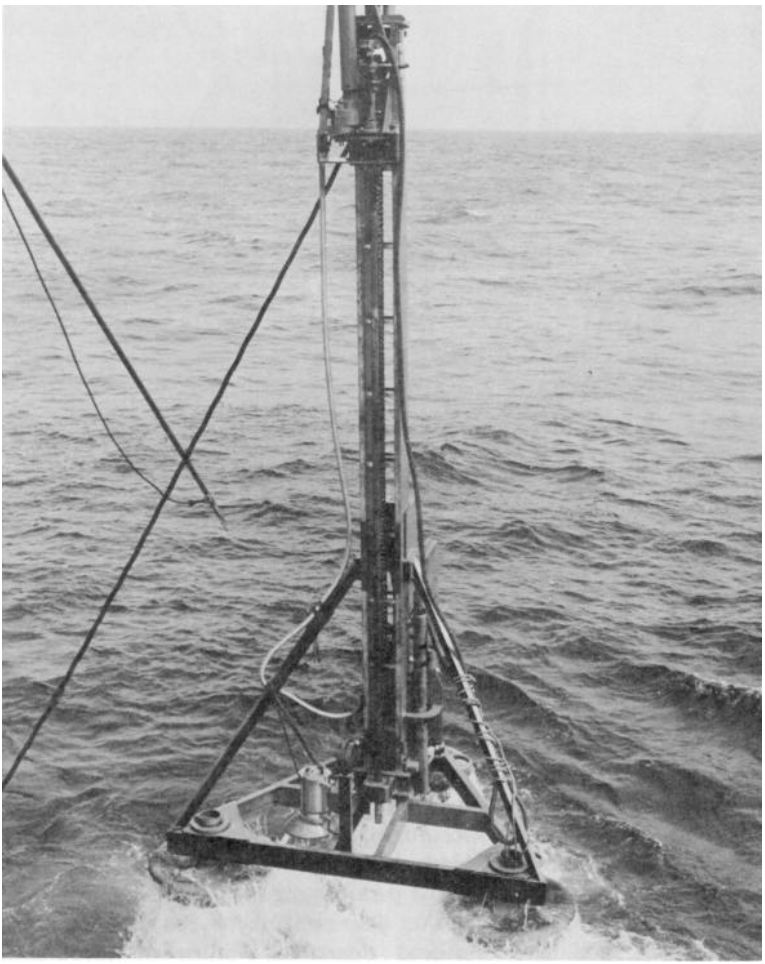
great numbers in cold water at higher latitude but are considerably reduced in frequency in equatorial waters. The determination of coiling indices of several species indicates that *Globigerina pachyderma* changes from dextral to sinistral coiling at about 42°N latitude. In surface waters the change to sinistral types is apparent at lower latitudes. Development of kummerforms was observed in several species including *Globigerina pachyderma* and *Globoquadrina dutertrei* and to a lesser extent in *Globigerinoides sacculifera, G. conglobata,* and *Globorotalia tumida.* It was noted particularly in species living in deeper waters and at higher latitudes. At times, the penultimate chamber is considerably smaller than normal revealing that development may be retarded at an earlier stage and later restored upon the return of favourable conditions.

R. Bannerji, C.T. Schafer

ToC

Special Instrumentation and Experimentation

In the spring of 1969, trials were carried out on a newly constructed all-electric rock coring drill developed at AOL. The drill, which stands 18 feet in height and has legs spaced eight feet apart in a triangular configuration, is designed to operate from ship's power at a depth of 1400 feet. It is actuated remotely on the sea floor by means of a control panel onboard, and has both forward and reverse, horizontal and vertical drives. Working on a chain drive and rotary principle, and using standard drill cores and diamond bits, the drill is capable of



Underwater electric drill (long-masted version) being recovered over Flemish Cap.

penetrating 14 feet of overburden and obtaining a ten-foot core of bedrock.

The first few tests were carried out in Halifax Harbour where several cores of hard quartzite up to 26 inches in length and 1 1/8 inches in diameter were recovered in water depths ranging from 25 to 80 feet. Next, a full scale sea trial was undertaken in the Atlantic Ocean in the area of the Flemish Cap, situated at the edge of the continental shelf, about 300 miles east of St. John's, Newfoundland. There in water depths of 470 feet a six-inch core of granite was retrieved. This rock was later dated by radio-genie methods and was found to be

approximately 600 million years in age. Such a discovery established not only the antiquity of the continental shelf in this area, but the existency of true continental material. From these results further development work on such drills was recommended, and they will be used in conjunction with shallow, near-surface seismic reflection profiling. Presently a short-masted version (8 feet) is being developed to work in areas characterized by a thin cover of unconsolidated sediments lying over the bedrock.

C.A. Godden, B.R. Pelletier

The modified Benthos multiple plankton sampler (see figure) was operational during the Tahiti-Vancouver leg of HUDSON 70. The acoustic telemetry system continuously transmitted information concerning net opening and closing functions, rate of water flow through the net, water temperature at net depth and depth of the net below the surface. Calibrated aluminum shear pins activated pressure-dependent triggers well within the required limits of accuracy. It is also hoped that a high frequency acoustic transducer or some kind of light-sensitive device can be developed and linked to the telemetry system in order to enable operators to sample plankton populations that are anomalously dense compared to those inhabiting nearby water masses.

A prototype multiparameter recording instrument was employed for several eight-hour periods to measure relative changes in pH, temperature and dissolved oxygen concentration adjacent to sewer outfalls in the Bedford Basin, Nova Scotia. Work on this instrument is continuing in order to improve sensors that may be reliably submerged to the desired water depth for long periods.

A deep sea sediment trap was anchored in 4500 feet of water at latitude 32°10'N, longitude 64°30'W during July 1969. An attempt was made to recover the system in December 1969 but the acoustic release failed to operate. An A.M.F. release system and a sacrificial anchor are presently being designed into the system in order to increase the chances for a successful recovery.

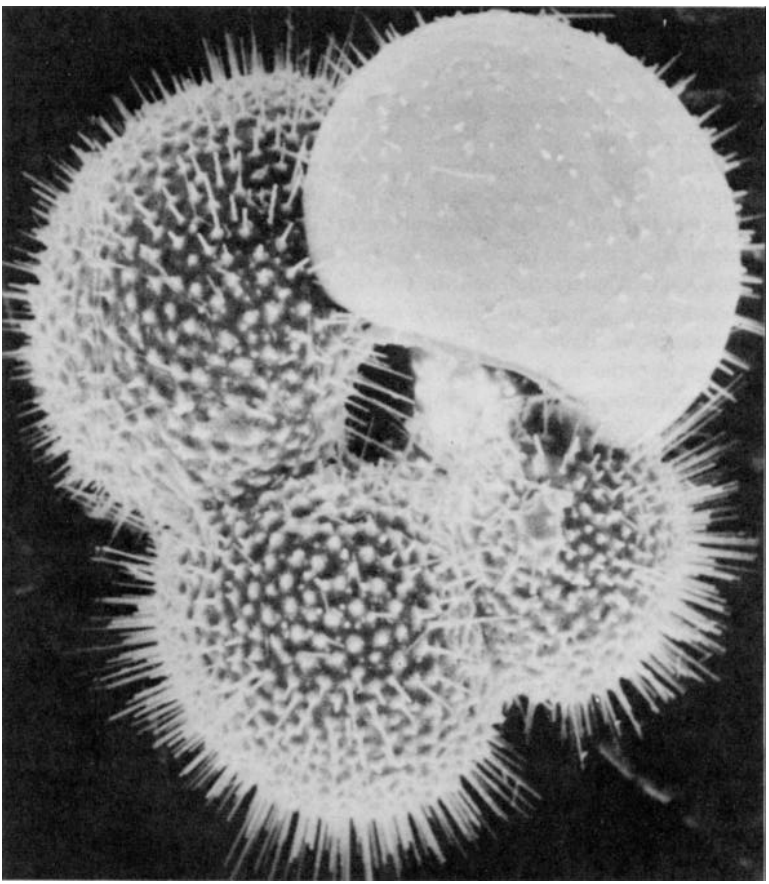
C.T. Schafer

The television system proved invaluable in observing the underwater operations. Permanent records of the electric rock coring drill in action were made on 16 mm film obtained from the monitor during some of the tests. The television camera was also fitted to a submersible and successfully used by the marine geologists. Further studies were conducted by scientists involved in the studies of marine environmental pollution using this equipment. An Ampex video-tape recorder was added to the system by means of which permanent records were obtained for future studies. The addition of a self-powered monitor

containing camera power and control circuits has been made due to uncontrollable frequency variations aboard the ships. This monitor renders the whole system completely stable.

C.A. Godden

Since the installation of the JEOLCO JSM-2 scanning electron



Scanning electron micrograph of planktonic foraminifera, *Globigerina bulloides,* X300.

microscope several techniques have been developed for sample preparation. Although much work has been carried out on mineral structure and suspended clays, the greatest use has been in the study of the test ultrastructure of the Foraminiferida. One of the techniques developed to date has been in the sample preparation of suspended material (e.g. clays). Whereas the conventional method has been to mount the sample

directly onto the copper specimen block, a new technique has been developed whereby the sample is first mounted onto a plastic or glass disc, which in turn is cemented to the copper block. In addition to eliminating specimen contamination from the copper, the use of plastic or glass as the supporting medium yields an electrically neutral background, resulting in a condition which allows higher image contrast and higher attainable magnification, with a corresponding increase in resolution. For example, the highest magnification (therefore highest resolution) attainable using the conventional preparation technique for studying clays had been about x15,000; we can now go as high as x50,000-60,000 with a resolution higher than was previously possible at x15,000.

D.A. Walker

In the late summer of 1968 the submersible *Pisces I,* built by International Hydrodynamics of Vancouver, British Columbia, was engaged by the Atlantic Oceanographic Laboratory to carry out a geological feasibility study in the Canadian Arctic. This program was carried out on a cost-sharing basis with the Defence Research Establishment Pacific, Esquimalt, B.C.; the Pacific Oceanographic Group, Fisheries Research Board of Canada, Nanaimo, B.C.; and the Johns Hopkins University, Baltimore, Maryland. Underwater mapping, photography and bottom sampling were undertaken to depths of 1520 feet and under ice cover with such good results that further investigation of the ocean bottom by means of research submersibles was warranted.

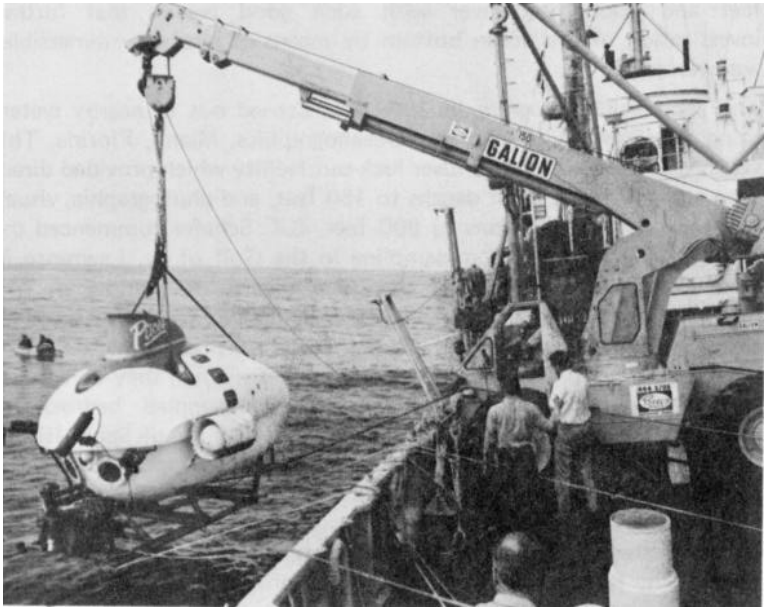
The submersible program in 1969 was carried out in nearby waters using the *Shelf Diver* of Perry Oceanographics, Miami, Florida. This vessel was equipped with a diver lock-out facility which provided direct access to the sea floor at depths to 150 feet, and photographic, visual, and television observations to 800 feet. C.T. Schafer commenced the AOL program with bottom sampling in the Gulf of St. Lawrence in which he utilized the diver lock-out facility to sample *in situ* populations of benthonic foraminifera in conjunction with his ecological studies of foraminifera in the Atlantic provinces. L.H. King and B. MacLean continued the submersible program when they dived over the Scotian Shelf and photographed and sampled bedrock of Cretaceous age from submarine cliffs in the vicinity of Sable Island, using the external accoutrements of *Shelf Diver.* G. Drapeau studied the movement of sand on the southwestern portion of the Scotian Shelf, and described the configuration and origin of giant sand waves in that area with the aid of underwater photography, television and video-tape replay. The final project of the geological program was carried out by B.R. Pelletier who directed an exercise on sediment sampling and bottom photography in the Bay of Fundy. This work was accomplished

with the aid of SCUBA divers of the Royal Canadian Navy, who carried out the lock-out sampling of the seabed, and by the photographic unit of AOL which undertook the task of fitting cameras and associated equipment to the submarine.

The success of this program with the *Shelf Diver* focussed attention on the need for a general on-going program with submersibles. In early 1970 the Department of National Defence funded the purchase of a strongly recommended diver lock-out submersible that was built by International Hydrodynamics and was delivered in late 1970 to Canadian Forces Base in Halifax, Nova Scotia. This vessel called CSL-1 will be available for the undertaking of scientific research projects on the sea floor after a trial period of several months.

During the summer of 1970 while the new CSL was being built, the biological station at St. Andrews, N.B., and the marine geology section of AOL entered into a cost-sharing arrangement for the charter of *Pisces 1.* One of our geologists, G. Drapeau, examined bottom conditions over Georges Bank in an attempt to relate his observations with those of the biologists on matters relating to the herring spawn in that area. This was an international program involving Canada, the United States, and the Soviet Union, and proved to be a successful venture.

B.R. Pelletier.



Pisces I.

In the living foraminifera laboratory observations and experimentation have been carried out on several benthonic species from local nearshore waters, and pelagic species from the Sargasso Sea. Microscopic observations have been conducted regarding reproduction, movement, feeding, cellular morphology, and regeneration of Rosalina *globularis, R. Floridana, Bolivina inflata, Quinque-loculina seminulum, Saccammina atlantica,* and *Discorbis columbiensis* (see B.I. Contribution No. 147). Experimentation has been carried out regarding changes in physiological activity, and hence changes in growth rate, in response to varying temperature, salinity and pH. Several long-term cultures have been established using low-temperature incubators and water-bath systems (the latter was developed in this laboratory), successful cultures having been maintained continuously for over two years. Specific experiments have been carried out on the effect of ingestion of R. *Floridana* and *Q. seminulum* by the common periwinkle *Littorina.* Scanning electron microscopy investigations have shown a definite etching of the surface layers in *Q. seminulum,* and pitting in the surface of *R. floridana.* This phenomenon has resulted from the acidic nature of the digestive juices in *Littorina,* and has been shown to be significant from a micropaleontological standpoint in that such occurrences in recent and fossil populations can now be explained by the normal feeding habits of benthonic invertebrates. Test ultrastructure of several species has been studied by scanning electron microscopy. These studies are being carried out to determine possible functions of certain architectural features as well as general descriptive analyses.

D.A. Walker

A new flexible epoxy system for the banding of waterproof splices and connectors to submersible electrical cables was evolved. This material matches the flexibility of the cables and was developed to assist the cable in passing over sheaves etc. without damage.

A constant-reading remote-indicating 'inclinometer' was designed and constructed for initial use in conjunction with the electric rock core drills. This instrument, which is ambient-pressure compensated, subsequently proved to be of use to other sections within the Institute.

C.A. Godden

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D.I. Ross

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D.A. Dalby[2]
F.E. Danis[3]
D.R. Druhan[1,2]
G.N. Ewing[3]
R .T. Haworth
M.D. Hughes
J.D. Hutchinson[1]
B.L. Johnston
G.J. Jollymore[1]
C.E. Keen[1]
R.B. Knapton[1,2]
D.R. Locke
B.D. Loncarevic[3]
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R.F. Macnab[1]
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D.M. Porteous[3]
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G. Ranalli[2]
A. Ruffman[1]
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P.A. Solowan[1]
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S.P. Srivastava
G.F. Stewart[3]
R.E. Walker[1,3]
A.B. Watts[4]
J.M. Woodside

The Marine Geophysics Section 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 the Grand Banks and the Gulf of St. Lawrence, to provide information about potential resources; research in regions where active formation of ocean bottom may presently be occurring or have occurred in the past, such as the Mid-Atlantic Ridge or the eastern Arctic; and the design, assembly, and evaluation of new methods to be used in gathering, processing, and interpreting data.

Techniques presently used in such studies include continuous measurement of the variation of the gravity and magnetic fields, and bathymetry whenever the ship is underway; seismic reflection and refraction measurements in selected areas; geological sampling with corers, dredges or the deep sea drill developed by Metrology Section; photography of the ocean bottom and electromagnetic and heat flow measurements on specific projects.

The marine environment imposes serious limitations on methods of direct sampling so that the studies have necessitated considerable development and adaptation of the conventional geophysical techniques employed on land. It has also emphasized other problems easily overcome on land, such as navigation and stabilization of the measuring platform. The high cost of ship time has required considerable research into efficient data acquisition and processing techniques.

[1] Joined AOL.

[2] Left AOL.

[3] Transferred within AOL.

[4] Postdoctorate Fellow.

As usual, the Section has participated in a wide range of cruises during the two-year period of this report. In 1969 although only one cruise was organized by personnel within the Section - a cruise to extend magneto-telluric measurements on the Nova Scotian shelf to deeper parts of the ocean and evaluate an underwater three-component magnetometer designed and built at Imperial College, London - the Section actively participated on four other cruises involving some eight months of sea time. Most important of these were continued participation on the hydrographic/geophysical survey of the Gulf of St. Lawrence and involvement in the planning and operation of a cruise to evaluate the U.S. Navy Navigation Satellite System in an area of the shelf where precise navigation control could be provided by Decca Hi-Fix.

In 1970 the major field effort was on two fronts: the hydrographic/geophysical survey in the Beaufort Sea and participation on the HUDSON 70 Circumnavigation of the Americas' cruise. On the latter, geophysical data were collected on all but three of the nine phases of the cruise. Data were obtained on phase I between Halifax and Rio de Janiero and from phase V to the end, i.e., Valparaiso to Halifax. Specific geophysical projects conducted on the cruise are discussed later in this report. In addition to these two major cruises, personnel participated on the annual hydrographic training cruise to the Caribbean and on leg 12 of the JOIDES Deep Sea Drilling Project aboard USDV *Glomar Challenger.*

Collaboration with university groups has been very active during the period of this report. During 1970 this was particularly important in projects associated with HUDSON 70 and involved personnel from Woods Hole Oceanographic Institution, University of Washington, University of British Columbia, and Dalhousie University.

Probably the most significant advances in measuring techniques made over the last two years have been in the field of seismic refraction and reflection measurements. Considerable effort has been put into developing techniques to complement those of the exploration industry. Thus the main emphasis in reflection measurements has been to obtain significant penetration in deep sea areas and to develop the rather different techniques for signal processing of data in deep sea areas. Refraction studies have been carried out using conventional techniques but new methods involving measurements with sonobuoys and measurements of the anisotropy of mantle P-waves have been emphasized.

During the fall of 1969, prior to the departure of the *CSS Hudson* on the HUDSON 70 cruise, the geophysics console area of the ship was completely refurbished by the Engineering Services Section. This

included completely air-conditioning the space on a separate system and replacing the old console electronic mounting racks with new enclosed racks in a U-shaped installation. The new console provides for permanent installation of the BIODAL data logging system, the Barringer proton precession magnetometer and recorders, the Alpine-Gifft bathymetry recording system, the Sperry EM log display, the ITT satellite receiver system and its computer, the sea gravimeter recording system with its associated cross-coupling computer and the general purpose PDP-8 computer. In addition, ample rack space is available for additional equipment such as the AMBAC vibrating string gravimeter recording system from Woods Hole Oceanographic Institution carried on HUDSON 70.

In April of 1970 the geophysical console area of the CSS *Baffin* was relocated and redesigned by the Hydrographic and Geophysics Sections with the assistance of the Engineering Services Section. The previous geophysics console in the starboard drawing office was relocated in the hydrographer's plotting room above the ship's bridge. The PDP-8 computer was left in the original console area and this area is now used for computing and geophysical data reduction purposes only. The new installation enables all underway geophysical recording and monitoring equipment to be housed in the hydrographic operations room together with the Lambda (Low Ambiguity Decca) Decometer and other navigation aids thus streamlining the watchkeeping functions while on survey and removing many of the inconveniences that occurred when the two operation areas were separated. The arrangement proved very satisfactory during the 1970 field season in the Arctic.

The incorporation of cross-coupling analog computers to the installations on *Hudson* and *Baffin* has improved the validity of data obtained with the Graf-Askania sea gravimeter. As part of the 1969 Satellite Navigation cruise, a test was designed to investigate cross-coupling errors more closely but calm weather prevented success. However, during cruises such as HUDSON 70 errors of up to 20 mgal were recorded by the computers and applied as corrections to the raw data.

D. I. Ross

Seismology

Over the past two years, Marine Geophysics has acquired the facilities for carrying out seismic refraction and reflection measurements at sea on a routine basis. Particular effort has been directed towards the development of a seismic reflection system which has now been used extensively during several geophysical surveys. The reflection system was first tested at sea on the CSS *Dawson* and not only functioned

successfully but also allowed us to obtain useful data over the continental margin near Sable Island and over the Sohm Abyssal plain. The main components of the system are a Bolt model 1500 air gun with a pulse shaper and a 400-foot eel comprising four 100-foot sections each containing 20 HP-2 hydrophones. A slacking winch is used to reduce noise caused by towing the eel. This allows the eel to remain almost stationary while information is being received. A time-varying bandpass filter and a mixer are used to obtain the final shipboard records. The raw data are also recorded on magnetic tape. The system has proved very successful in deep water and we have been able to define deep sedimentary basins, the top of the oceanic basalts and in one case, the top of layer 3 may have been observed. However, some problems remain in defining structures on the continental shelf where water multiples obscure the deep reflectors.

In order to evaluate the results of seismic reflection profiling performed by an exploration company, a contract was given to Catalina Exploration and Development Co. Ltd. to obtain a profile over the continental margin. The results have been published in the AOL Data Series (1970-6-D).

The ability to perform seismic reflection and refraction experiments has made an important contribution to studies of some of the geophysical problems currently being examined. The reflection profile and refraction experiments in Baffin Bay and in the Pacific, off the coast of British Columbia, are necessary to the interpretation of the tectonics of these areas and supplement the gravity and magnetic data which were also collected.

A new technique for defining the direction of sea floor spreading. by measuring the anisotropy of the P-wave velocity in the upper mantle using refraction methods is being evaluated. This may provide invaluable information and, in some cases, may be an acceptable alternative to time-consuming, expensive, geophysical surveys.

A study of the velocity distributions with depth within the Canadian Shield has been undertaken. Group velocity curves have been obtained for surface waves recorded at relatively short ranges from the earthquake epicentre and models of the corresponding velocity distributions are presently being constructed. If this study is successful, an important application could be to define the velocity-depth distribution in the upper mantle beneath mid-oceanic ridges.

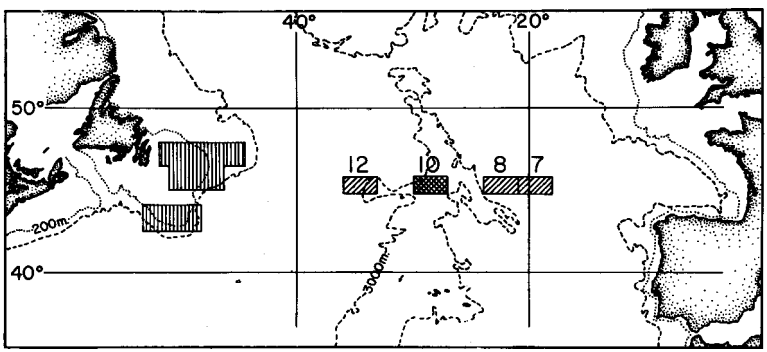
(See B.I. Contribution No. 45, 197.)

C.E. Keen, D.L. Barrett

ToC

Mid-Atlantic Ridge Survey

The *Hudson* geotraverse survey is a continuing cooperative project organized by the Marine Geophysics Section to study a 1° wide strip of the Atlantic Ocean between the latitudes of 45°N and 46°N and longitudes 25°W and 60°W. Prior to 1969 the project had involved three major surveys on the Grand Banks of Newfoundland and three



Areas now surveyed on the geotraverse of the Mid-Atlantic Ridge.

surveys over the crest of the Mid-Atlantic Ridge between 26°W and 60°W. The surveys over the crest of the ridge have been unique in that they have provided for the first time detailed geophysical data of an area of the deep sea outside the range of normal electronic positioning aids. Included with the detailed geophysical work carried out on these cruises has been an extensive geological sampling program for studies undertaken by personnel in the Geological Survey of Canada, Earth Physics Branch, and seismic reflection and refraction work in cooperation with Dalhousie University and Cambridge University, England.

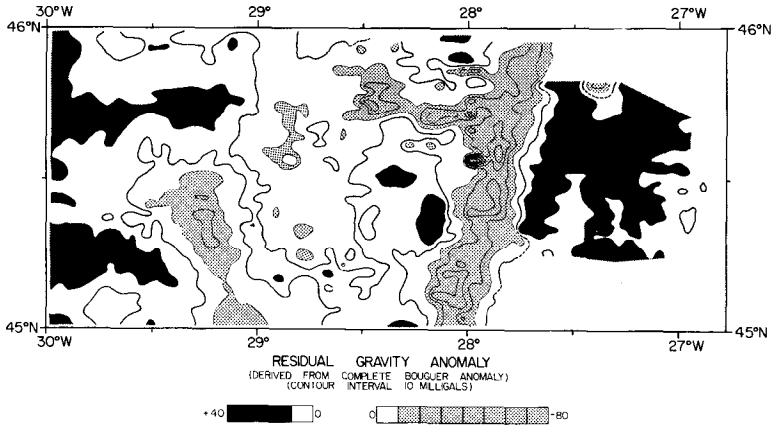
During 1969-70 one additional cruise has worked in the area of the Mid-Atlantic Ridge. This was a multidiscipline trans-Atlantic cruise involving studies in Marine Geology, Ocean Circulation and Marine Geophysics. The geophysics part of the program was confined to the return track from Lisbon to Halifax and included bathymetry and magnetic measurements on the track across the Atlantic providing further data along the geotraverse strip. In addition, reconnaissance type surveys on two areas of the flanks of the ridge were completed. These areas are some 500 km to either side of the ridge crest. The figure shows the areas surveyed together with the prior coverage obtained on the geotraverse project. Navigation on this cruise was provided solely by satellite navigation. Magnetic data obtained suggested that the pattern of lineations was much more regular on the flanks of the ridge than had been observed over the crestal regions.

During this cruise the crest of the ridge was successfully drilled from *CSS Hudson* using a hydrostatic rock core drill developed by the Metrology Section. A total of 12 cores, amounting in total to approximately 120 inches, was collected from nine different peaks in the area. The cores consisted of coralline limestone, basalt and consolidated foraminiferal sediment. They have been studied by experts from a number of Canadian laboratories for age determinations, physical, chemical and other geological properties.

Considerable effort has been put into the analysis of data from the surveys over the crest of the Mid-Atlantic Ridge during the past two years. B.D. Loncarevic has been carrying out a statistical analysis of the magnetic data in terms of the conventional ocean floor spreading model. His work has shown a strong correlation exists between the presently accepted ocean floor spreading model and an average profile along the direction 75°W of north assuming a spreading rate of 1.28 cm per year. There is an indication that the spreading rate to the east of the crest may be somewhat lower.

P.J. Bhattacharayya has been working on the spectral analysis of the data for a Ph.D. degree at Dalhousie University. His work first involved the development of techniques for accurate interpolation of the survey data onto a regular grid with a grid spacing of 1 km. This was done by fitting overlapping Lagrangian polynomial surfaces in a piece-wise manner. The resulting data are being used for producing detailed contour charts of the area and for carrying out trend and spectral analysis of the data. The methods of analysis have shown up new small scale trends and offsets which heretofore had been masked by the smoothing techniques involved in analyzing the data.

Analysis of the gravity data is being carried out by J.M. Woodside. Free-air anomaly, simple and complete (terrain-corrected) Bouguer anomaly, and residual gravity anomaly charts have been produced. The terrain correction for each data point is carried out to a radius of over 27 km which is sufficient to correct for over 95% of the terrain effect. The residual gravity anomaly is computed by subtracting from the observed values of the complete Bouguer anomaly the values predicted according to the depth at each data point using the relationship established between depth and complete Bouguer anomaly. The resulting anomaly is independent of the Bouguer density and tends to remove regional trends and better display major local anomalies (see figure). As well as the pronounced anomalies associated with the median valley and crestal mountains two other linear anomalies trending east-west are clearly indicated. These may be associated with microfracture zones hypothesized to be present on the ridge. The relationship of complete Bouguer anomaly to depth is linear and positive but lower than that quoted for more typical oceanic areas. This



Gravity map from Mid-Atlantic Ridge Survey.

suggests that the bottom relief is not compensated by roots or anti-roots but by some other means, probably tectonic.

Analysis of the seismic refraction data collected on the cruise of 1968 has been completed by C.E. Keen as part of her Ph.D. work at Cambridge University. The analysis of the data indicates that the crust near the axis of the ridge is composed of two layers with velocities of 4.6 and 6.6 km/s. These layers are underlain by a mantle with the velocity of 7.9 km/s, the M-discontinuity occurring at a mean depth of 7.5 km. The mantle appears to be anisotropic with respect to its P-wave velocity; the direction of the maximum velocity being 080°. Time term analysis of the data shows that the structure is lineated approximately parallel to the median valley and that large variations of the depth to the M-discontinuity, up to 3 km over the area, may occur. Measured seismic refraction velocities have been correlated with velocities measured in a representative suite of rocks dredged from various elevations in the area. Velocities were measured in the laboratory up to pressures of 10,000 psi. The relationship between rock type and elevation on a particular scarp has provided the first direct evidence of block faulting on the mid-ocean ridge. Seismic reflection data obtained on the same cruise has given considerable information on the sediment distribution and thickness in the area of the crest of the ridge.

(See 81 Contribution No. 56, 79, 88, 116, 137, 162, 168, 185, 193, 197,210,211,212,215.)

D.I. Ross, K.S. Manchester, D.L. Barrett

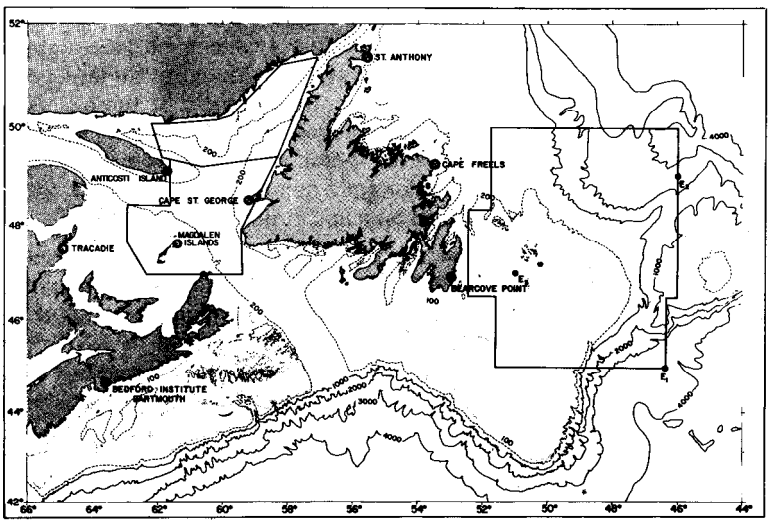
Magnetic Measurements

A three-component fluxgate magnetometer built by Scintrex Co. Ltd. was acquired at the beginning of 1969 to measure the variations of the earth's magnetic field along three mutually orthogonal directions. The sensing head of the magnetometer has been buried in the ground on a concrete bedrock base with a nonmagnetic cannister enclosure to keep it at a constant temperature. The electronic part of the magnetometer is housed in the nonmagnetic hut on BI property. The variations of the earth's magnetic field are monitored on three single channel recorders located in the hut.

The total magnetic field at the Institute continued to be monitored by a proton precession magnetometer and the data obtained published regularly in the form of monthly data reports. The three component fluxgate provides the extra facility of monitoring the components of the earth's field for specific studies but will not be included as part of the routine monitoring.

To monitor the diurnal variations in a survey area at sea, a three-component magnetometer incorporating a total force and a two-component fluxgate magnetometer are being built at Imperial College, London. The magnetometer consists of two fluxgates and a proton precession sensor. When lowered to the sea floor, it orients the fluxgates in a direction perpendicular to the total field and records variations along the two fluxgates together with those in the total field. The magnetometer is self-contained and can operate continuously for a month sampling the variations once a minute.

A detailed analysis of the magnetic recordings from five magnetic observatories in India and two temporary stations operated during 1968 as part of a joint project with Scripps Institution has been carried out. Simultaneous recordings from these stations were examined to find the differences in the amplitudes and phases of long as well as of short period variations among these stations. The analysis showed that the differences observed in the amplitude and phase of the long period magnetic variations were due to the effect of the electrojets on them. However, the large amplitude of short period variations in the vertical component of the magnetic field observed at stations near the magnetic equator (Trivandrum and Colombo) could not possibly be accounted for by a similar source effect. In order to see if the large variations at these stations could be explained by the concentration of induced electric current near these stations, a detailed analysis of the pattern of the induced currents in the ocean was carried out. It is interesting that at each of the coastal stations the normal to the plane along which the induced currents are concentrated points towards the deep ocean. These results are to be published as a joint publication with Professor Cox from Scripps Institution of Oceanography who is analyzing the electric and magnetic fields recorded at sea during the same time near Trivandrum.



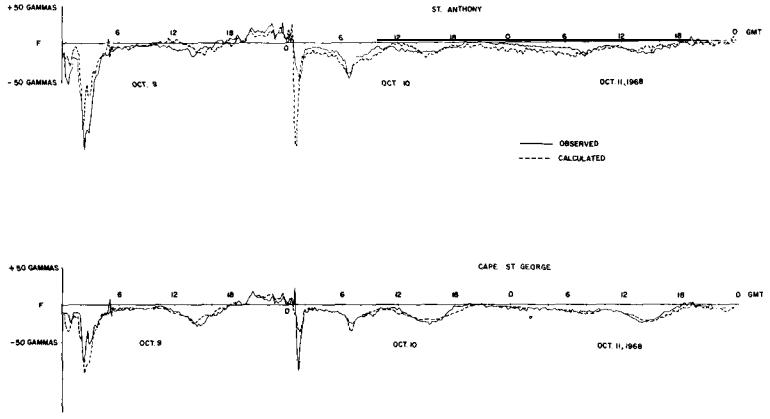
Maritime stations measuring magnetic and electric fields. Outlined areas indicate regions of Hydrographic-Geophysical surveys.

Studies of the magnetic and electric fields at stations in the Maritimes have indicated an anomalous behaviour in the vertical component of the magnetic field observed at Halifax. To further investigate this phenomenon, measurements of the temporal variations in the electric and magnetic fields have been made on the N.S. continental shelf and slope. Measurements were made in collaboration with Imperial College, London, in October 1968 and again with Imperial College and Dalhousie University in 1969. Digital electric field recorders and a three-component magnetometer designed and built at Imperial College were used for measurements at sea. Commercial fluxgate magnetometers were used to monitor magnetic field variations at Halifax and Sable Island. Correlation between magnetic electric measurements prove the large induced currents in the sea are due to fluctuations in the magnetic field. Detailed harmonic analysis of the data has shown the large amplitude of the lunar semi-diurnal (tidal) component in it. The amplitude obtained agrees well with that expected from water current velocity data in the area.

Observations of the earth's magnetic field show variations with time at a fixed point. Magnetic measurements made at sea to locate regions of anomalous field strength are complicated by the effect of temporal variations during the time of the survey. For accurate analysis of data in regions of small amplitude anomalies it is essential to remove these temporal variations from the measured field strength. Ideally the temporal variations should be measured within the area where the

magnetic survey is conducted, The three-component bottom magnetometer being built by Imperial College will enable some such measure ments to be made. However, in survey areas close to land-based monitoring stations, the temporal variations recorded at these stations can be used for this purpose. A method has been developed to calculate the amplitude and phase of the temporal variations from the simultaneous recording of these variations at a number of stations around the survey area. The method is based on a linear interpolation scheme.

To examine the accuracy of the method, the variations recorded at Bedford Institute, Tracadie, N.B., and St. Anthony, Nfld., were used to calculate variations at Cape St. George, Nfld., and compared with those observed. Similarly, the variations from Bedford Institute, Tracadie and Cape St. George were used to calculate those for St. Anthony (see figure). The calculated and observed variations at the two stations seem



Observed and calculated temporal variations of the magnetic field for two Maritime stations.

to be in good agreement for long-period variations but poor for short-period variations. In a magnetic survey the long period variations are the main source of errors. Thus the present method seems to be satisfactory for applying diurnal correction to marine magnetic survey data. The method is at present being used to apply correction to Gulf of St. Lawrence data collected during 1968.

Harmonic analysis of the recordings from the stations shown on the map was carried out to study the differences in the diurnal component of the total magnetic field at these stations. The objective of these computations was to find the pattern of amplitude and phase of the diurnal component on the east coast of Canada and to examine the effect of the induced electric currents on these variations. The results obtained have failed to show any systematic change in amplitude and phase values for the-area and show a decrease in the amplitude value

at stations located near the continental margin (Sable Island) in comparison to the coastal stations (Dartmouth). This is contrary to the expected effect from the induced currents in the deep ocean.

S.P. Srivastava

ToC

Hydrographic-Geophysical Operations

Since 1966, the Atlantic Oceanographic Laboratory at the Bedford Institute has greatly increased its geophysical coverage of the eastern continental margin of Canada. This has been largely due to the cooperation between the Marine Geophysics and Hydrographic Sections of the Institute. The prime responsibility of the AOL Hydrographic Section is charting all navigable waters within the Atlantic Region, as applicable to navigation requirements. The Region is defined as Canada's Atlantic Seaboard, the Gulf of St. Lawrence east of Pointe des Monts, Hudson Bay and the eastern Arctic. The surveys conducted by the Hydrographic Section satisfy requirements in navigation, fisheries and mineral exploration. All positioning of the ship is done using a Lambda Positioning System in the range/range mode, since this provides the most accurate navigation available in the areas surveyed so far.

After a mutual study of each others surveying techniques, it was decided that the two disciplines could be combined to produce a highly effective multidisciplinary survey operation covering the Canadian east coast continental margin with bathymetric, gravimetric and magnetic measurements. An initial multidisciplinary survey of the proposed survey area is carried out at a line spacing of two or four miles, depending upon the density of measurements required to give good geophysical control. The hydrographers then continue surveying the same area at a reduced line spacing. During this latter portion of the cruise geophysical studies are carried out as opportunity and manpower permits. The data collection and reduction operation has now passed into the hands of the Hydrographic Section and a series of Natural Resources Charts are to be produced by them, including bathymetry, gravimetry (free-air anomaly) and magnetometry (total field). (At present the three editions of sheet 14956 are available (latitude 45°-46°N; longitude 46°-48°W). Four sheets covering the Tail of the Bank area (latitude 42°-44°N; longitude 48°-52°W) are expected to be published during the summer of 1971. The Great Bank of Newfoundland and the Gulf of St. Lawrence will follow.) The feasibility of extending Natural Resources Charts to cover all Canadian offshore areas is presently being investigated by the Canadian Hydrographic Service.

While the routine data collection, reduction and chart production are in the hands of the Hydrographic Section, responsibilities for the initial planning of the geophysical aspects of the multidisciplinary cruises and their data interpretation still lie with the Marine Geophysics Section. This development is still in its infancy to the extent that the Hydrographic Section is still learning the techniques of geophysical surveying and data reduction. Meanwhile, Marine Geophysics is still attempting to exploit the positioning facilities provided by the surveys in increasing the accuracy of sea surface gravimetry as limited by the calculation of the Eötvös correction. The Seismic Group is also investigating the possibility of adding seismic reflection profiling to the functions of the survey.

Following the 1968 survey season in the northeast Gulf of St. Lawrence the CSS *Baffin* returned to the Gulf in 1969. Approximately 24,000 km of magnetic and gravimetric data were obtained. The extent of this coverage is approximately from 49°10'W to 63°W between latitudes 46°55'N and 49°20'N. This area has previously been covered with sea-bottom gravity measurements made by the Gravity Division of Earth Physics Branch, Department of Energy, Mines and Resources, Ottawa. The data in the eastern Gulf of St. Lawrence from both the 1968 and 1969 AOL surveys are being analyzed to determine whether this type of survey with a concentration of survey lines (one or two mile intervals), continuous underway collection of data, and higher resolution of gravity anomalies is a better investment of money and manpower than the eight-mile grid bottom gravimeter survey providing more accurate gravity values. Initial comparison of the data yields a mean difference of 2.1 mgal between AOL and the Earth Physics Branch (EPB) over the 1969 survey area with the EPB measurements being higher. Separating the EPB measurements into different years of operation, there also appears to be a temporal variation in the underwater measurements. This is suspected to be the result of using different depth transducers in each of those years' operations. These and further results derived from the analysis will provide a basis for planning future complementary surveys by the two agencies (see BI Contribution No. 180).

In response to the requirement for better navigational charts in the north, the locale of the mapping program was shifted to the western Arctic for the 1970 field season. In the Beaufort Sea, bathymetric, gravimetric, and magnetic (total field) measurements were made at a quarter-mile line spacing over 1500 square miles. The area surveyed was centered on the Admiral's Finger, a shoal located approximately 50 miles north of Atkinson Point, and discovered in 1969 by CCGS *MacDonald* while accompanying SS *Manhattan* during her passage to Prudhoe Bay, Alaska.

During the course of the survey, about 80 additional shoals were discovered, some rising to within 17 metres of the surface. Observed gravimetry in the area was dominated by the shelf anomaly, exceeding 80 mgal at its maximum value, and parallelling the 100-metre contour. Except for the northeast corner of the survey area, there was no indication of shallow disturbances to the earth's magnetic field.

Shipboard gravimetric and magnetic measurements were made during 1964 in the Bay of Fundy. The survey area covered lies approximately between latitude 44°05'N and 45°10'N and longitude 66°W and 67°10'W. About 5300 line kilometres of gravity magnetic readings were collected and digitized on paper tape through a prototype automatic data logging system designed in 1963.

The collected data have been reduced and compiled during the last two years. Free air, magnetic anomaly, Bouguer anomaly and bathymetric contour maps are available and will be eventually published as part of the Natural Resource Chart series. The data are also available through the computerized data storage and retrieval system.

Preliminary interpretations of the results indicate that a syncline with a 1600-2000 metre thick layer of Triassic rocks and a layer of basalt flow, which lies within the Triassic sedimentary rocks, forms a major part of the Bay of Fundy. To explain a negative anomaly belt east of Grand Manan Island, a 1500-2000 metre thick layer of carboniferous sedimentary rocks is assumed between the Triassic rocks and basement. Comparison of sea gravity data with available land gravity data near the New Brunswick shoreline indicates that there is a deep normal fault, striking east-west along 45°07'N. This fault may have a displacement of about 2000 metres and bounds the Carboniferous sedimentary rock layer at its north side.

In support of regional studies, gravimetry and magnetometry have been recorded in conjunction with bathymetry along several reconnaissance tracks in the North Atlantic Basin between Nova Scotia and the Caribbean Sea. For this program, the Canadian Scientific Ships *Baffin* and *Hudson* were used on an opportunity basis as they travelled to and from the Caribbean on hydrographic training and geological research cruises. Although the majority of the cruises have been used primarily for the purposes of training personnel in the operation of underway geophysical equipment and in the shipboard processing of data, the tracks obtained provide valuable additional information for a regional study of the northwest Atlantic.

R.T. Haworth, R.F. Macnab, K.G. Shih

ToC

HUDSON 70

Marine Geophysics Section was responsible for a number of projects undertaken as part of the HUDSON 70 expedition. In addition, geophysical data were collected on the track from Halifax to Rio de Janeiro, from Vancouver to the western Arctic, and as part of the geological/geophysical survey in the Beaufort Sea. On passage from Vancouver to the Beaufort See an interesting profile was obtained across the Aleutian Trench and through the Aleutian Island Arc via Unimak Pass. The characteristic low free air anomaly across the Trench is about 80 mgal and the high is about 150 mgal. High frequency magnetic anomalies with a peak amplitude of over 1200 gamma were recorded through the Unimak Pass. In the Beaufort Sea sufficient data were obtained to prepare an excellent gravity chart of the area. Because of the large diurnal variations in the Arctic areas, correction of the magnetic data is necessary before a reliable magnetic chart of the area can be obtained. Data were obtained at a monitoring station at Atkinson Point during the entire survey period for this purpose.

Determination of the difference in height between the isobaric sea surface and the geoid gives the change in gravitational potential energy of an isobaric sea surface. From this, with a knowledge of the internal distribution of water density, can be calculated the potential of all other isobaric surfaces, and therein lies the key to ocean current transport. Orbital perturbation analysis of satellite track observations provides the low order harmonics of the geoid. At present the higher order harmonics may only be obtained at the sea surface. In order to determine the higher order harmonics of the geoid along the path of a polar orbiting satellite, a gravimetric determination of the geoid was made along 150°W between 63° and 57°N.

The meridian of 150°W was chosen since it was thought (from satellite observations) to follow a region of small free air anomaly so that geoidal undulations due to mass anomalies in the crust would be small. This work was carried out during HUDSON 70 using a Graf-Askania and a vibrating string accelerometer gravimeter. By steaming with a northerly heading, the Eötvös correction would remain small, or zero under ideal conditions. Since the measurements were made at sea level, no altitude correction was necessary.

One particular result which it was hoped to obtain was a value for the flattening of the spheroid to which the geoid along 150°W can be approximated. A worldwide flattening of $(298.25)^{-1}$ was obtained from satellite data and adopted by the International Astronomical Union in 1964. Uotila found a flattening of $(298.5)^{-1}$ in the northern hemisphere and $(297.3)^{-1}$ in the southern hemisphere using mean free air anomalies over one-degree squares, although there was an inhomo-

geneous distribution of gravity data. It was hoped to ascertain whether this worldwide distinction between the two hemispheres also existed along 150°W.

Preliminary results do indicate that there is a difference between the two hemispheres. Excluding the effect of the Alaska shelf, the southern hemisphere appears to have a greater flattening than the northern as indicated by Uotila. However, in each case the flattening seems to be greater than his values.

The value of this geoidal section will be seen with the advent of the radar altimeter measurements from satellites planned for the mid-seventies. The satellite altimeter profiling of the sea surface with reference to this geoidal section will allow for an absolute, dynamic section to be completed.

R.T. Haworth. J.M. Woodside

The track of the CSS *Hudson* from Valparaiso to the southern end of the 150°W meridian crossed a little known area of the South Pacific where features of geophysical interest were found. At 54°36'S, 95°12'W a depth of 6103 metres was recorded, the greatest depth of the entire Pacific track. Sixty km before this at 54°19'S, 94°33'W a peak with a depth of 2920 metres had been crossed. The names Hudson Deep and Hudson Peak were unofficially given to these two features. Bathymetric data show that Hudson Peak and Deep lie at or near a boundary separating contrasting physiographic provinces. To the northeast, an extensive, smooth sedimentary surface slopes down towards Hudson Peak after a distinct change in slope from the horizontal. To the southwest, the topography is irregular but again slopes down towards Hudson Deep. These regional variations in topography indicate that Hudson Peak and Deep lie in an area of progressive subsidence. Due to the apparent pattern of sedimentary deposition, and the correlation of the features with similar ones on parallel tracks of the USNS *Eltanin,* it appears that Hudson Peak and Deep are part of a fracture zone. Most features on the free-air anomaly profile are reflections of the topography, but it appears that there is a regional 20 mgal negative Bouguer anomaly coinciding with Hudson Deep. The simple Bouguer anomaly profile is, however, very noisy and little weight can be put on this observation at present. The magnetic anomaly profile contains no anomalies of amplitude over 600 gammas. There is a striking absence of even moderate anomalies over Hudson Peak and Deep.

R .T. Haworth

Recent proposals with regard to continental drift have the earth composed of a series of plates which are moved over the surface of the earth by forces acting at their edges. These plates grow by accretion along the mid-oceanic ridge system and are consumed in oceanic trenches; continents passively rise as superficial parts of plates. A knowledge of the transition from the continental shelf to the younger oceanic crust is essential both to our knowledge of the evolution of that crust and also to our exploitation of minerals in adjacent areas. At present there is considerable interest in the potential mineral deposits on the Canadian continental shelf. Such deposits may extend into the deep waters of the continental slope and ocean basin. Our knowledge of such deposits will, however, remain sparse until we become familiar with the large scale tectonic processes active at our continental boundaries. On the west coast of Canada it appears that there is a small plate, Juan de Fuca plate, which is complicating the interaction between the larger Pacific plate and the North American plate.

Geophysical investigations in the northeast Pacific included the survey of an area adjacent to the contact between the Juan de Fuca, North American, and Pacific plates (see chart). Seven thousand kilometres of

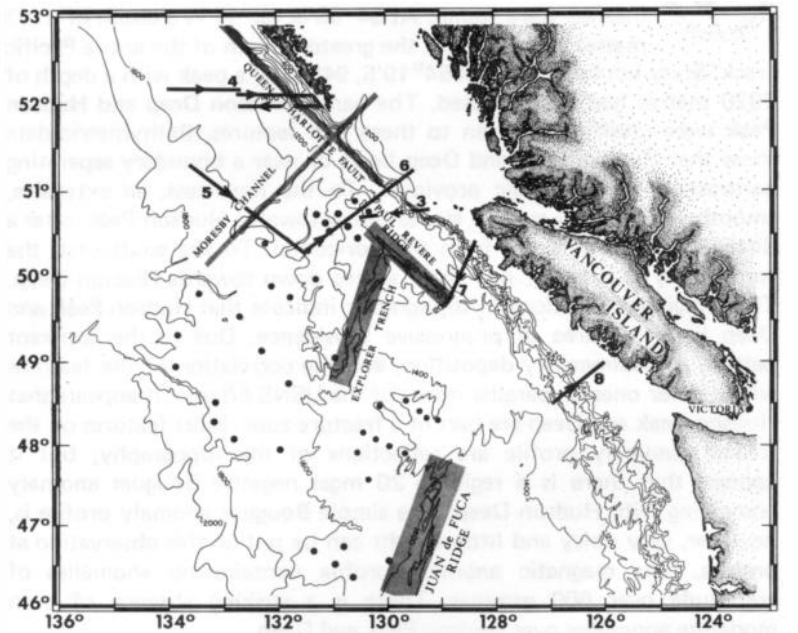


Chart of geophysical survey area off Vancouver and Queen Charlotte Islands (HUDSON 70). The numbered tracks indicate positions of seismic reflection profiles. The dots are seamounts.

gravity and magnetic data and 9500 km of bathymetric data extended the previously surveyed section of the Juan de Fuca Ridge (the western boundary of the Juan de Fuca plate) towards the Queen Charlotte Island Fault. Detailed station work was also carried out in the Explorer Trench which may be the last expression of the East Pacific Rise before its termination at the Queen Charlotte Island Fault. Fourteen dredge hauls recovered a wide range of rock types from normal oceanic basalt to continental grey wacke and sandstone, the oceanic rocks lying at the base of the trench and overlain by the continental sedimentary rocks. Seven measurements of high heat flow together with the fresh basalts indicate that the Explorer Trough is part of an actively spreading zone.

A seismic refraction experiment was carried out to determine the anisotropy of the velocity of compressive (P) seismic waves in the mantle. It has been suggested that these waves have a maximum velocity in the direction of sea floor spreading. Supporting evidence for this hypothesis came from the experiment which was conducted during HUDSON 70 in the abyssal plain off Queen Charlotte Islands. A circular pattern of shots with a radius of about 75 km was fired from the CNAV *Endeavour* and was recorded at the centre by the CSS *Hudson.* The arrival times from shots to receiver were found to vary systematically with the azimuth from shot to receiver. The mean direction of the maximum velocity (8.5 km/s) was found to be 106° east of north; the minimum velocity was 8.1 km/s. The direction of spreading in this area, indicated by the magnetic lineations, is about 90° east of north. This is somewhat different from our estimate; however, both methods of measurements may have uncertainties of 5° or more.

About 1700 km of seismic reflection data were collected during the cruise using the deep seismic reflection system developed at the Bedford Institute. Several of the profiles were run across the continental margin to study the complexity of the structure which exists off the west coast of Canada. All the profiles across the continental margin suggest that the transition from oceanic to continental crust is abrupt. On many profiles a deep sedimentary basin separates the continental shelf from the oceanic basin. In some areas this sediment has been severely folded and perhaps faulted. In the ocean basins the sediment cover varies from nil to about one second, two-way travel time. In one case, towards the deep ocean, a rugged reflector was observed below the top of the volcanic layer. This may represent the top of layer 3 or a secondary reflector within the volcanic layer. Profiles taken across the Queen Charlotte trough and fault indicate that the trough appears to be an erosional feature. The continental margin in this area seems to consist of a series of faulted blocks against which the oceanic crust abuts; there is no evidence of distortions within the sediments on the seaward side of the margin.

The large negative gravity anomalies obtained near the margin seem to agree with the seismic reflection data. Numerous large magnetic anomalies were found near the continental margin. The correlation of these anomalies with the gravity and seismic data will give direct evidence of the interactions between various plates near the margin.

D.L. Barrett, C.E. Keen, K.S. Manchester, D.I. Ross, K.G. Shih, S.P. Srivastava

Geophysical Work in the Eastern Arctic

During the last phase of HUDSON 70, Marine Geophysics Section had the opportunity to start a systematic investigation of the structure of Baffin Bay and its relation to the tectonics of the northwest Atlantic area. Prior to the summer of 1970 considerable magnetic data had been

Tracks of the *CSS Hudson* and the CSS *Baffin* during the last phase of HUDSON 70 (geophysical survey).

obtained from ships of opportunity, particularly DOT icebreakers working in the eastern Arctic, but there had been no opportunity to mount a full scale geophysical study of the area.

A seismic refraction experiment was carried out in cooperation with the U.S. Coast Guard using the USCGC *Edisto* as shooting ship while the CSS *Hudson* stationed herself at the end of the line as receiving ship. A 66-mile reversed refraction line was successfully shot. Both the thickness of the crust and measured velocities obtained during this experiment showed that the central deep portion of Baffin Bay was indeed oceanic and that it could not be attributed to extended and faulted continental material as had been suggested a possible origin. A total depth of 11 km from the surface to the M-discontinuity was obtained with a mantle velocity of 7.7 km/s. While the observed mantle velocity is somewhat lower than normally observed in oceanic areas, it is not significantly so, particularly considering the rather thin crustal section observed.

Having proved that Baffin Bay is an ocean and therefore possibly was formed by sea floor spreading processes, it was of prime importance to determine as much as possible about the continental-oceanic transition regions on both sides of the Bay and investigate the nature of Davis Strait to the south and Nares Strait to the north. Five thousand miles of gravity data obtained by the *Hudson* and the *CSS Baffin* (the first surface ship measurements in the area) together with seismic reflection data from the *Hudson* have provided important information on the extent of the oceanic crust and the nature of the boundaries with the continents on either side of the Bay. Model studies are presently in progress to provide quantitative values for the margin structures. The data have clearly shown the marked asymmetry in the Bay and the complex nature of the margin areas which have been cut by deep channels presently filled with sediment. In addition, strong gravity gradients are observed on one profile across the central portion of the Bay which are difficult to explain by present ideas on the origin of the Bay. Magnetic data, obtained in conjunction with the gravity data, together with that obtained in earlier years, are being used to follow some of the major features delineated in this work over greater distances and strengthen the conclusions drawn. In addition, sufficient data are now available to look for magnetic lineations that might be associated with perhaps a once-active ocean ridge structure in the Bay.

(See BI Contribution No. 46, 192.)

D.L. Barrett, C.E. Keen, K. S. Manchester, D.I. Ross, J.M. Woodside

Information Storage and Retrieval

The chart storage and retrieval system created in 1967 has been used extensively by the Section and other members of the Institute since that time. The system has been, as intended, customer-operated in both storage and retrieval. Due to different interpretations of the instruction manual, this has resulted in a multitude of keywords having to be specified in order that the customer may be reasonably assured of retrieving relevant information stored by other customers. To remedy this situation, discussions between members of the Section were arranged to clarify the operation of the system and the entire thesaurus of the system was purged. Rekeywording and indexing of the nearly 700 charts presently in the system, plus the considerable backlog of newly generated charts, is nearing completion.

The facilities provided by the system and its adaptability to similar projects in other organizations has led to the development of a computerized version by Consolidated Computing Services in Halifax for use from their remote computer terminal facilities. A practical version is now available and is being tested at the Institute.

A storage and retrieval system for all geophysical data collected on Institute cruises was developed in 1967 and the prototype version put into use in 1968. The system proved of immense value in making large amounts of data obtained on detailed surveys available for analysis and as an aid in dissemination of data to outside organizations. Initial use of the system showed up several important restrictions and development has continued during the past two years to improve the versatility and efficiency of the system. An important consideration built into the retrieval facilities has been the requirement to provide data in a format immediately available for processing on other computer facilities in the country and in a format compatible with other data systems, particularly the gravity files of Earth Physics Branch, Department of Energy, Mines and Resources, Ottawa, and the Hydrographic Service data system, Department of Energy, Mines and Resources, Ottawa. Considerable use has already been made of the system by universities, industry and other government organizations; considerably more use is expected as the data file is expanded.

K.G. Shih

Metrology

ToC

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C.S. Mason

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E.G. Banke[1]
E.A. Bendell
A.S. Bennett
J.J. Betlem[3]
J. Brooke
R .J. Cassivi
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J.-G. Dessureault
F.W. Dobson[1]
D.R. Eisener[1]
G.A. Fowler
P.A. Gouldthorpe
W.W. Hall
B.B. Hartling
D.R. Harvey
D.L. Hendsbee
A.E. Johnson
P.G. Jollymore
P.F. Kingston
D.F. Knox[1]
M.B. Lumsden[1]
E.W. Moody[1]
D.L. McKeown
E.F. Phillips[1]
W.M. Proctor
SD. Smith
M. Stepanczak[1]
R .G. Stevens[2]
J.P. Thorburn[1]
M.R. Thorpe[4]
B. Trudel
R .J. Vandal
D.E. Wells
W.J. Whiteway
L.A. Wright[3]
S.W. Young

Over the past two years, instrumentation research and design has been directed to carrying through many of the innovations conceived by Dr. Gilbert*; one new major development, acoustic positioning, has been started. The hydrostatic rock core drill, the porpoising *Batfish* and the temperature recording Digibridge have all reached a stage where routine manufacture should be possible. Mr. J.-G. Dessureault, developer of the *Batfish,* is now working with industry in the Halifax/Dartmouth area to assist them in producing this and other AOL equipment and it is anticipated that this equipment will be available, commercially, to other research institutes. Design of drills, *Batfish* and the Digibridge is also continuing at AOL and a liaison with local industry should help us considerably in devising improvements and new applications.

The section worked briefly on several problems associated with Operation Oil investigating the use of nets to trap and move heavy oil, building a model of a vertical disc licker to remove oil from a rough sea surface, and considering a variety of pumps to pump up

[1] Joined AOL

[2] Left AOL

[3] Transferred within AOL

[4] Postdoctoral Fellow

* Dr. R.L.G. Gilbert, previous section head, transferred to Ottawa, Department of Fisheries and Forestry.

Bunker C oil from trapped pools. A differential pressure gauge was built to measure the water head across the dam at Lennox Passage in Chedabucto Bay.

The main project of the Air-Sea Interaction Group continues to be the measurement of wind stress on the sea, under open sea conditions, over a wide range of wind speeds. This involves placing a sensitive three-component anemometer on a stable platform exposed to the open sea. The platform, which is now located at the entrance to Halifax Harbour, has been designed, installed and maintained by the Systems Engineering Group, Engineering Services, who have also designed the command and telemetry link from the tower to a shore station.

The work of the section is divided into seven main project areas and the following detailed descriptions highlight the work done in each area over the past two years.

C.S. Mason

Applications of Underwater Sound

The oblique echo sounder produces a record of the sea bottom topography in a strip 350-450 metres wide on either side of a ship's track. Designed specifically for use in Canadian continental shelf waters where there are strong temperature structures, a system has been developed which will work in depths up to 180 metres. Two transducers are housed in a Defence Research Establishment Atlantic towed body, *Moby,* and enable a strip of bottom on either side of the ship's track to be studied simultaneously. Thus far the control and display units have been constructed for only one of the two transducers. Engineering design and preliminary field trials (on the Nova Scotian continental shelf) have been completed and full evaluation trials with AOL Marine Geology and with MEL are planned for 1971.

Staff from Defence Research Establishment Atlantic collaborated with AOL during field trials of the *Moby* body.

P.J. Jollymore, D.L. McKeown

When an acoustic pinger is used in conjunction with a graphic recorder the time bases of the pinger and the recorder vary with respect to each other, causing the pinger signal to drift across the record. If the pinger is being used to telemeter data such as water temperature or rock drill penetration, reading the recording is made difficult by the continual record drift. The zero lock unit has been designed to receive the pinger signal and the recorder trigger pulse and provide, from these, a correction signal to lock the time base of the graphic recorder to that of the pinger by varying the motor speed of the recorder. The unit will

keep the two signals synchronized at lowering and recovering speeds of up to 100 m/min.

P.J. Jollymore, D.L. McKeown

Since 1965 the section has been developing a hydrostatic rock core drill for underwater drilling; such a drill for use in water depths from 550 to 1800 metres can now be used routinely. We now wish to use the drill to obtain rock samples from specific points in a survey area - such as the area surveyed by AOL geophysicists on the Mid-Atlantic Ridge at 45°N. Development of an acoustic positioning system is now underway using commercially available acoustic transponders, a shipboard transmitter and receiver, and the deep mooring system developed for the Digibridge project. Design of the positioning system is complete and preliminary trials in Bedford Basin to test the surveying technique have been successful.
The positioning system will be useful for any type of detailed bottom sampling such as bottom photography, dredging or temperature measurements.

D.R. Harvey, D.L. McKeown

Twenty low power pingers were constructed to AOL specifications in order to provide a general purpose, low cost pinger for the use of all research sections in the Institute. The acquisition of the units proved to be more costly than initial estimates because of the failure of the units to meet specifications and, after field trials, the units were twice returned to the manufacturer for extensive modification. The pingers are now performing and are being used routinely at sea.

D.R. Harvey, D.L. McKeown

ToC

Radio-Controlled Launch

Development work has continued on the 14-foot radio-controlled unmanned launch. The project is based on the premise that several drone echo-sounding launches controlled from one hydrographic ship could increase several-fold the productivity of offshore bathymetric surveying. Using the hull of a commercial system, a new master control system has been constructed which permits the simultaneous operation of up to eight launches, equipped with echo sounders, using only one radio VHF band. The operator is able to manoeuvre the launch, alter speed and course, change gears and stop the engines, all with a hand-held control. An echo-sounding system and data telemetry link has been commercially developed to AOL specifications.

The control system and one launch have performed successfully in conditions corresponding to sea state 4 (waves 4 to 8 feet, wind 17-21 knots) at a speed of 15 knots. The echo sounder system has been used

in water depths of 60 metres without the telemetry link. Full scale field trials of this system (control and one launch with sounder) are planned for early 1971 and, if these be successful, a second launch system will be acquired and a trial survey carried out. Commercial cost of each launch system in production quantities of eight units is estimated at $25,000.

E.A. Bendell, P.A. Gouldthorpe, D.L. McKeown

Oceanographic Sensors for Data Logging

Development is completed of an instrument, Digibridge, which will measure and record temperature, *in situ,* in the deep ocean with a resolution of 0.001°C and an accuracy of 0.01°C. The instrument is moored on the bottom on a 'pop-up' frame which is released acoustically upon a surface command. The recorder will operate for up to 20 days recording the resistance of three glass bead thermistors every five minutes. The recording period can be increased by decreasing the number of thermistors or increasing the interval between recordings. Design construction and testing of one instrument is complete and two additional units are now being built commercially to AOL design. The recording thermometer will be used jointly with AOL Ocean Circulation on the East Newfoundland Rise in 1972 and will also be installed on the stable tower used in Air-Sea Interaction studies.

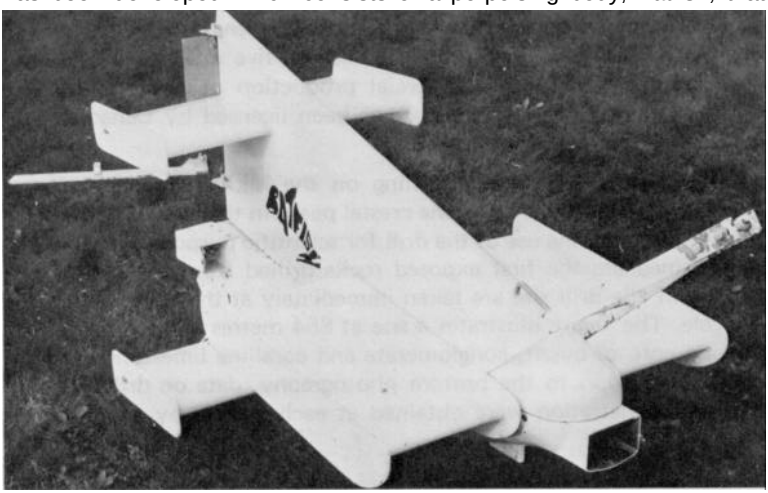
AS. Bennett, G.A. Fowler, P.A. Gouldthorpe, D.R. Harvey

In order to ensure that absolute accuracy of the Digibridge temperature recorder is achieved, a facility for precision temperature calibration has been assembled and the International Practical Temperature Scale of 1968 can now be realized to an accuracy approaching 0.001°C over the whole oceanographic range. A small constant temperature bath for thermistor calibration and a large bath designed for calibrating a completely assembled Digibridge have been constructed. The small bath has been used for the calibration of a number of thermistors to very high precision over the temperature range 0-30°C. The results of repeated ice point calibrations over the past two years indicate a remarkable stability, better than 0.003°C over the two years, for the Digibridge thermistors.

The calibration facility has recently been extended to enable calibration of the conductivity cells used in salinity/temperature/depth systems.

E.A. Bendell, A.S. Bennett, J.J. Betlem, M. Stepanczak

Measurement of water temperature is of prime importance in oceanography. Standard techniques are time-consuming and expensive and give a single location temperature profile. An automatic bathythermograph has been developed which consists of a porpoising body, *Batfish,* that



Batfish: towed, undulating body.

undulates between two depths carrying a pressure transducer and a thermistor to measure temperature and depth. Using a faired conducting cable, the present system can be towed at any depth between the surface and 180 metres at a ship's speed of ten knots. Depth is controlled using variable angle depressing wings activated by a servo-control via command signals from the ship. The system has been used on the Great Lakes in conjunction with the Canada Centre for Inland Waters. Production drawings have been completed and Hermes Electronics Ltd., Dartmouth, has been granted the licence to manufacture the *Batfish* by Canadian Patents and Development Corporation.

To increase the capability of the *Batfish* body a Guildline Instruments salinity/temperature/depth apparatus (STD) was purchased and modified for installation in the *Batfish.* The instrument is interfaced to a PDP-8 computer which controls data acquisition and stores data on magnetic tape for subsequent processing (see BI Contribution No. 144). Several hours of data from the towed *Batfish* have now been obtained together with data from several hundred more conventional vertical stations in the Gulf of St. Lawrence. The *Batfish* STD and the other AOL STD equipment are calibrated using the temperature calibration facility developed for the Digibridge. Calibration for the conductivity measurement is also possible. An investigation into the accuracy and precision of STD measurements at sea has been started.

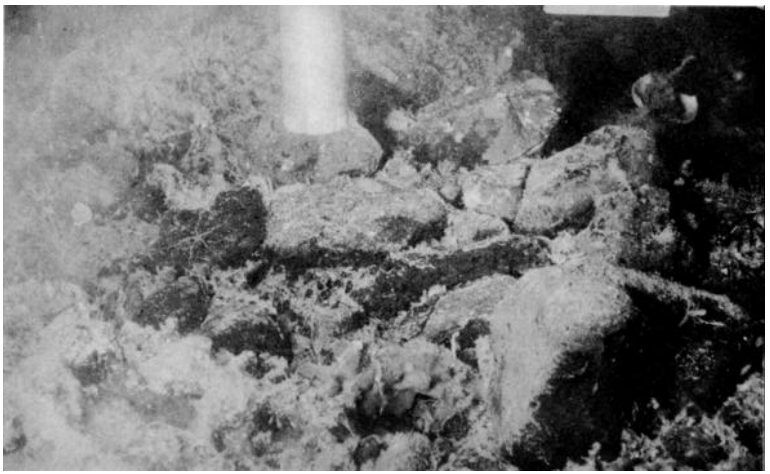
A.S. Bennett, W.C. Cooke, J.-G. Dessureault

ToC

Rock Core Drills

A hydrostatically powered rock core drill has been developed which will operate in depths from 600 to 2000 metres. Originally designed to recover cores six inches long by. one inch in diameter, the drill has successfully recovered samples up to 15 inches in length. Production drawings of the drill are complete and checked; five drills have been manufactured for AOL and commercial production of the drill by Hermes Electronics Ltd., Dartmouth, has been licensed by Canadian Patents and Development Corporation.

In 1969, eight days were spent drilling on the Mid-Atlantic Ridge. Twelve cores were obtained from the crestal peaks in the area of 45°N. This was the first routine use of the drill for scientific purposes and the samples obtained are the first exposed rocks drilled from the Ridge. Photographs of the drill site are taken immediately at the start of the drilling cycle. The figure illustrates a site at 854 metres from which a 12-inch long core of basalt, conglomerate and coralline limestone was recovered. In addition to the bottom photography, data on drill rate and depth of penetration were obtained at each station by acoustic telemetry.



A deep sea photograph of the drill bit of the AOL hydrostatic rock core drill poised just above exposed rock on the Mid-Atlantic Ridge prior to the start of the drilling cycle.

As a result of recommendations from a committee (with representatives from AOL Marine Geology and Geophysics and Dalhousie University, Halifax), the cycle time for the present drill is being increased by 50%. Laboratory experiments are also being carried out to obtain a better understanding of the drilling efficiency and the relation between rate of

rotation, download and flow of drilling fluid. Longer cores may thus be obtained, hopefully, up to lengths as great as one metre. In addition, a hydrostatically powered sediment corer is being designed which it is hoped will retain the unconsolidated material overlying the hard rock which is not presently retained.

A second camera, mounted at the maximum height of the drill frame, is being installed to photograph the area surrounding the drill site.

J. Brooke, J.-G. Dessureault, G.A. Fowler, P.F. Kingston

The drill described above is limited in its operation to depths of 600 to 2000 metres and hence can be used to sample only the relatively shallow crestal peaks of the Mid-Atlantic Ridge in the vicinity of the median valley. We wish to sample rocks from the deeper flanks of these peaks and from the valley floor. First tests of a deeper range drill to operate in depths up to 4000 metres have been successful and a field program with Dalhousie University is planned for the summer of 1971.

It is expected that there will also be a demand for material from the deep ocean trenches and development of a drill which can operate even deeper is planned.

J. Brooke, P.F. Kingston

In cooperation with the AOL Marine Geology Section, an electro-hydraulic drill is being developed to operate from 0 to 400 metres. In addition to acquiring the ability to sample in shallow depths, tests of drilling efficiency will be more easily carried out. The initial design of a drill, powered by an hydraulic motor driven electrically from the surface, is now complete and trials are planned for early in 1971.

J. Brooke, W.C. Cooke, G.A. Fowler, W.J. Whiteway

Mooring Studies

There is an increasing use of recording instruments located at a fixed point in the ocean as part of an instrumented mooring. The length of time a mooring may be left in place is presently limited by the durability of the mooring. Hence a series of investigations is being carried out to determine the factors which affect mooring life and thereby to increase the reliability and durability of moorings. Initially, the effect of corrosion on a non-instrumented mooring is being studied.

A series of field tests were conducted to evaluate the effects of corrosion on mooring components. The basis for judging corrosive activity were material weight loss during exposure and changes in tensile breaking strength of wire rope. Complete moorings consisting of subsurface float, test line and anchor were set in a water depth of 100

metres so as to approximate, as closely as possible, an operational mooring. Three identical strings of moorings were set at the same time and one string was recovered at the end of one, two and three month's exposure. Results from the test indicate that for up to three month's exposure neither weight loss nor tensile strength deterioration are severe enough to affect the integrity of the mooring.

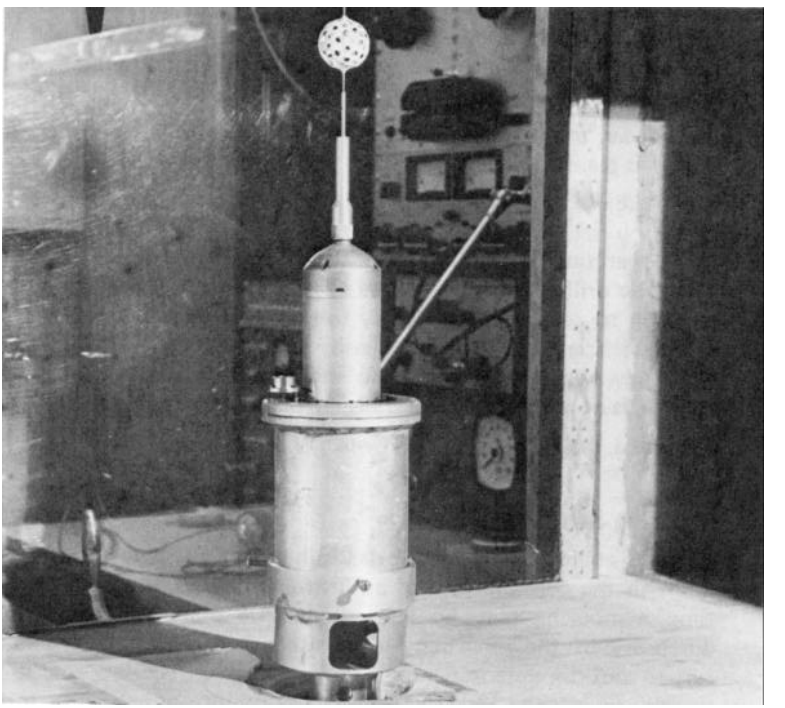
Further tests are to be conducted to gain evidence of the cause of past operational mooring failures.

J. Brooke, G.A. Fowler

ToC

Wind Stress Measurements

The Mark VI Thrust Anemometer has been developed at AOL to sense the three vector components of wind fluctuations. It is unique among



The Mark VI Thrust Anemometer mounted in the Bedford Institute wind tunnel for calibration.

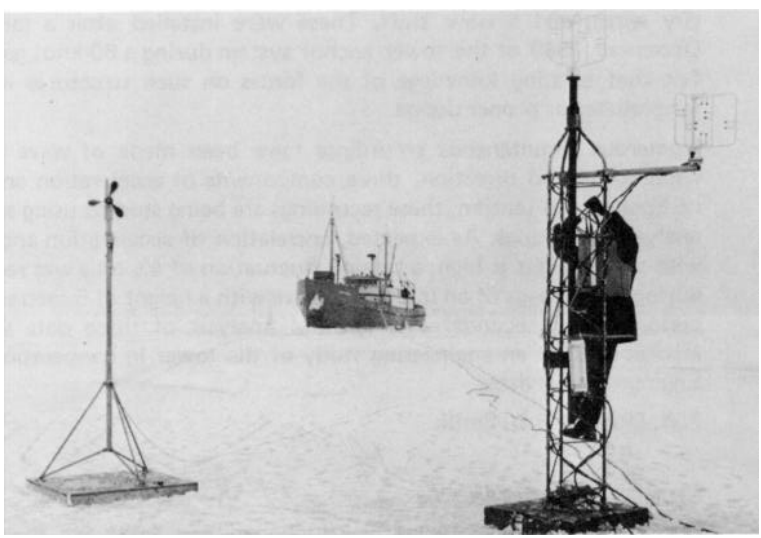
such sensors in being able to operate and maintain its calibration in the field for months at a time. Design of the thrust anemometer is complete, engineering drawings are finished and two units, commercially built, are now being calibrated by the Nova Scotia Research Foundation. The thrust anemometer operates on the stable

platform installed by Engineering Services and is controlled by a remote control and telemetry unit, also designed and assembled by the Systems Engineering Group, Engineering Services.

In experiments at the approaches to Halifax Harbour (essentially open sea conditions) in April-June 1968, September 1968, December 1969 and December 1970, wind stress measurements have been obtained at wind speed up to 16 m/s (see 81 Contribution No. 205). Attempts to operate up to double this wind speed are continuing. Over the range covered, wind stress appears to be proportional to the square of the wind speed.

S.D. Smith

In a joint project with McGill University (Gulf of St. Lawrence Ice Drift Study (see 81 Contribution No. 184)) commercially available sonic anemometers are being used to measure wind fluctuations and stress over ice floes (see figure). Experiments were carried out in February 1969 and in March 1970. Similar measurements over Arctic Ocean ice near Tuktoyaktuk were started in June 1970.



Two sonic anemometers (right) and an Aerovane anemometer (left) over a smooth ice floe in the Gulf of St. Lawrence. MV *Stephenville* in the background.

Wind stress over rough ice (floes 0.3 to 1 metre high) (Gulf of St. Lawrence, 1969, and Tuktoyaktuk, 1970) is about double that over smooth ice (Gulf of St. Lawrence, 1970).

E.G. Banke, S.D. Smith

Over the past year the digital (computer) analysis software used by the Air-Sea Group has been extensively modified. The capability has been added for computing power and cross spectra with the Institute's CDC 3150 computer, using the Fast Fourier Transform technique. (The programs used are adaptations of those developed and presently in use at the institute of Oceanography, University of British Columbia.) The digitizing and digital preconditioning software has been rewritten allowing a 50% increase in speed, better accuracy, more flexibility in use, and the possibility of adding subroutines to handle a wide variety of sensors without any modification of the main program. The whole package, from digitization to printing and plotting of spectra and cross-spectra, is now stored on disc files and is in routine use by the Air-Sea Group, and also by individual scientists in Coastal Oceanography and Ocean Circulation. It is also being modified on a day-to-day basis to meet the needs of the users.

F.W. Dobson, S.D. Smith

The Air-Sea Stable Tower (Engineering Services) has been instrumented with a three-component accelerometer, strain gauges on all four main guy wires, and a wave staff. These were installed after a failure in December 1969 of the tower anchor system during a 60-knot gale; it is felt that existing knowledge of the forces on such structures is quite inadequate for proper design.

Numerous simultaneous recordings have been made of wave height, wind speed and direction, three components of acceleration and four components of tension; these recordings are being studied using spectral analysis techniques. As expected, correlation of acceleration and strain with wave height is high; a tension fluctuation of 4½ tons was recorded during the passage of an individual wave with a height of 5 metres and a period of 12 seconds. The spectral analysis of these data will be incorporated in an engineering study of the tower in cooperation with Engineering Services.

F.W. Dobson, S.D. Smith

Studies of Water Waves

During 1970, a new cover was designed and built for the thrust anemometer by the Nova Scotia Research Foundation which, because of improved symmetry, allows wind turbulence measurements to be taken for the first time at the Air-Sea Stable Tower in winds from every direction. This has allowed the recording of wind stress during off-shore winds in which a ten-second swell was running against the wind. Study of these data has begun in order to better understand the process of wave damping.

F.W. Dobson, M.J. Thorpe

An investigation into the feasibility of measuring the properties of the air flow within a few centimetres of the sea surface has commenced. In order to better understand the process of wave growth under the action of the wind, we intend to measure the turbulent and wave-induced fluctuations of pressure and downwind and vertical wind speeds. It appears possible that sensors of pressure and wind may be kept at a fixed distance from the water surface using a wave follower device developed by the Chesapeake Bay Institute (CBI) of the Johns Hopkins University.

Some of the data collected by CBI have been analyzed using the Air-Sea spectral analysis software. Results of this analysis are very promising and duplication of the CBI instrument for use at AOL is under consideration.

Meanwhile, evaluation of pressure sensors and modifications of the Air-Sea wind tunnel into a return type is underway. A field program, monitoring wave conditions at a site in Bedford Basin, was begun in August 1970, with the idea of using the site for wave follower studies.

A mobile field laboratory consisting of a small trailer, an electrical generating plant, data acquisition and recording apparatus and ten 1½-foot long wave height measuring wires has been designed and built by the Nova Scotia Technical College. Field use of this equipment has not yet been attempted.

F.W. Dobson

ToC

Support Facilities

There are four main support facilities in the Section which are used both by the Section and by the Institute as an entity; also, several instruments were developed as direct support to other AOL sections.

About 50% of the resources of the instrument development shop are available as a service facility for the Institute. In 1970 there were 251 job requests in excess of one man-day, totalling 774 man-days. The remaining time was spent on jobs requiring less than one man-day.

The shop has been divided into two sections, the precision workshop used only by the qualified instrument technicians and a technicians' workshop which is used by all Institute staff openly.

P.F. Kingston

The electronics store provides a source of electronic components for AOL. Engineering Services has been the major user of the store; it has now been transferred into that Section.

D.R. Harvey

The technical library is a collection of data sheets for a wide range of electronic and mechanical components. In 1969 the collection was increased to include data sheets on the specialized oceanographic equipment used in the institution. Data sheets from over 2000 different manufacturers are stored.

D.R. Harvey

The primary responsibility of the standards laboratory is to provide reference standard facilities for all significant units of measurement which are of importance in AOL operations and, where feasible, to strive for traceability to National Research Council or National Bureau of Standards national standards. Two types of standards are kept: primary reference standards, which are normally kept in the BI Standards Laboratory room and secondary or transfer standards for use elsewhere in the Institute or in the field. Work has concentrated on building up a temperature calibration facility and developing techniques for calibrating salinity/temperature/depth equipment.

J.J. Betlem

Some engineering support has been provided by Metrology. A light-weight portable sounding system was assembled from commercial components for use in helicopter surveys to measure the depth of water under arctic ice. The system was built for the Canadian Hydrographic Service for use in their program in the Polar Continental Shelf Project. Field trials of the instrument were conducted out of Tuktoyaktuk and the system is now being used routinely.

P.J. Jollymore

Following a request by Coastal Oceanography a towed body system to pump water continuously from a shallow depth to a surface ship underway was designed and built. The system measures the depth of the towed body and water temperature continuously as sea water is pumped to a surface fluorometer for Rhodamine B dye-tracing experiments.

G .A. Fowler

Copying a design of the Woods Hole Oceanographic Institute, a stable rotating table was built for use in hydrodynamic model studies by Ocean Circulation.

G.A. Fowler

A 35 mm film transport system was built to create visual movement from a sequence of time lapse photographs of events which occur over a prolonged period of time. The 35 mm still camera photographs are converted to a 16 mm motion picture by exposing a selected number of 16 mm frames to each 35 mm frame. The system, developed for Marine Geology to study sediment movement created by wave action, is also used for sequenced 35 mm frames produced by computer displays.

D.R. Harvey, D.F. Knox

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Ocean Circulation

C.R. Mann

B.D. Carson
R.A. Clarke[1]
D.M. Garner
J. Gavan
S.J. Glazebrook
A.B. Grant
W.B. Griefeneder
J.R.N. Lazier
J.G. Murray
G.T. Needier
N.S. Oakey[1]
C. Quon
R.F. Reiniger
C.K. Ross
R.L. Russell
H. Sandstrom

In 1969 and 1970 the Ocean Circulation Section continued to develop a program aimed at understanding the physical processes that occur in the body of the ocean and their causes. The work has fallen naturally into two categories, experimental studies and theoretical studies. The experimental work, which forms the bulk of the program, has been concentrated on measurements with current meters. A mooring system has been developed to the point that measurements of currents in the deep ocean are possible. Meters were installed and recovered at four locations across the Drake Passage to study the Antarctic Circumpolar Current during HUDSON , and a project was set up to reactivete work on the Gulf Stream as it passes the Tail of the Banks of Newfoundland. This project, with direct current measurement providing new information, is being carried out in collaboration with the Woods Hole Oceanographic Institution. The dynamics of rotating fluids and internal waves have been studied using numerical models and wave tanks, respectively, to provide an insight into the phenomena under controlled conditions. Some development has begun on new instrumentation techniques.

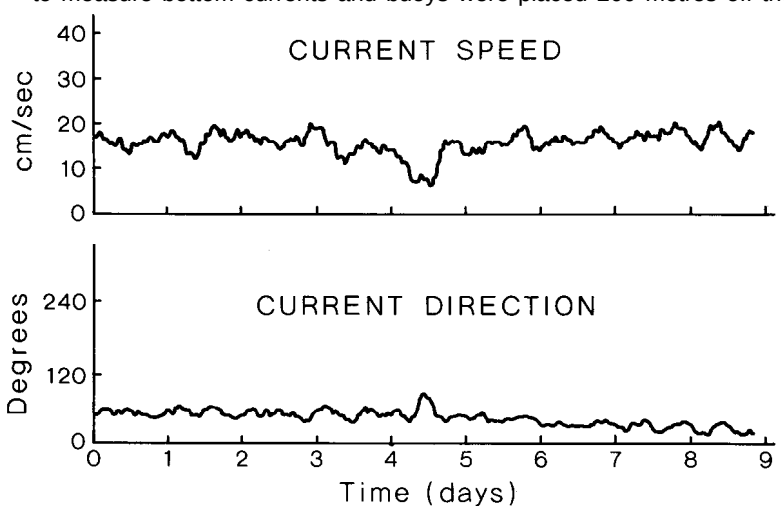
C.R. Mann

North Atlantic

From 1963 to 1966 the Section had investigated the current pattern of the Gulf Stream in the vicinity of the Grand Banks. A general description of the current system was obtained but then the project was left because direct current measurements became essential to further progress. With the development, at the Atlantic Oceanographic Laboratory, of mooring techniques suitable for deep ocean work the project has been reactivated. The present work is aimed at a large scale experiment in the Spring of 1972 when it is planned to measure volume transports, to study changes in the current systems, and to determine the vertical structure of the current.

[1] Joined AOL

The primary phase of the project has been the development of a mooring which would be suitable for use in the Gulf Stream. This phase started in 1969 with the acquisition of equipment which appeared to be the most suitable amongst what was commercially available. In December 1969 the first field trial was conducted to test and evaluate the new acoustic release system, the buoyancy, and other components of the buoy installation. As the components of the buoy system proved adequate, a second field program was carried out in 1970 during which three moorings were placed across the path of the Gulf. Stream, south of the Newfoundland Banks, at depths of 5400 metres for two of the moorings, and 3600 metres for the third. The moorings were designed to measure bottom currents and buoys were placed 200 metres off the



A current meter record from under the Gulf Stream south of the Grand Banks. The instrument was moored at 5270 metres in 5400 metres of water.

bottom with current meters between them and the anchor. Analysis of the data obtained is still in its early stages; however, several interesting comments can be made. Of the seven current meters used, five have yielded results. The current meter nearest the Banks (3600 metres) showed a variable current which ranged from 0 to 35 cm/s. The most interesting feature is that when the speeds are greater than 20 cm/s, the current direction is generally parallel to the edge of the Banks and in the northwest direction. The second mooring which was between the slope and the Gulf Stream showed a reasonably steady current of about 14 cm/s in the westerly direction. The third mooring, which was in the Gulf Stream, showed a reasonably steady current of about 17 cm/s in the easterly direction. A section of temperature and salinity across the Stream was made three times in order to calculate sectional current

profiles. The data has been analyzed for one crossing and, when combined with the direct current meter measurements, shows the Gulf Stream is transporting about 160 million m^3 which is much more than oceanographers were lead to believe in the past.

Plans are now underway for a further cruise in 1971 during which an attempt will be made to extend the mooring to about 2500 metres off the bottom. Preliminary plans for a joint survey of the area in spring 1972 with the Woods Hole Oceanographic Institution are also being drawn up.

R.F. Reiniger, C.R. Mann

In order to study the deep circulation a general description has been made of the distribution of reactive silica in vertical cross-section through the Atlantic Ocean each side of the Mid-Atlantic Ridge from Arctic to Antarctic waters, using a compilation of data from the literature and Data Centre files (Ottawa). These sections have been related to the water mass structure of the Atlantic Ocean by a comparison between the temperature-salinity and temperature-silica correlations characteristic of various regions. In particular, the great contrast between silica-rich Antarctic bottom water (-100 urn) and silica-poor Arctic deep water (~10 um) seems to provide a sensitive means for tracing the intermingling in North Atlantic basins of deep waters containing the last recognizable residues of contributions from these sources.

Some measurements were made from the CSS *Hudson* during August/September, 1968, of the physical and chemical properties of deep water in the Median Valley of the Mid-Atlantic Ridge. Temperature, salinity, dissolved oxygen, silica, and fluoride were sampled. The topography of this region provides the interesting situation of a fairly extensive body of homogeneous deep water in mid-ocean which is physically isolated from adjacent deep waters of the main North Atlantic basins, and whose properties are derived from water at the depth of saddles in the flanking mountain ranges of the Ridge. In particular, this isolation leads to a marked contrast between the reactive silica concentrations of deep waters in the Median Valley and those in the adjacent open ocean. The absence in the Valley of the relatively high silica concentrations found in deeper outside waters perhaps provides evidence that these higher concentrations (tentatively associated above with spreading of the Antarctic bottom water) are not predominantly due to solution of siliceous particulate matter falling from above. No evidence of any thermal or geochemical anomalies in the bottom water of the valley was found.

A cruise during May/June, 1970, by the CSS *Dawson* measured the deep water transport through the Mid-Atlantic Ridge Fracture Zone near 53°N, and examined the effect of this transport on the adjacent deep water mass structure. Current meters were moored in a depth of about 4000 metres for a period of seven days in each of the two deep troughs of the Fracture. Preliminary examination of the records indicates a west-going flow of water through the Fracture, with a mean speed of about 3 cm/s and a superimposed oscillation of a semidiurnal tidal period with an amplitude of 2-3 cm/s. A pattern of hydrographic stations with deep sample spacing of 100 metres was worked in and around the Fracture measuring temperature, salinity, dissolved oxygen silicate, and fluoride. Bottom photographs obtained in the southern trough of the Fracture showed indications of sediment ripples due to current flow.

D.M. Garner

An opportunity to study Scotian Shelf storm surges came in October 1968 when hurricane GLADYS moved along the eastern North American seaboard, its centre following approximately the shelf edge from Florida to Nova Scotia. Two strings of current meters were moored on the Scotian Shelf during this period, one over Emerald Basin in the middle of the shelf with meters and thermographs at 50, 95, and 250 metres, and the other at the shelf edge with meters at 20, 150, and 980 metres. A detailed case history of this event is being prepared; this may be of some interest since very few documented observations of the ocean's response to a well-defined meteorological disturbance are available to guide theoretical work. Preliminary examination of the current meter records indicates that the passage of the low pressure centre across the site in Emerald Basin was associated with a rapid rise in general current strength of about 0.4 knot at the surface, accompanied by the generation of inertial-type current oscillations of similar amplitude. The velocity record was fairly quiet before the passage. The mid-depth meter showed little response to the storm, but an onset of large 'inertial' oscillations in the deeper basin waters also marked the passage of the low pressure centre. Basin oscillations do not appear to be coupled to those at the surface. At the shelf edge mooring, on the other hand, the surface record contained large amplitude (0.5 knot) 'inertial' oscillations for several days before the storm passed over the site. The amplitude of this oscillatory disturbance decreased rapidly with depth at this mooring and little coherence between records from the three levels was apparent. Very large velocity shears, both horizontal and vertical, are indicated in the vicinity of the shelf edge.

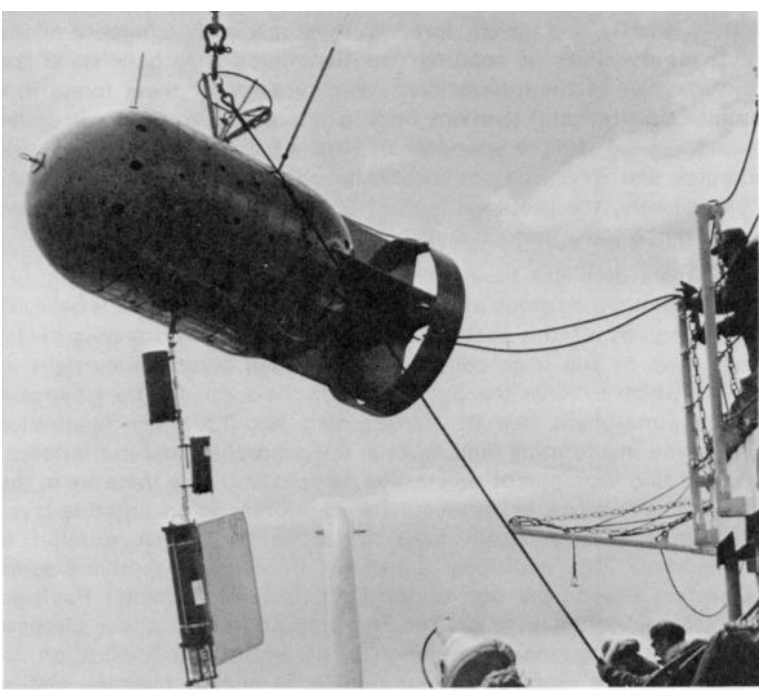
The preliminary results of this study have been useful to oil company engineers concerned with storm surge stresses on offshore drilling rigs. Arising from this, proposals for the exploitation of such platforms for oceanic work are being explored.

The program of the Air-Sea Interaction group (Metrology Section) in measuring the stress of the wind on the sea surface from the stable platform moored in the approaches to Halifax Harbour provides another opportunity to obtain some data on the response of the shelf waters to meteorological disturbance. A mooring of five current meters separated by five metres in the vertical was laid adjacent to the platform for a period of 48 days during November/December, 1969, and data is being examined for correlation between the applied surface stress and the vertical shear in the currents.
D.M. Garner

ToC

South Atlantic and Antarctic

As part of the HUDSON 70 program, four buoys each carrying three current meters and three temperature recorders were installed across the Drake Passage between Cape Horn and Anvers Island. The current meters were placed at 150 and 1500 metre depths and at the bottom



A subsurface float with temperature recorder, pressure recorder and current meter being streamed in the Drake Passage. Whip antennas provide a radio signal for location of the float when it surfaces on recovery.

(~3500 metres). The instruments were in place 11 days and all except two worked satisfactorily. Analysis of the records is near completion. A west-to-east current appears to operate close to Cape Horn with surface velocities of 0.5 knot. The currents further south are weaker.

During the transit down the 30°W meridian in the South Atlantic, a temperature/salinity section was made across the southern side of the Argentine Basin to determine whether a strong narrow flow of Antarctic bottom water occurred westward into the Argentine Basin. Previous work by other investigators had indicated that this flow might be as much as 90 million m^3/s. The Hudson Section did not confirm this and it is difficult to interpret because of a possible deep eddy lying in the southern extremity of the basin.

C.R. Mann

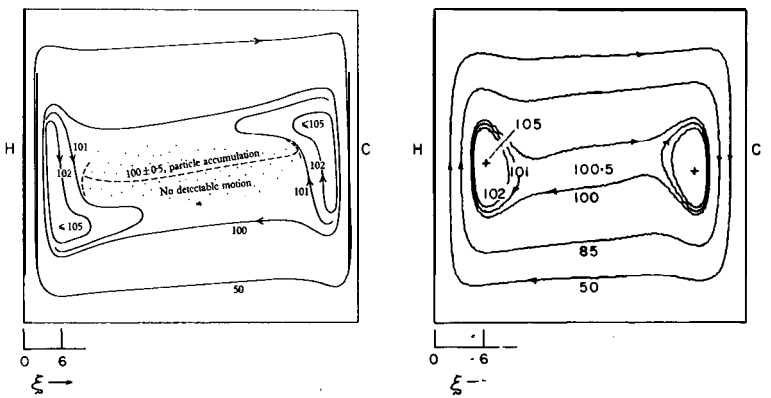
ToC

Theoretical Studies

In order to understand the dynamics of the ocean and planetary atmospheres, one must understand the interactions of buoyancy, coriolis, inertia, and viscous forces in these media. The purpose of the study of dynamics of rotating stratified fluids is to understand the fundamentals of the interaction of two or more of these forces in a simpler environment' than one finds in nature (e.g., to replace irregular boundaries by straight boundaries). Most of these problems are very complex and it is often impossible to obtain an analytical solution. Consequently, the problems studied in the past two years have been solved numerically through digital computers.

Three main problems have been completed in the last two years: (1) The axisymmetric regime of the rotating annulus problem. It is believed that the study of this problem will help in the understanding of the basic state of the large collection of so-called baroclinic currents in nature, which includes the Gulf Stream in the ocean and the jet stream in the atmosphere (see BI Contribution No. 136). (2) Penetrative convection in a rotating fluid. Both in the atmosphere and in the ocean, one can find examples of penetrative motion. Normally these are in the form of turbulence or other modes of motion in an unstable layer penetrating into a stable layer in scales for which rotation is unimportant. The additional constraint of rotation produces some interesting phenomena due to the Coriolis force. (3) High Rayleigh number convection in a cavity. The interest in this rather classical problem is longstanding because of its immediate application in engineering (the problem of heat transfer in nuclear reactors) and in geophysics (geyser or other convection phenomena in geology).

Two more problems are presently underway: convection in a slant cavity, and axisymmetric baroclinic instability in a rotating annulus.



These figures show the pattern of particle paths in a fluid at steady state in a cavity heated on the left- and cooled on the right-hand wall, while the top and bottom were insulated. This problem has been extensively studied as an idealized model in connection with building insulation, nuclear reactor heat transfer, heat flow in a geyser and other geophysical fluid dynamical phenomena. The left-hand figure is the result of Dr. J.W. Elder's experiments in Cambridge University, and the right-hand figure is a computer simulation done with the CDC-3100 at the Bedford Institute.

A rotating table of one metre in diameter has been set up in the fluid mechanics lab by the Metrology Section. Some preliminary tests of stability and vibration show that it will be a useful apparatus to augment the numerical studies carried out so far. The table will be used to study three-dimensional flows which only the largest computer can handle numerically.

C. Quon

In connection with internal wave studies, research has continued on details of the mechanisms of topographic coupling of surface tides with internal tides and of distribution of energy among the various internal modes. The results of this effort can be applied towards a better understanding of energy propagation in waves whose frequency lies between inertial and an intrinsic frequency imposed by stratification (the Brunt-Väisälä frequency). For example, the apparent lack of agreement between the existing theory of tides of semidiurnal frequency and the few existing deep ocean pressure and current measurements points out the need for continued investigation and improvement of tidal theory in stratified, rotating media.

A study of the effect of topography on the propagation of waves in stratified fluids was completed in 1969; a ray theory solution to wave propagation in a variable depth wave guide was compared to experiment. Striking similarity in the main features encouraged further development of theoretical models, based on ray theory, for the case of

ocean basins of arbitrary shape. A study is underway of internal wave eigenfunctions for water of variable depth, and was augmented by numerical studies carried out during the summer of 1970 with the assistance of a summer student.

Another theoretical approach, aimed at circumventing some of the complexity of comparing observation in open ocean to theory, has been proposed in which currents along the ocean bottom are measured as an indicator of internal wave activity instead of current and temperature fluctuations at mid-depths.

Experimental studies with laboratory models have as yet not come up to expectations, although some tests of efficiency of different structures as wave reflectors, transmitters or absorbers were carried out. The wave tanks used in these models have been recently located in a proper fluid mechanics laboratory which will facilitate their use.

H. Sandstrom

Many geophysical time series have gaps or are irregularly spaced because of circumstances beyond the control of the experimenter. Much of the information contained in these records cannot be extracted because Present techniques for generating power spectra, for example, have been developed for regularly spaced records. A start has been made on developing techniques for analyzing irregularly spaced records. An analytical investigation has been completed but, as several approximations have been necessary, their validity is being checked by artificially gapping a known time series. The techniques are being applied to a time series from station P (North Pacific Ocean) as this is one of the more important time series of oceanographic parameters.

C.K. Ross

Experimental evidence shows that bottom topography is an important factor in determining the course of ocean currents. A theoretical study of the effect has been started and is particularly directed at the influence of the Southeast Newfoundland Ridge on the path of the Gulf Stream.

R .A. Clarke

To get some feeling for the nature of the vorticity balance in the region of interaction between the Labrador Current and the Gulf Stream systems, experiments are being conducted with a numerical model of the vertically integrated transport driven by a wind stress varying sinusoidally in the meridian over a square B-plane ocean with (a) a rectangular boundary indent in the northwest corner to represent the Grand Banks of Newfoundland; (b) a transport source on the northern boundary just east of this block to represent the northern boundary.

The effect of variation of Rossby and Ekman numbers, strength, and vorticity of source, and wind stress curl have been studied. Variable bottom topography and an extension to three-dimensions are being considered, particularly to see how the nonlinear convection terms in the hydrodynamic equations integrate over depth.

D.M. Garner

ToC

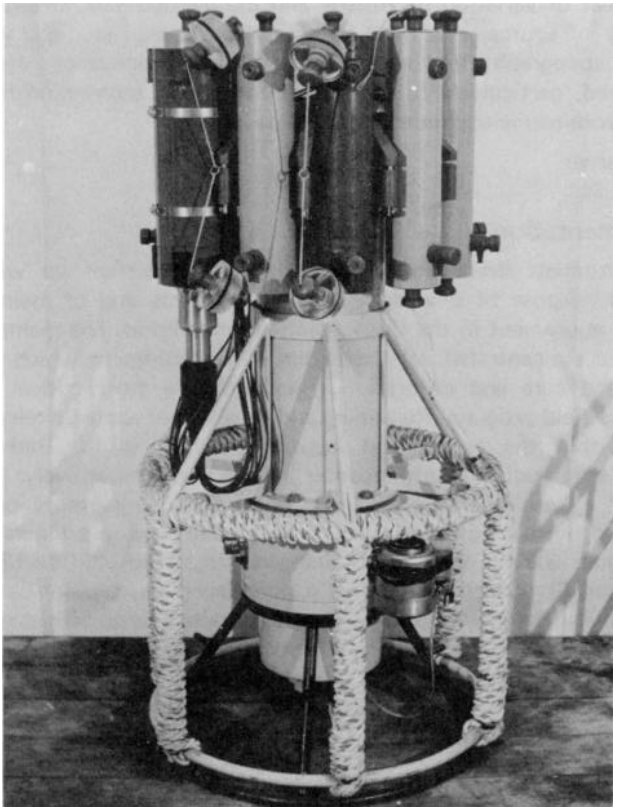
Instrumentation

An instrument development laboratory has been set up with the twofold purpose of developing new instruments and of maintaining existing equipment in the Ocean Circulation Section. The maintenance tasks are concentrated on those pieces of equipment which require specialized care and calibration and which are most critical to the Section's field program. Re-arming and repairing of acoustic releases are done within the group, and instruments such as the Bathysonde salinity/temperature/depth recorder (STD), used extensively in field work, are kept operative and calibrated. The temperature probe is calibrated by placing the probe in a bath controlled in temperature to better than 0.01°C and by obtaining readings from -2°C to +30°C in 0.5° steps. Standardization at sea is done using an ice-point bath. The conductivity channel calibration curve is obtained using precise resistors in the inductive measuring probe. Standardization at sea is obtained from simultaneously acquired water samples. The depth channel is calibrated using a dead weight pressure standard.

In conjunction with the STD, a considerable amount of time has been devoted to the design and development of a suitable and reliable multiple water sampler. By using this, water samples may be collected at various depths for determination of dissolved oxygen, silicates, etc. The salinities of the samples are used as a check of the STD conductivity calibration. The final version of the rosette sampler (see picture) is in the last stages of assembly and testing. The unit consists of ten PVC (plastic) bottles of 1.3 litre capacity mounted on a ring about the upper pressure casing of the STD. The bottles can be closed sequentially by means of a shipboard command signal. The unit is constructed of PVC and aluminum with specially built pressure equalized solenoids so that the unit can operate over the whole depth range of the Bathysonde (2500 metres).

A PDP-8L computer is on order to be used with the STD to obtain conductivities and temperatures in a convenient digital form. Salinities will be calculated immediately and interesting profile features and anomalies will be obvious while the ship is still on station.

N.J. Oakey.



This rosette sampler can be used to collect water samples at various depths.

In 1970 the Atlantic Oceanographic Laboratory took part in an intercomparison of the Geodyne tape, Bergen, Plessey, Braincon film, and Alexeev current meters during the seventh expedition of the USSR Academy of Science's research vessel *Akademik Kurchatov* in the southern North Atlantic. The experiment consisted of four 12-day moorings with current meters at 50, 200, and 1000 metres. An Alexeev current meter was placed at each depth on each mooring as control with one of the other current meters separated in distance by four metres. Each manufacturer had a meter at each of the three depths on different moorings. Also included in the moorings were four LSK meters of the Institut für Meereskunde, Warnemunde, D.D.R. One Braincon meter and four Alexeev meters did not give full records.

Scientists from the National Institute of Oceanography, the Woods Hole Oceanographic institution, the Institut für Meereskunde (Kiel) and the Atlantic Oceanographic Laboratory participated in the cruise.

All the data available from the current meters were forwarded to the Woods Hole Oceanographic Institution for analysis. Participants from the Atlantic Oceanographic Laboratory, the National Institute of Oceanography, and the USSR Academy of Sciences met in Woods Hole in late 1970 to undertake the analysis.

C.K. Ross

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R.C. Melanson

A.L. Adams
R.C. Amero
V.N. Beck[3]
J.R. Belanger
A.T. Bent
T. Berkeley
K.S. Budlong
R.G. Burke[1]
T.M. Calderwood
R.M. Cameron
A.M. Canning[2]
G.G. Clark[2]
E.J. Comeau
P.L. Corkum
W.J. Danson
F.L. DeGrasse[2]
D.L. DeWolfe[1]
G.R. Douglas
S.S. Dunbrack
R.M. Eaton
G.N. Ewing[3]
R.G. Fairn[2]
N.E. Fenerty.
J.R. Gasparac[2]
V.J. Gaudet
E. Gidney
R.G. Gillies[1]
R.P. Haase
M.A. Hemphill
G.W. Henderson
D.H. Herman[2]
E.G. Howse[2]
D.J. Lambe[1]
D.D. LeLievre
R.C. Lewis
J.R. Lord
J.R. MacDougall
W.B. Millar[2]
C.G. Miller
B.T. Noel[1]
J.M.R. Pilote
M.D. Price[2]
L.D. Quick
D.G. Robichaud[1]
J.I. Schneider
G.R. Sellers[1]
J.G. Shreenan
K.G. Spence[2]
T.B. Smith
R .A. Squires[1]
M.G. Swim
R.L. Tracey
J.S. Warren
H. Weile[1]
D.E. Wells[3]
K.T. White
R.K. Williams
G.M. Yeaton

The prime responsibility of the AOL Hydrographic Section is the charting of all navigable waters for Canadian navigational requirements. The Region of concern is defined as Canada's Atlantic Seaboard, the Gulf of St. Lawrence east of Pointe des Monts, Hudson Bay, and the Eastern Arctic. Three auxiliary groups are maintained within the Section: Development, whose function is to develop instruments and techniques in order that the collecting and processing of hydrographic field data will proceed with increased efficiency. Navigation, whose responsibility is to evaluate present and new means of positioning and to become the authoritative voice of the Institute on all navigational requirements; and Drafting, Illustrations, and Photography, whose function is to provide a service to the Institute.

[1] Joined AOL

[2] Left AOL

[3] Transferred within AOL

A great deal of emphasis was placed on training during the past two years, both in-house and at university. We continue to send all new junior survey technicians to headquarters each fall to undergo Hydrography I training, a course of study consisting of 2½ months in the classroom and 2½ months in the field. A more advanced six-week course, Hydrography II, was introduced in 1968 and to date nine field officers from the Section have taken this training.

One of the major highlights over the past two years was the introduction of the newly developed automated data acquisition system. In 1969 part of the system was evaluated in conjunction with a survey field party or establishment from the Central Region of Canada operating in the St. Lawrence River, and in 1970 the complete system was placed on board the CSS *Kapuskasing* for a three-month period. The 1970 implementation was so successful that it will become a full-time tool for the hydrographers of one of the field establishments during 1971. Other field establishments will be similarly equipped over the next few years as funds become available.

A second very significant highlight is the close association of the hydrographers and geophysicists in carrying out systematic multi-disciplinary (Hydrographic Geological and Geophysical) surveys.

A third event worthy of special comment was the 1970 hydrographic survey of the Beaufort Sea. The priority for the area was very high, and in order to comply with the requirement, the three regional offices combined resources. The contribution by AOL consisted of the CSS *Baffin* with a full complement of hydrographers and technicians on a full-time basis, and geophysicists for periods of short duration. The cooperation effort of 1970 may be a good indication of how projects with a high national priority may be handled in the future.

R .C. Melanson

Hydrographic Charting

The main function of the Hydrographic Charting Unit is to chart all navigable waters within the Region. The field season in which the data collection takes place usually lasts from early May until late October each year; the remainder of the year, except for special projects, is spent processing the data to its completed form. Field manuscripts are produced in the Region; the final charts, compiled from the field manuscripts, are made in Ottawa. Surveys are conducted by both ship-based and shore-based parties.

The departmental ships from which we conduct our surveys are the CSS *Baffin,* the CSS *Kapuskasing,* and the CSS *Maxwell.* The CSS *Acadia* was decommissioned after the completion of her 1969 hydrographic assignment. Surveys in the Arctic generally are undertaken from

Canadian Coast Guard Ships of the Department of Transport, although in 1970 an extensive survey was carried out in the western Arctic from the CSS *Baffin.* Shore parties are generally supported by two or three 10-metre survey launches and two land vehicles.

Hydrographers also participate in oceanographic cruises to collect bathymetry and navigational data for the General Bathymetric Charts of the Oceans (GEBCO). In 1970, this participation was particularly apparent on the HUDSON 70 cruise where some 74,000 km of GEBCO data were collected and are presently being processed by the Drafting and Illustrations Group.

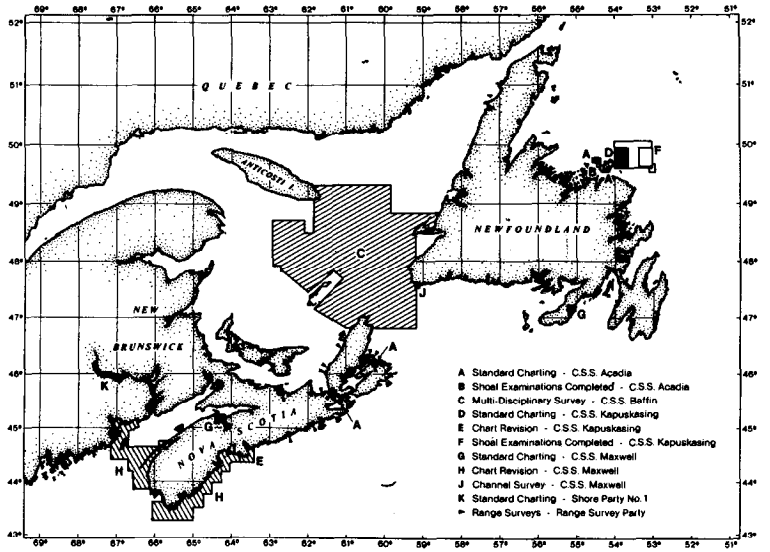
Our main charting effort continues to be concentrated in and about the Maritime Provinces, although increasing priority was placed on eastern and western Arctic programs during 1970.

In 1969 the hydrographic survey parties, operating under the direction of the Atlantic Region, were chiefly involved with detailed surveys in support of coastal development in the area of the Atlantic Provinces; charting for pleasure boats in the Mactaquac Head Pond area of the Saint John River; surveys of opportunity, operating from Department of Transport vessels along the Labrador coast and eastern Arctic; completion of the multidisciplinary survey in the Gulf of St. Lawrence; positional and sounding surveys of Department of Transport navigational ranges in the Nova Scotian area; and chart revisory surveys from Halifax, Nova Scotia, to Grand Manan, New Brunswick.

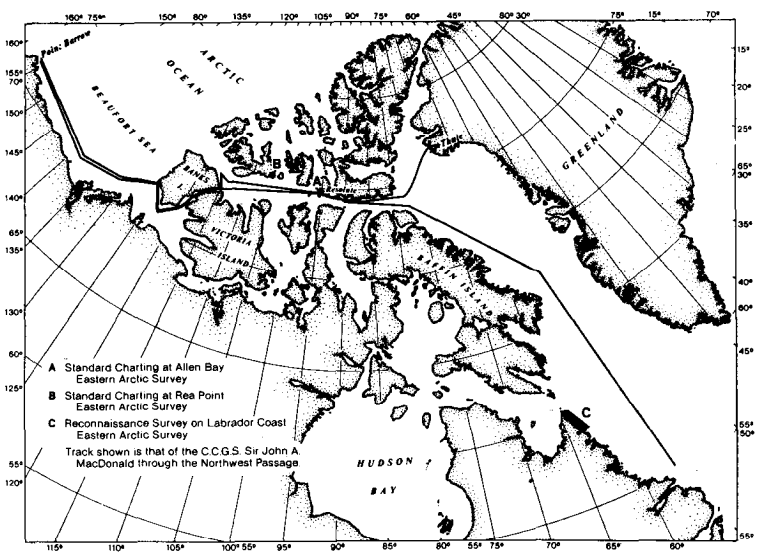
Two special assignments were carried out in 1969 utilizing the personnel and equipment resources of the Atlantic Region. The first involved the hydrographic responsibility on board the CCGS *John A. MacDonald,* while the ship was escorting the *Manhattan* on her historic voyage through the Northwest Passage. The second involved a rigorous evaluation of the Lambda (Low Ambiguity Decca) electronic positioning system in a range/range mode. A number of senior personnel from the Nautical Geodesy Section of the Canadian Hydrographic Service and the Surveys and Mapping Branch (both, Department of Energy, Mines and Resources, Ottawa) participated in the experiment.

1969

The areas of operation for each establishment working in the Atlantic Provinces and in the Arctic in 1969 are shown on the first two maps.



1969 areas of hydrographic survey operations in the Atlantic provinces.



1969 areas of hydrographic survey operations in the Arctic.

The honour of being the last hydrographer-in-charge of a party on the CSS Acadia belongs to Mr. R.C. Amero. His establishment conducted a coastal development survey in the Strait of Canso area in response to a requirement for detailed bathymetric information prior to the construction of new docking facilities for deep draft tankers. The *Acadia* party then continued with the recharting of the east and northeast coasts of Newfoundland. A major revisory survey of the waterfront area of North Sydney, Nova Scotia, was also carried out.

A combined hydrographic-geophysical survey (F.L. DeGrasse, Hydrographer-in-charge) in the Gulf of St. Lawrence was completed using the CSS *Baffin;* positioning was accomplished using Lambda (range/range mode). Then a detailed evaluation of the Lambda electronic positioning system was carried out in the Gulf.

The CSS *Kapuskasing* establishment (under D.D. LeLievre) continued coastal surveys along the northeastern approaches to Fogo Island, east coast of Newfoundland. This survey made extensive use of the Decca Hi-Fix navigation system (hyperbolic mode).

The survey party (under M.A. Hemphill) on board the CSS *Maxwell* undertook the revision of navigation charts covering the area from Halifax, Nova Scotia, to Grand Manan, New Brunswick. Upon completion of this program, they finished a survey project begun in 1968 near Marystown in Mortier Bay, Newfoundland; this survey was particularly urgent because of the new wharves constructed in conjunction with the new fish plant at Mooring Cove. A second project in Newfoundland involved a survey of the approach channel at Port aux Basques to determine if any of the large boulders used in construction of the breakwaters at Graveyard Point and Pikes Island had washed back or rolled into the channel. An urgent request for a survey of the Avon River estuary was received from the Gypsum Transportation Limited, which was intending to replace two of its present 10,000-ton vessels with larger cargo capacity vessels, possibly 20,000 tons. A survey was sufficiently completed to answer initial queries.

The one shore party (under P.L. Corkum) that operated from the Atlantic Region in 1969 charted the Mactaquac Head Pond area of the Saint John River between the Mactaquac hydro-electric power station and Woodstock. This covered a section of the river over 50 miles long and included several navigable tributaries and coves bordering on the main river. The survey had been requested by the New Brunswick Government for the purpose of making charts available to pleasure-boat users.

A new assignment to the Canadian Hydrographic Service that began in 1969 involves a systematic program of surveying all navigational ranges in each region. To meet our responsibility in this respect, a navigational range survey party was established (under M.G. Swim). Ranges

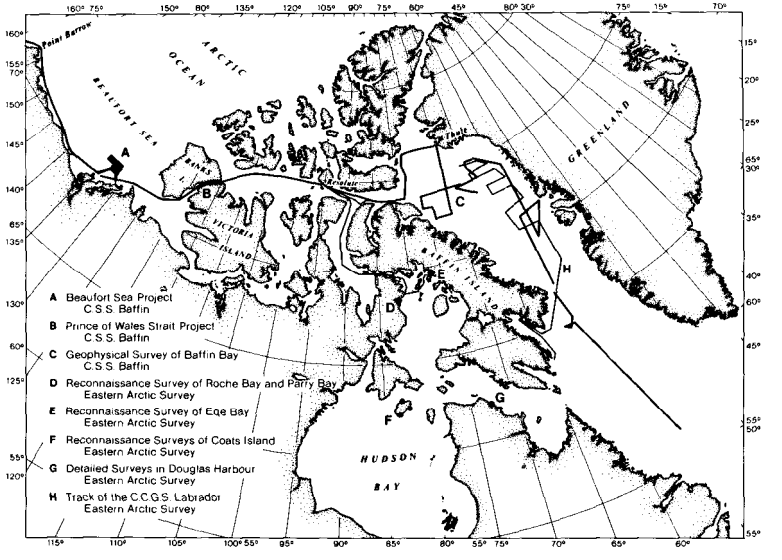
northeastward from Sheet Harbour, near Halifax, around the coast of Cape Breton Island and southeastward to Pictou were positioned and sounded. Navigational ranges in the Strait of Canso were also surveyed.

The Eastern Arctic survey establishment (under R.K. Williams), working from the Department of Transport vessel CCGS *C.D. Howe,* carried out a reconnaissance survey along the Labrador Coast to determine which were the outermost islands within the limits of chart 4771. Islands proven to exist will be used in establishing baselines to define the limit of Canada's territorial waters.

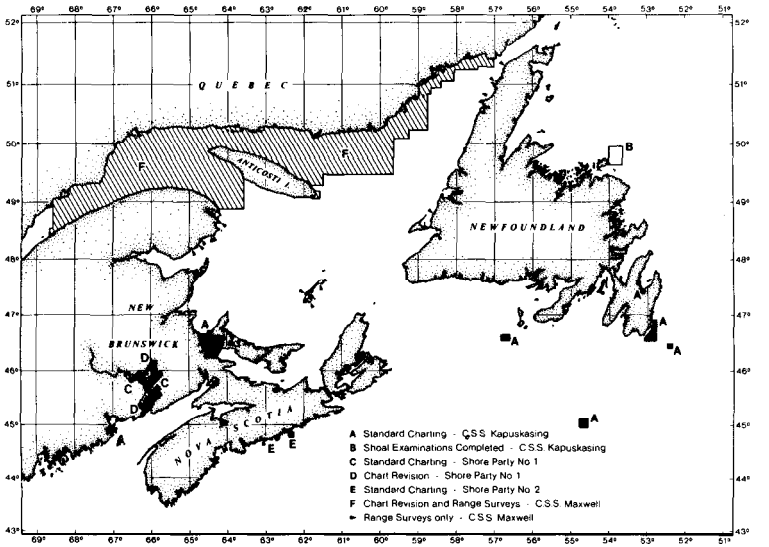
A small hydrographic charting program in the Allen Bay area of Cornwallis island was conducted (under R.K. Williams) in support of finding an alternative to Resolute Bay for landing cargo. The survey party also carried out a limited hydrographic survey at Rea Point on Melville Island, to meet the needs of Panarctic Oil Limited. They then joined the Department of Transport vessel, the CCGS John *A. MacDonald,* to carry out the hydrographic responsibility on this ship during her escort duties for the famous voyage of the *Manhattan* through the Northwest Passage.

1970

Areas of hydrographic survey operations in the Arctic and in the Atlantic Provinces during 1970 are shown on the next two maps.



1970 areas of hydrographic survey operations in the Arctic.



1970 areas of hydrographic survey operations in the Atlantic provinces.

Due to the oil discovery in Prudhoe Bay, on the Alaskan north slope, and a second discovery at Atkinson Point east of the mouth of the Mackenzie River, an increased emphasis was placed on Arctic hydrographic and scientific surveys. Our major multidisciplinary establishment (under T.B. Smith), on board the CSS *Baffin,* was placed under the operational control of the Pacific Region and a major hydrographic-geophysical survey of the 'Admiral's Finger' area of the Beaufort Sea was conducted. A second conventional hydrographic survey was carried out in the Prince of Wales Strait in the vicinity of the Princess Royal Islands. The *Baffin* obtained GEBCO soundings on her passage from Halifax through the Panama Canal to Victoria, B.C. From Victoria to the Beaufort Sea and through the Northwest Passage, GEBCO soundings, gravity and magnetic data were collected as conditions permitted. Upon completion of the western Arctic surveys and the eastward traverse of the Northwest Passage, the *Baffin* establishment carried out a reconnaissance multidisciplinary survey of Baffin Bay in conjunction with the CSS *Hudson.*

The CSS *Kapuskasing* establishment (again under D.D. LeLievre) surveyed Ballard Bank, southeast coast of Newfoundland: in recent years there had been several reports of less water than charted in this area. As Cape Race is such an important turning point for navigation and as the depths of these banks are extremely important to fishermen, this survey received a high priority. Positioning for the survey was accomplished using Decca Hi-Fix (range/range mode). The *Kapuskasing* then continued the 1969 survey of the northeastern approaches to Fogo Island. This survey was terminated in early August so that a

survey of a portion of the Northumberland Strait could be undertaken using the automated data collecting and processing techniques mentioned in the introduction and described in the Hydrographic Development subsection of this report. This survey was carried out with members of our Development group on board so that initial faults could be examined and corrected on the spot.

Revisory surveys of 32 charts along the coast of Gaspé Peninsula to Rimouski, and along the Gulf of St. Lawrence north shore from Les Escoumins to Chateau Bay were again carried out (under M.A. Hemphill) from the CSS *Maxwell.* Navigational range surveys along the west coast of Newfoundland, the Magdalen Islands, and southwards from Gaspé along the north shore area of New Brunswick were also completed.

A shore party (No. 1, under R.K. Williams) continued the survey of the Saint John River area. This survey project had commenced in 1969 above the Mactaquac Power Development, and in 1970 began charting below Fredericton in Belleisle Bay, Washademoak Lake, Foshay Lake, Harts Lake and the Oromocto River. These bodies of water are all connected to the lower Saint John River, below the Mactaquac Power Development. This shore party also carried out a revisory survey of the Saint John River charts from Saint John to Fredericton.

Further work by other shore-based parties included standard hydrographic charting in the Ship Harbour to Sheet Harbour area on the eastern shore of Nova Scotia (Shore Party No. 2, under R.C. Amero) and in the approaches to Musquodoboit Harbour (the *Maxwell* establishment working from shore and No. 2). The latter survey was undertaken in response to a Department of Transport request. Charting was continued on the east coast of Nova Scotia in the Tusket Islands-Yarmouth area (Shore Party No. 3, under M.J.R. Pilote). A survey party (No. 3) also participated with the Department of Transport in an extensive buoy-laying project in the Strait of Canso area.

Eastern Arctic surveys (under M.G. Swim) in 1970 were carried out from the Department of Transport vessel CCGS *Labrador* in support of industrial developments in the Douglas Harbour area of Hudson Strait and in similar developments at Parry Bay, Roche Bay, and Ege Bay in Foxe Basin. Surveys of opportunity were conducted around Coats Island in Hudson Bay and track sounding was done in conjunction with a geological sampling program in Baffin Bay and Davis Strait.

During 1969 and 1970 a great number of small, high-priority hydrographic surveys in the local area were carried out by our personnel on rotational assignments. The need for these surveys is usually due to the hydrographic information required before and after projects such as new wharf construction, dredging, bridge building and

so forth. An increasing demand for our services has been made by the Department of Transport concerning positioning of buoys, ranges and other aids to navigation. There has been a sharp increase in requests for services from the scientific community at the Bedford Institute for pollution studies, local sparker seismic surveys and large-scale geophysical and oceanographic surveys.

G.N. Ewing

ToC

Hydrographic Development

The Hydrographic Development group at AOL, together with groups located at the University of Saskatchewan, Canada Centre for Inland Waters, Pacific Region, and Headquarters (Ottawa), form the basis of an overall technical development program within the Canadian Hydrographic Service. The aim of the program is to increase the efficiency of all phases of hydrographic data collection and chart production by the use of modern techniques and automated processes. The group located at AOL is primarily responsible for investigating and implementing means of improving and modernizing the techniques of hydrographic field data collection and preliminary data processing. The more important aspects of the group's activities are outlined below.

A very large portion of the task of collecting hydrographic data utilizes small survey launches as working platforms. The group's investigations of methods of increasing productivity in this area indicated that an automated system of data collection would produce excellent results. The instrumentation required for this program has been developed and tested over the past two years. The Hydrographic Acquisition and Processing System (HAAPS) includes electronic positioning digitizers, a depth digitizer, a miniature data logging unit and a magnetic tape recorder on board each survey launch. On board the ship, or on shore, a small computer-plotter system provides the editing, quality control and preliminary processing functions. This preliminary processing provides a plot of the water depths in their appropriate position, corrected for tidal fluctuations and sound velocity variations, within one hour after the end of the work day. A complete package of computer programs written in the interpretive language FOCAL has been developed to perform these functions. Trials in the St. Lawrence River and Northumberland Strait have shown that HAAPS fully meets our requirements. One complete survey will be equipped with three of the automated data collection systems and the facility for computer processing and plotting of data for the 1971 survey season.

Investigations into the use of U.S. Navy Navigation Satellite Systems for providing accurate, oceanic navigation continued to be an active project of the group. Computer programs for the reduction of satellite data to a usable form have been developed to a state where a minimum

of instruction is required for the scientist or navigator to operate and fully derive the benefits of the system. A ten-day cruise in 1969 with the CSS *Baffin* investigated in great detail the many aspects of satellite navigation. Participants in the cruise included representatives from the manufacturers of the satellite receivers and many government departments. The analysis of the data has been undertaken by Dalhousie University and is currently the subject of an M.Sc. thesis. Although the analysis has not been completed at the time of writing, preliminary results show that by using dead-reckoning techniques to provide the required velocity and direction of a ship, accuracies in the order of 300 metres can be achieved by complex processing of the data.

An area now causing concern within the Canadian Hydrographic Service is the demand for complete coverage of critical depth locations, so that present-day and future deep draft vessels can navigate with confidence. The present methods of providing complete coverage are not adequate for the 30-metre depths in question. The group has developed a sonic 'sweeping' device that is simple and operationally feasible. The system consists of a series of downward-looking sonar transducers, housed in floats that are towed between two survey launches approximately 50 metres apart. The testing of the prototype system has been completed and it is now ready for field use.

Several smaller projects were undertaken and completed by the group.

A complete set of computer programs for the reduction of horizontal geodetic survey data as related to hydrography has been written for the shipboard computers. A limited number of programs for similar purposes have also been written for programmable calculators. These programs have proven to be a valuable tool to the field hydrographers.

The continuing study of hydrographic accuracies and standards demonstrated the need for more precise knowledge of the velocity of sound in the water column. Velocity tests have been conducted using a system assembled from commercially available velocimeters. The computer programs to provide the rapid processing of the data have been prepared as part of the system.

A recent investigation of the Lambda positioning system was undertaken by members of the Marine Sciences Branch to evaluate its potential in determining the positions of boundaries and structures at sea. The group participated in this evaluation by providing various types of instrumentation, computer program development and assistance in the analysis of the data. Results are currently being published by the Nautical Geodesy Section of the Canadian Hydrographic Service.

G .R. Douglas

Navigation Group

A Navigation Group was formed at the Bedford Institute in July 1970 to provide Institute surveyors and scientists with the best possible positioning for investigations at sea. This is distinct from navigating the ship from place to place, which is the art of the ships' officers.

As the major Canadian centre for marine research, it is a Bedford Institute responsibility to take full advantage of current advances in navigation, and to investigate the physical phenomena which determine the performance of navigation systems. Precise navigation is rapidly becoming a complex technology. Developments in radio and satellite navigation have made possible work that could not be considered earlier, but to exploit them effectively demands a degree of specialist knowledge which can only be gained by full time work. Even scientists whose navigational requirements are less demanding seldom have time to find out about alternative methods; this group should be in a position to advise and assist them.

Research and development in navigation has been going on since the Institute first opened. A head-count of navigation projects shows that nearly all sections have been involved, and that the amount of work has recently been increasing at the rate from about two man-years per year initially, to about 7½ man-years in 1969. The Hydrographic Development Group and the Geophysics Section introduced satellite navigation to the Institute in 1968, and they have done much work in evaluating it and in developing operating techniques. As a result, Institute scientists have come to look on satellite navigation as virtually essential for offshore cruises, and the Institute has gained a reputation for expertise in this field. In 1969 the Hydrographic Development Group took part in a test to make accurate phase lag measurements over sea water using a Lambda positioning system, with the result that the accuracy of offshore hydrographic and natural resources surveys can now be stated with some certainty for the first time.

Although these and other developments were successful, it was found that they took up more time than could be afforded at the expense of the prime functions of the groups concerned. Accordingly the Navigation Group was established to carry on with the work already underway, and to prepare for future problems. The latter include navigation in the Arctic, positioning for pollution surveys, and the determination of legal boundaries hundreds of kilometres offshore. The first field operation for the new Group was to participate in a joint experiment with the University of New Brunswick and Shell (Canada) Ltd. to determine the precision with which an oil drilling rig can be positioned by satellite navigation in the 'simultaneous' mode; that is, using a control network of satellite receivers at precisely known points on shore.

The Navigation Group is to perform mission-oriented research, development and evaluation. It is also to provide advice on navigation methods and training in the operation of navigation systems under development, but it does not act as a service group for the operation of routine navigation systems. Although the Group's main responsibility is to the Institute, its knowledge and experience will be freely available, and it will eventually be able to take on general problems of navigation which are in the national interest.

R.M Eaton.

ToC

Drafting and Illustrations

The Drafting and Illustrations Unit has continued its services to the entire Institute. The main work load was generated by Hydrography, Marine Geology, Marine Geophysics, and Coastal Oceanography with somewhat lesser demands by the other sections. This work consisted of the preparation of scientific information for projection slides and publication in various journals, preparation of displays, and drawings for the construction of models, as well as computations and compilation of map projections and navigational lattices for scientific use. Included in this was the preparation of material for the reports on the HUDSON 70 cruise and Project Oil.

In addition, the Unit is responsible for the compilation of Canada's (east coast) contribution to the General Bathymetric Chart of the Oceans (GEBCO), a project of the International Hydrographic Organization. Approximately 130,000 km of soundings have been collected by scientific ships operating from the Institute over the past two years.

T.M. Calderwood

Photographic Unit

Photographic support for the various sections and groups of AOL continued and expanded with the overall growth of the Institute.

During the report period, our personnel have been involved directly with such projects as the *CSS Hudson* cruise to the eastern Atlantic (1969); the *Shelf Diver* submersible operation (1969); Project Oil (1970); and the HUDSON 70 expedition. In addition to providing direct technical support to such projects, much valuable film was obtained for report and public relations use. Motion picture footage taken on the *Hudson* cruise of 1969 was released to the Nova Scotia Information Service and included in a production of theirs entitled "Ologies and Isms", a science documentary. Recently released, this film has already won two international awards.

An extension of our facilities in February 1970 was made to accommodate our cartographic camera and its support facilities. The quality and quantity of our chart and report reproductions showed a marked improvement. The equipment provides greater versatility and size capability than was previously available. Hydrographic chart reproduction is now being done by our unit, and has provided much more rapid reproduction of field sheets than was previously possible through the Department's (Energy, Mines and Resources) Ottawa office.

N.E. Fenerty

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Scientific Services and Special Projects

C.D. Maunsell

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The Scientific Services and Special Projects Section was formed in March 1970 when the former Oceanographic Research Section was disbanded. It includes the Computing Services Group and the Scientific Information Services and Library Group, and temporarily included two groups from the Oceanographic Research Section until permanent arrangements were completed later in 1970. The Chemistry Group was included until the Head of the Chemical Oceanography Section arrived in August and the Frozen Sea Research Group (Victoria, B.C.) was included until the Director, Pacific Region, assumed duties in October.

C.D. Maunsell

Frozen Sea Research

The Frozen Sea Research Group was formed at Dartmouth shortly after the Bedford Institute opened. In mid-1964 it moved to Victoria, B.C., permitting closer cooperation with other research laboratories carrying out studies of, or operations from, sea-ice. In late 1970 the group was detached from the Atlantic Oceanographic Laboratory to become part of the Pacific Region, Marine Sciences Branch.

Laboratory experiments, data reduction and equipment construction are carried out at the group's base in Victoria. Completed equipment and various supplies are shipped to the field base on the shore of Greely Fiord by Coast Guard icebreaker or chartered aircraft. Members of the

[1] Joined AOL

[2] Left AOL

[3] Transferred within AOL

[5] Transferred to Pacific Region, MSB

group visit the station usually on two trips per year, once in late winter to make measurements under an ice sheet of maximum thickness and once in late summer to prepare for the coming winter and to study the initial stages of freeze-up.

At Greely Fiord base the group has two self-contained Arctic Research units built on tracked vehicles which can tow sleds from which equipment can be lowered through holes in the sea ice. Much of the program consists of studies of variations in temperature and salinity. In the course of the work systematic errors were found in previously accepted relations between salinity and conductivity of sea water at temperatures near freezing.

Studies of the properties of sea ice and of the water below sea ice have been described in two papers in the Journal of Geophysical Research (Lake and Lewis, BI Contribution No. 131 and Lewis and Walker, BI Contribution No. 202). The rejection of salt from the ice crystals formed during the freezing process produced a heavy brine in the immediate vicinity of the ice (including trapped pockets). The escape of this brine from the ice and its subsequent mixing with the sea water beneath produces inhomogeneities in the ice structure and fluctuations in the temperature and salinity of the water.

E.L. Lewis

ToC

Scientific Information Services and Library

The Scientific Information Services and Library Group was formed in 1967 to broaden the function of the Bedford Institute Library which jointly serves both AOL and MEL.

With the growth of the Institute the work of the Library has increased greatly. The increased staff require access to a great number of books and journals, particularly because of the variety of disciplines. This need is partly met by accessions of books and journals to the Library, requiring cataloguing, binding and circulation control and partly met through use of the Interlibrary Loan procedure. The Library provides contact with the National Science Library for use of the Canadian Selective Dissemination of Information Project whereby current literature with titles containing specified keywords are called to the attention of scientists.

Work has been carried out on preparation of an in-depth index of the large number of reports and reprints held in the Library in order to make them more easily recovered by interested scientists. Project Oil involved SISL in an effort to rapidly increase the Bedford Institute holdings of books and reports dealing with problems related to oil pollution in the ocean.

The plan to introduce a series of Collected Reprints has been realized; two volumes of Bedford Institute contributions have been issued. Volume I contains reprints of papers published during 1968 and a list of earlier papers; Volume 2 includes those papers published during 1969.

R.M. McMullen, C.S. Allan

Computing Services

The Computing Services Group provides support to all research and survey activities in the Institute. This ranges from the operation of keypunches and computers up to the mathematical development of computer techniques and assistance with complex computer programming.

The Institute Control Data 3100 computer has been upgraded through the acquisition of core memory to the maximum of 32K words and of a number of additional peripherals including disk drives and of a communication data set which allows programs and data to be passed to external computers to do work not practicable on the internal computer. Results can be returned and printed at the Institute.

With an increased requirement for computing at the Institute, operations of the computing centre were put on a closed shop basis. Because of restrictions on personnel it was necessary to reduce the amount of application programming support which could be given in-house. Such support in a number of cases was provided by outside contracts.

There has been a continuing use of small PDP-8 computers for data processing both at sea and in the laboratory. The efficiency of many projects involving data collection at sea has been markedly improved. In particular, the utilization of satellite navigation information would be virtually impossible without computing facilities aboard ship.

R.C. Richards

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The Engineering Services Section provides engineering design, development and fabrication of mechanical and electronic equipment together with maintenance, design changes, and modifications to existing equipment at the Bedford Institute, on the ships, and at the shore installations, in support of the research and survey operations of the Bedford Institute. The section is divided into three groups, Marine Electronics, Systems Engineering and Depot Workshops, with all groups having different functions, but supporting one another when required.

Marine Electronics, with a total staff of 30 technicians and technologists, is the largest group. This group is responsible for the repair, maintenance, modifications, design changes, and overhaul of all

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electronic equipment installed in the 5 major ships and 30 launches, as well as the small computers and peripherals, and the calibration of much of the electronic equipment being used in the engineering design labs.

The Systems Engineering Group consists of engineers and technologists who develop new equipment, mechanical, electro-mechanical, or electronic, for use by scientists and survey staff. They also provide engineering consultation for scientific and survey personnel.

To provide fabrication of mechanical and electro-mechanical prototype equipment developed at the Bedford Institute, the Depot Workshops have a staff of tradesmen skilled in welding, machinery and engine repairs, carpentry, and electrical work. This group performs the overhaul on survey launches as well as much of the heavy mechanical instrumentation used during oceanographic and hydrographic cruises.

A.S. Atkinson

Marine Electronics

The Marine Electronics Group is comprised of five subgroups or shops under the headings of Communications, Computer/Microwave, Electronic Positioning, Instrument Repair and Calibration, and Sonar. As a support group, it is only natural that considerable technician time is spent in the field complementing scientific programs and survey projects. Although technicians are assigned to shops for the repair and overhaul of electronic equipment, they are employed on field assignments as ships' technicians or are placed in charge of the remote shore stations which are used as part of an electronic system for fixing the ships' position during hydrographic survey operations.

The communications subgroup maintains some 450 units of radio and other communications equipment on departmental ships, launches and at AOL. Special requirements for individual projects are facilitated by modification, and sometimes by design changes, to existing equipment to accommodate the requirements of the project. Solid-state single-sideband radio telephone equipment has been installed in the survey launches. Where short range communications (up to 15 miles) to launches is required, VHF radio-telephones have been provided. All departmental ships have been fitted with distress tone generators for use on their radio telephone equipments; this facility is not required under International Regulations until 1972, but its early installation greatly increases the safety of the ships.

Personnel within the Institute are trained by the- communications sub-group in proper techniques of communications and, in cooperation with the Department of Communications, arrangements are made for

examination of personnel and consequent issue of certificates in the proficiency of radio. This subgroup is also responsible to ensure that all communication equipment in use in departmental programs meets the relevant requirements of the Radio Act and/or the standards of the radio regulations of the Canada Shipping Act including radio licences, renewals, and applications for licensing of all departmental radio facilities.

Preparation for HUDSON 70 took a great deal of attention. Each item of communications equipment onboard the ship, after receiving a complete overhaul, was tested to meet AOL specifications. Several special installations were made on the CSS *Hudson* for this major cruise including a portable 'party-line' two-way talk-back system covering all working areas of the ship, a specially adapted radio installation for seismic operations permitting both voice contact and shot control facilities with the shooting ship, and a special facsimile system capable of receiving weather, ice and oceanographic information in graphic form from transmitting stations in all parts of the world. Logistic support details were assessed and where necessary spares complements were increased to support a one-year operation. The success of this project is evidenced in the fact that, without exception, the *Hudson* did not require any spares for communications equipment during the entire 11 -month cruise.

Considerable liaison was made with various commercial telecommunications organizations to ensure that the *Hudson* would be able to maintain radio contact to ensure the efficient passing of the large amount of radio traffic involved in such a voyage. Special liaison was made with the U.S. Coast Guard to ensure that the USCG *Edisto* would be in full communication with the *Hudson* during the latter part of HUDSON 70. Considerable liaison was done with the SS *Manhattan,* Collins Radio, and Department of Communications, Halifax. A visit was made to the *Manhattan* on her first trip to Halifax and her communications and other electronic facilities *were* noted.

To assist studies carried out by Coastal Oceanography at AOL, whereby drogue buoys were tracked in and out of St. Margaret's Bay, the organization and establishment of an HF radio direction finding system was completed. Three shore-based stations were sited, fitted and calibrated.

The Arrow disaster in Chedabucto Bay raised considerable demands upon our resources, both operationally and in terms of immediate provision of portable radio facilities; all such demands were adequately met.

The computer microwave subgroup is responsible for the technical support of a number of computers of the PDP-8 family complete with the associated peripheral punches, readers, tape transports, plotters, teletypes, etc.; X-band radar transponders; radar range positioning system; tellurometer equipments; satellite navigational receiving systems; X-band/S-band radar systems in departmental ships; BIODAL data logging systems; and a complete underwater TV camera and video recording system. In all, over 100 units are involved.

Permanent installations of PDP8 computers have been made in both the CSS *Baffin* and the CSS *Hudson.* The *CSS Dawson* has carried another PDP-8 on several cruises and it is the responsibility of this subgroup to ensure that this computer is installed, checked out and operational prior to the ship's departure, and removed to the shops for a complete check upon the ship's return. A PDP-8L system was also installed in the CSS *Kapuskasing* for the use of the hydrographers. At the same time, two new X-band radars were installed in two launches onboard the *Kapuskasing.* An X-band radar system reserved for use on chartered vessels was installed in the MV *Stephenville* for use during the McGill Ice Drift Study program in the Gulf of St. Lawrence. X-band transponders were supplied together with teletypes, and a Decca digitizer to complete the equipment complement for this particular project. During the report period an existing X-band radar was removed from the *Dawson* and a more modern and versatile replacement was installed.

Considerable time was spent in preparing for, and supporting, a satellite navigation evaluation experiment carried out by AOL, Shell Oil, and the University of New Brunswick. Arrangements were made to provide technical support to all sites requiring such support but it was fortunate that the only site requesting assistance was the University of New Brunswick, in Fredericton. A technician travelled to the more inaccessible site at Goose Bay, Labrador.

Prior to the *Hudson's* departure on her 11-month cruise, HUDSON 70, a major alteration was made in the data logging centre of the ship. A new console area enclosed in an air-conditioned space necessitated the removal and reinstallation of the data logging equipment, satellite navigation receiver, and computer. Her radar systems were also updated. A new S-band radar system now replaces an obsolete X-band Decca radar; an existing X-band system was completely overhauled and reinstalled in the chart room behind the bridge for the specific use of scientists during their particular cruises. When the *Hudson* arrived in Victoria, the opportunity was taken to carry out a complete overhaul of her computing and positioning facilities. A Radar Positioning System (RPS) was installed for operations with the CNAV *Endeavour* on the second phase of the West Coast operation. Also, radar transponders were

tuned with the helicopter and *Hudson's* 969 radar prior to the beginning of the northern phase of HUDSON 70.

The Positioning Systems Laboratory is responsible for electronic aids used for surveys. These systems are distinct from those utilized as aids to navigation in that more precise positioning of ships and launches is necessary during survey data collection. The systems employed include low-, medium- and ultra-high-frequency phase comparison systems (Decca 12f Lambda, 12f, Hi-Fix and Tellurometer Hydrodist) as well as conventional Loran equipment. The systems are normally deployed during the periods March to November as positioning support for multidisciplinary surveys encompassing bathymetric, geophysical and geological data collection. During surveys, personnel from other laboratories within the Marine Electronics Group are employed on a loan basis, to staff the several chains operating in the field.

During the reporting period, a Decca Hi-Fix system has been used by the hydrographers working from the CSS *Kapuskasing.* It is of interest to note that the system has been used both in the range/range (one user) and hyperbolic (multi-user) modes. Decca 12f Lambda has been utilized as a one-user system only. Hydrodist has been used generally in line-of-sight positioning by mainly shore-based survey parties.

Decca Hi-Fix has provided positioning for surveying in the coastal ranges of Newfoundland and New Brunswick, while 12f Lambda, due to the greater pattern coverage, has been used in both coastal and remote coastal area surveys of Newfoundland (Grand Banks) and the Gulf of St. Lawrence. The Decca Hi-Fix chain was also employed during the spring of 1969 to provide accurate positioning fixes of CSS *Baffin* during an evaluation cruise on Satellite Navigation Systems. The hydrodist has been used by Institute technicians to support the Canadian Armed Forces (Navy) electromagnetic log calibration project and also with Department of Transport during laying of navigational buoys for deep draft ships entering the Strait of Canso.

The Positioning Systems Laboratory, in conjunction with surveying personnel, carried out a program of site selections for future operations in the Viscount Melville Sound (Canadian Arctic). During the past two years evaluation of antenna systems has been conducted with a view to improving hardware portability and increasing signal strength. It has also been attempted, with some degree of success, to extend pattern coverage by increasing RF power as well as improving sensitivity and signal-to-noise ratios in the receiving equipments. Housing of equipment and personnel continues to be the responsibility of the Positioning Systems Laboratory as well as the supply of rations, fuel, and other commodities.

An evaluation of the 12f Lambda positioning system was carried out in the Gulf of St. Lawrence in October 1969, following a federal government workshop on surveying positions at sea. The prime consideration was to provide information necessary for introducing regulations governing surveying for offshore oil and gas exploration. The object of the evaluation program was the collection of data relative to accuracy parameters together with observations of the system's electronic operation under varying states of weather, ground and sea conditions. Instrumental effects and errors in observations were reduced to a minimum by repeated equipment calibration and referencing of harmonic circuitry to ensure optimum readout. Data include weather, reception and transmission amplitudes, ground conductivity conditions, etc.

The prime purpose of the calibration laboratory is the repair and calibration of the electronic test equipment held at the Institute; all such equipment is entered on a computer inventory control system. The facilities in the calibration lab are used to monitor the repair and calibration work done by outside contractors, and in this regard the lab is capable of d.c. voltage measurement to 0.0024% of the voltage being measured, frequencies better than 2 parts in 10^9, resistance to ±0.02% and a.c. voltages to 0.02%. In any instance where greater accuracies are required, the facilities of the standards lab (Metrology Section), which holds standards traceable to NRC, are available to the personnel concerned.

The sonar subgroup has the responsibility of providing and maintaining some of the most modern and accurate depth recording equipment available. A prototype, variable-depth echo-sounder transducer was designed for the *Hudson* to overcome her inability to produce satisfactory sounding graphs from hull-mounted transducers during high-speed and inclement weather operations. This system has been redesigned, fabricated and installed as a permanent assembly. The new assembly ensures rigidity, stability and ease of installation. The raise/lower pushbutton switches for the transducer, with associated indicator lights for controlling the hydraulic system, are located in the oceanographic labs. The transducer dome can be lowered to a depth of four feet below the hull in less than a minute.

Of primary interest to the user of the system is the newly designed dome which houses three transducers. Two units containing lead titanate zirconate elements as the active material have a resonant frequency of 12 kHz while the third unit is broad-banded at 10-15 kHz. All transducers have impedances of approximately 200 ohms. All transducer cables are terminated in a change-over panel mounted in the oceanographic lab where any transceiver system can be quickly interconnected to either the variable depth or hull-mounted transducers.

Four BIODAL sounding systems consisting of a PESR control unit, Alpine precision echo sounder recorder and a Gifft transceiver are now installed in the CSS *Hudson,* One system is located in the newly constructed console; a second system, replacing the MS26-J, is installed in the plotting area for ship navigation and GEBCO work; a third system is in the oceanographic lab and the fourth located in the winch lab. All control units are driven from the Master Clock/timing generator combination. Under the new arrangement, it is possible to have all systems recording with only one transceiver in operation and yet have individual control of gain, number of fathom lines and time mark selection.

During the past year, our inventory of the new Edo Model 9040, 24 kHz, solid-state echo sounders increased from 6 to 11. Some modifications have been carried out to improve the performance of the 9040 sounder. Among these is a new receiving bar to prevent excessive breakage of stylus holders, a filter added to the receiver card to eliminate noise pickup, a second draught control potentiometer and an external speed monitor meter. The necessary changes are being incorporated into all echo sounders to convert the units from feet/fathoms to metric measurements for the 1971 field season.

A number of solid-state portable echo sounders were acquired in time for the 1970 field season on the Saint John River. During acceptance trials, a modification to the stylus holder was effected by the sonar lab personnel and the use of three equipments during a complete season has proven them to be entirely reliable units.

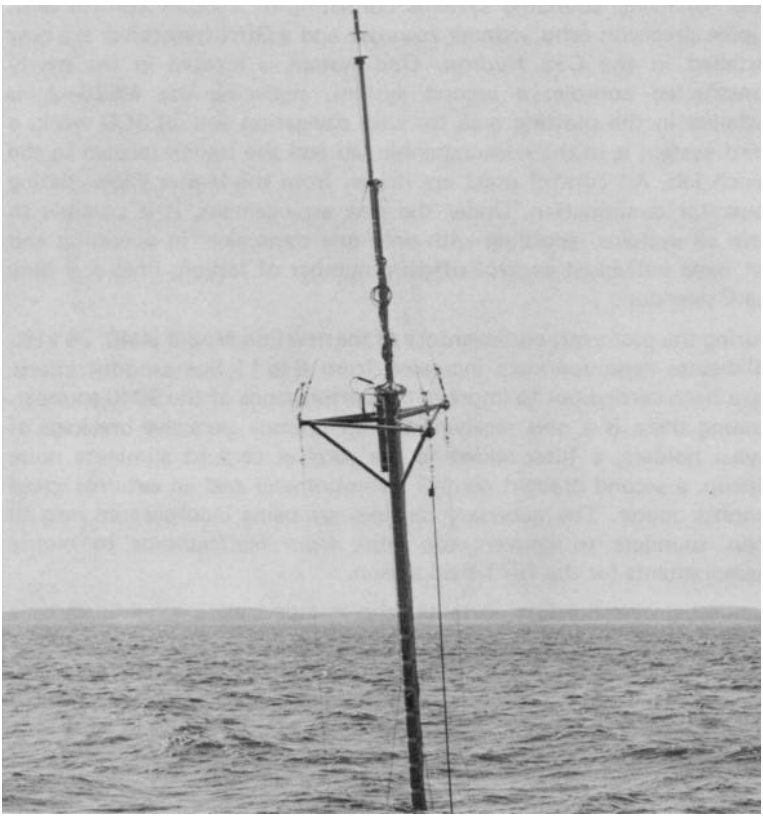
C.R. Peck

ToC

Systems Engineering

The Systems Engineering Group provides engineering support (electrical, electronic, mechanical and electromechanical) for the research and survey programs at Bedford Institute. The work involves engineering designs, investigations, and the supervision of construction carried on by outside contract. Most of the projects undertaken by Systems Engineering are short term and completed in six months or less, the longer research programs being carried out by the Metrology Research Section. The program for this group is decided jointly by the section heads of Engineering Services and Metrology. Typical projects carried out during the period covered by this report are as follows:

Instrumentation for Measuring Waves. In support of inshore wave studies, Halifax Harbour, a commercially designed wave measuring and recording system was modified and installed at three locations in Halifax Harbour. Information was transferred by a radio link and



Wave measuring tower.

undersea cables to shore telephone lines and then to a central recording station at the Bedford Institute. A fourth station was obtained using a portable recording system. During the winter of 1969-70, an improved system was designed, consisting of low-power electronics, powered by a battery pack installed on the sea bed. This was used in the spring of 1970 in the Chedabucto Bay area, Nova Scotia. At this time, the wave measuring installation was mounted on an 87-foot portable tower, held in the vertical position by a taut wire mooring line. A larger tower, 115 feet long, capable of being moored from a small boat in water depths up to 300 feet and of measuring waves up to a maximum of 20 feet, was developed to obtain vertical wave energy profiles during the 1970-71 field season. This system (see figure) fitted with a 35-foot resistance wave staff and pressure transducers at 20 feet, 40 feet and 60 feet, below the low water line, and one metre from the sea bottom, was installed in November 1970 (see Coastal Oceanography).

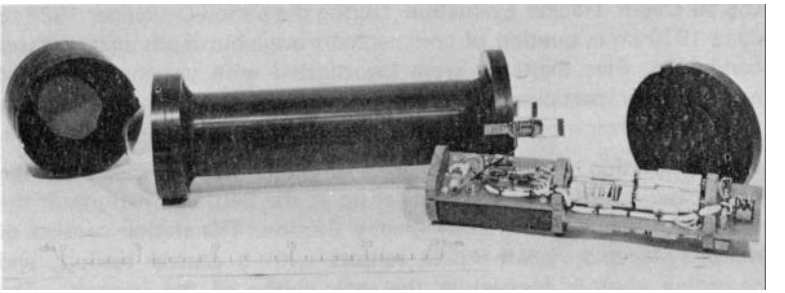
Digital Depth Tracker Evaluation. During the period December 1969 to June 1970 an evaluation of commercially available depth digitizers was conducted. Five digitizers were investigated with varying degrees of manufacturer participation. Recommendations were made as to the type of digitizer most suited to the needs of the Bedford Institute users.

Weather Station. A station designed to gather weather data from the ocean and atmosphere has been set up at the Bedford Institute at the request of the Coastal Oceanography Section. The station consists of remotely-located, weather-data sensors with a central readout and recording console located in the main lobby of the Institute. The following parameters are presently being measured and recorded: wind speed, wind direction, air temperature, water temperature, tide height, and solar radiation.

Battery Charger. At the request of Applied Oceanography, a battery charger was designed to charge the sealed, nickel-cadmium battery pack used in the Braincon Current Meter Model 753. The charger is basically a constant current type with the added feature of a 'charged state detector'. The charger is designed to limit the maximum charging current regardless of the discharged state of the battery. At a preset charged condition, the circuit automatically reduces the charging current to 'trickle-charge'. The battery pack may be left 'on' continuously without damage to the pack.

Decca Digitizer Matching Unit. A matching unit was designed and constructed to interface the CDC LPDIIIA Decca Digitizer to the data logging system. The design involved the use of level shifters, digital storage elements, and output buffers. The matching unit contains the logic circuitry required to sample and hold the digitized data until required by the punch programmer. The unit was used on the CSS *Baffin* during the 1970 hydrographic field season.

Integrating, Submersible Radiometer. To determine the relationship between the rate of production of phytoplankton and the mean solar radiation, the solar energy per unit area at a given depth should be measured. Previously, the method used to determine this quantity was to measure the solar radiation at the surface, then to calculate the energy at the desired depth using estimated values for surface effects and attenuation coefficient. To make *in situ* measurements, an Integrating Submersible Radiometer (see figure) was designed using a thermopile radiation sensor and an electroplating type integrator. Sensor and integrator were interfaced with a low-current, stabilized, dc amplifier. Three units were built and are being used by the Biological Productivity Group of the Marine Ecology Laboratory.



Integrating submersible radiometer

Optical Beam Transmittance Meter. At the request of several groups from AOL and MEL, the design of an Optical Beam Transmittance Meter has been undertaken. This instrument will be used to measure the attenuation of light, at various wavelengths, as it travels through a sample of water. Normally, a one-metre long sample is used but this may be altered depending on the turbidity. From this measurement will be obtained the attenuation coefficient which can be used to: determine the light level at any depth when the surface light level is known; determine underwater visibility; characterize water masses; study pollution fields; measure the relative plankton density in ocean waters; and measure the amount of suspended sediment near ocean or lake bottoms and in estuaries. The instrument's light source, whose spectrum can be controlled, gives a narrow, well-collimated beam. This beam is passed through the water sample and detected by a photo-sensitive device whose output is compared to a reference. Thus a measurement of the light transmittance of the water, and hence the attenuation coefficient, is obtained. The readout will be calibrated in the units of attenuation coefficient per metre. Presently, the instrument is in the prototype stage of construction.

Low-Power, Portable Winch. In response to a demand for a low power portable winch, the design of an electrically driven and electronically controlled unit was undertaken. Specifications for the device include a pulling capacity of 100 lb at a rate of one metre per second with gearing provisions for substantially heavier loads at reduced rates, Additional requirements of the winch are a drum capable of supporting 200 feet of 5/16 inch diameter cable and provision for signal-carrying slip rings. Operation from either a 115 volt ac or 24 volt dc supply is also a prime requirement for employment of the unit on any oceanographic vessel.

Building Power Distribution. An examination of the main power distribution system at the Bedford Institute has been initiated. This study has as its immediate objective the location of the source of serious voltage regulation problems occurring within the main building.

Involved in the broader aspects of this examination is an evaluation of the existing transformer capacity of the system in relation to the increasing electrical energy demands of the Institute.

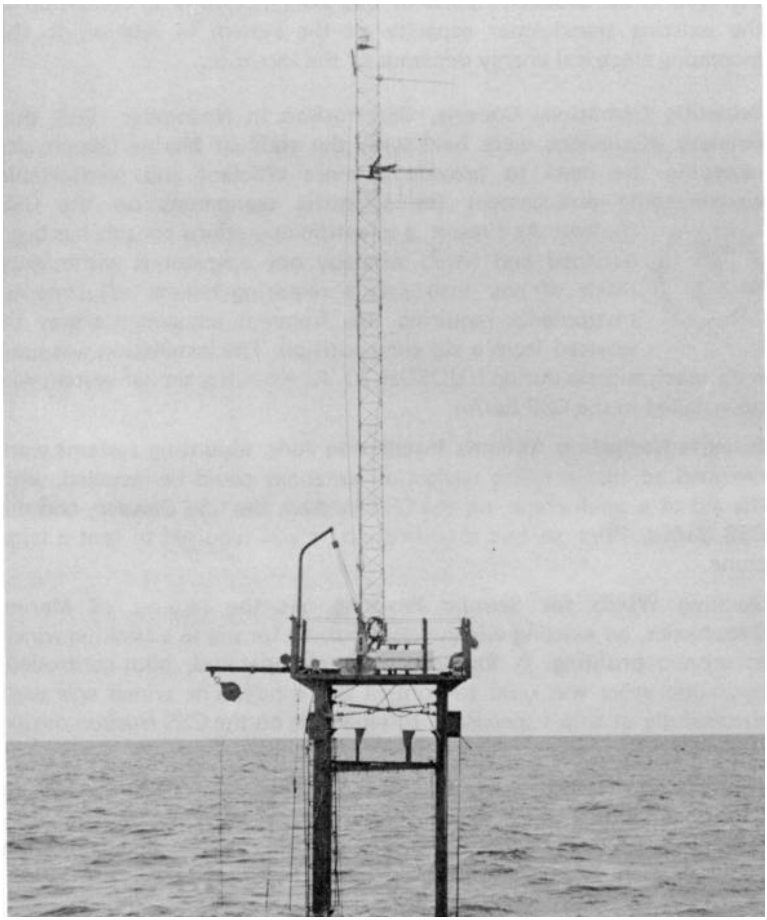
Scientific Operations Console, CSS *Hudson.* In November 1968, preliminary discussions were held with the staff of Marine Geophysics regarding the need to provide a more efficient and comfortable watchkeeping arrangement for scientific equipment on the CSS *Hudson.* As a result, a scientific operations console has been designed and fitted whereby one operator is within easy reach of any instruments requiring regular adjustments. instruments requiring less frequent adjustments may be serviced from a standing position. The installation was used with much success during HUDSON 70. As a result a similar system will be installed in the CSS Baffin.

Satellite Navigation Antenna Installation Aids. Mounting systems were designed so that satellite navigation antennas could be installed, with the aid of a small crane, on the *CSS Hudson,* the *CSS Dawson,* and the CSS *Baffin.* Prior to this modification, it was required to rent a large crane.

Slacking Winch for Seismic Profiling. At the request of Marine Geophysics, an existing winch was modified for use as a slacking winch in seismic profiling. A four-way, solenoid-operated, pilot-controlled, hydraulic valve was used to control the winch. The winch was used successfully at ship's speeds up to ten knots on the *CSS Hudson* during HUDSON 70.

Wind Tunnel Return Duct. At the request of the Air-Sea Interaction Group, a return duct has been designed to improve the flow characteristics in the wind tunnel. The tunnel is used for the calibration of thrust anemometers and for pressure fluctuation studies.

Stable Platform. During the past two years, Systems Engineering Group has been giving support on a continuing basis to the Air-Sea Interaction Group (Metrology Section) on an extensive instrumentation project. The Air-Sea Interaction program being conducted by AOL obtains its data from scientific instruments mounted on an offshore structure known as the Stable Platform. The platform is moored in an exposed location and in sufficient depth of water to allow observation of high winds and fully developed seas. The present structure was installed in October 1970 and is the third major installation of its type attempted by AOL, although smaller structures of a similar configuration were investigated as early as 1964. The first installation, completed in October 1967, was successful and the platform remained in position until its removal a year later. It consisted of a floating structure held in position (44°27'33"N, 63°31'45"W), near the approaches to Halifax



Stable Platform used in the Air-Sea Interaction program.

Harbour, by thirteen 25-ton anchors. The second major installation was a bottom-mounted structure moored in the approaches to Halifax Harbour (44°29'26"N, 63°23'31"W) in April 1969 and held in position by three 5-ton ship anchors. This was not a successful installation and, after numerous problems, the structure was removed in January 1970 by Systems Engineering group. The present installation is in the same location as the second in 189 feet of water and consists of a bottom-mounted structure 220 feet high and triangular in cross-section with a side length of 8 feet. The structure is held in position by guy wires and eight 12-ton concrete clump anchors. To enable the structure to be towed to the desired location and to assist in the mooring operation, positive bouyancy is provided by four flotation tanks.

Prior to the autumn field season in 1969 two remote-controlled, data-telemetry systems which had been built by the Air-Sea Group were evaluated and the better one chosen for use on the stable platform. Design modifications were made to improve reliability and the system was refurbished and installed on the stable platform in November 1969. The receiving/remote-control station for the telemetry line was set up at Osborne Head, N.S., in a small trailer. The complete system performed without fault acquiring data on wind stress over the ocean until late December 1969, when rough seas severely damaged the platform resulting in the loss of all equipment and sensors. Systems Engineering Group were then given the task of producing a new telemetry system to be ready for autumn 1970. This equipment is now in the field and performing well. The new system incorporated many improvements over the previous one, including: halving the physical size of the electronics package; halving the power consumption, resulting in longer battery life; further improvement in the system reliability resulting from simplification of circuitry; the addition of wave height and turbulent air temperature sensors (the latter built by Metrology); and the addition of a three-component accelerometer to investigate the motion of the platform. In conjunction with the production of the telemetry system, an electronic tension-measuring device was designed and built. This device is used to indicate the true tension in each of the four main mooring wires of the stable platform. The tension information is available on the platform from four direct reading meters and is also transmitted to the shore receiving station by the telemetry system. The data obtained from the tension-measuring device, the accelerometers, and the wave height sensor will be used to determine forces and motions imposed on the platform structure by various sea states. This information will be useful in planning reliable moorings of similar structures.

Projection Lamp Controller. The Drafting and Illustrations Group, concerned over the short life of projection lamps (two each 500 watt) in their Saltzman projector, requested that Systems Engineering devise an automatic controller for the lamps. A device was designed and built which brought the lamps from off to full brilliance in approximately eight seconds after turn-on and reversed the procedure on turn-off, reducing the thermal shock to the lamps. The device also kept power on the fan motor until approximately six minutes after turn-off thus preventing any heat build-up. No lamp replacement has been required in the past 12 months, whereas previously several lamps were replaced each month.

Magnetic Recording System for the Hydrowerkstratten (HW) Current Meter. The Coastal Oceanography Group have approximately 20 HW current meters which record current direction and speed on photographic film. Reducing the information to a form useful for analysis required much human effort and is generally slow. Systems Engineering, with Coastal Oceanography, have developed a prototype electronic recording system to fit in the existing HW case. The data are recorded on a Uher 4000 Report-L audio tape recorder as burst-FM signals and the resulting tape may be fed to the CDC 3100 computer automatically, via the FM/Analog/Digital interface. Tests are being conducted, in the laboratory, on the electronics while field tests should be in progress before the end of the present fiscal year.

S.B. MacPhee

ToC

Depot Workshops

Facilities in the Depot Workshops have been expanded by the addition of a new 48 by 70 foot boat shop and the enlargement of the shops used for welding, machining, woodworking, electrical and engine overhaul.

Some 1500 work orders were processed during the past two years. Some of these were short-term jobs requiring a few man-hours such as construction of special plywood instrument cases, fabrication of winch-mounting pads, machining of engine and equipment parts, installation of electrical/hydraulic winches, scientific aids, etc. Many were longer term projects, however, and among those completed during the period of this report are the following: parts and assemblies for rock core drills; support frames and assembly racks for type 600 air gun; new mounting hardware for fastening current meters to mooring wires; underwater television camera frames; plankton and special net frames; hydraulic parts for an experimental launch; rebuilding of circulation pumps for CSS *Maxwell;* conversion from diesel to gas engines on Bertram launches; the fabrication of an hydraulic coiling machine; the manufacture of a small portable winch and electric drill combination for use in boring holes in the ice and lowering instruments into the water; equipment and services provided for the recovery and refurbish of the air-sea moored stable platform; the construction of living and working accommodation and general outfitting of the charter vessel MV *Sfephenville;* construction of floating towers for wave studies during Project Oil; the fabrication and assistance in the development of the pilot filtration system for use at fish plants - Project Oil; the installation of shore power facilities at the small boat marina; services provided in preparation of the *CSS Hudson* for HUDSON 70 cruise; and special outfitting of five motor launches for the CSS *Baffin* cruise to the Beaufort Sea.

R.D. Wardrope

S.W. Howell[2]

D.H. Chamberlain
M.F. Faulkner
A. Holler
G. Smith
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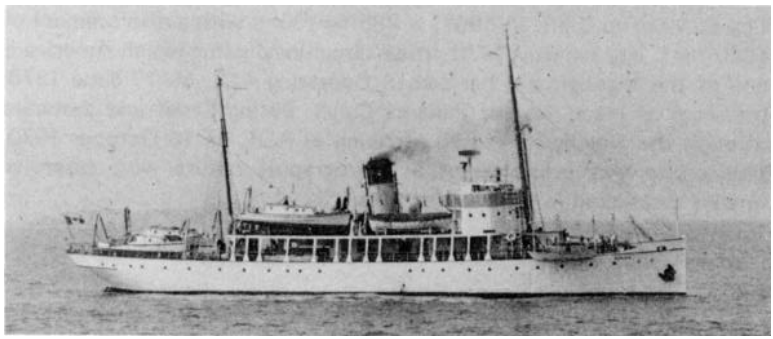
W. Thorne
M.J.A. Wagner

The Ships Section operates the six vessels of the AOL fleet and coordinates the programming of these and other ships used in support of the research and survey activities of the Bedford Institute and various other agencies, notably the Institute of Oceanography, Dalhousie University, and the Marine Sciences Centre, McGill University.



The CSS *Acadia,* built in 1913, is 182 feet long with a displacement of 1350 tons. At the end of the 1969 season the Acadia was decommissioned and retired from active service as a seasonal hydrographic vessel. She had an enviable record with the Canadian government service which dates back to 1913. As the first northern survey vessel of the Canadian Hydrographic Service she did most of the charting of the Hudson Bay route prior to World War I I. Her many other assignments in charting were carried out along the rugged and fog-shrouded coasts of Newfoundland and the stormy waters of the Gulf of St. Lawrence. In wartime she served her country as a patrol vessel from 1916 to 1919 and as a training vessel from 1939 to 1945. She is presently moored alongside AOL and during the summer of 1970 was a popular attraction for visitors who were provided with conducted tours of the grand old lady of the high seas.

[2] Left AOL

The CSS *Baffin,* built in 1957, is 285 feet long with a displacement of 4620 tons. Her lengthy 1970 cruise circumnavigating North America is one of the highlights of her career. Departing AOL on 13 June 1970, passage was made via the Panama Canal, Bering Strait and eastward through the Northwest Passage arriving at AOL on 16 October 1970. This cruise was primarily of a hydrographic nature with extensive surveys conducted in the Beaufort Sea.

The CSS *Dawson,* built in 1968, is 211 feet, 9 inches, long with a displacement of 1997 tons. She experienced her first cruise into the Arctic in 1970, working mainly in areas west of Godhavn, Greenland, off Bylot Island, in Lancaster Sound and westward to Cornwallis Island. She has the capability of working in the north if ice conditions are not too severe, otherwise icebreaker support would be needed.

The CSS *Hudson,* queen of the AOL fleet, was built in 1963. She is 293 feet 6 inches long with a displacement of 4793 tons. To date her major cruise has been HUDSON 70, the circumnavigation of the Americas. She left AOL on 19 November 1969, returning practically 11 months later on 16 October 1970. Canadian and foreign scientists participated in the many phases of oceanography on HUDSON 70 and hydrographic information was obtained throughout the entire cruise. Stops at many foreign and Canadian ports were made to exchange scientific personnel and crew members. At Valparaiso, Chile, (after the first four phases of the eight-phase cruise) the ship was met by Ottawa departmental officials and Ships Division personnel. In company with the CSS *Baffin,* she steamed through the Northwest Passage escorted by the Department of Transport icebreaker, the *John A. MacDonald,* and found little difficulty in penetrating the ice floes and ice fields encountered. The federal minister of Energy, Mines and Resources, Honourable J.J. Greene, and a large dockside gathering were on hand to welcome home both major ships. The *Hudson* and the *Baffin* were presented with plaques by the Honourable J.J. Greene and all who were active in HUDSON 70, scientists and crew members, were given a medal to commemorate the first circumnavigation of the two American continents.

The CSS *Kapuskasing,* built in 1943, is 222 feet long with a displacement of 1250 tons. She was involved in many different hydrographic and oceanographic cruises throughout 1969-1970.

The CSS *Maxwell,* built in 1961, is 115 feet long with a displacement of 230 tons. This smallest ship in the AOL fleet has been kept busy in a variety of hydrographic and oceanographic operations.

The CNAV *Sackville,* built in 1941, is 205 feet 3 inches long with a displacement of 1250 tons. She is under full-time charter to the Bedford Institute from the Canadian Department of National Defence.

The following table serves to illustrate the scale of operations of the fleet during the past two years.

TABLE: Operational Statistics of the AOL Fleet and the CNAV *Sackville*

Name	No. of Cruises		Days away from Base		Mileage Steamed	
	1969	1970	1969	1970	1969	1970
CSS *Acadia*	1	-	161	-	4,634	-
CSS *Baffin*	3	2	248	196	36,463	25,578
CSS *Dawson*	22	14	161	172	30,295	35,697
CSS *Hudson*	8	1	150	289	27,943	42,332
CSS *Kapuskasing*	2	1	156	148	18,219	12,225
CSS *Max well*	3	2	181	155	4,534	7,461
CNAV Sackville	10	8	144	131	24,271	19,966

To meet requirements that could not once again be accommodated by our own fleet of AOL vessels, we depended heavily on six chartered ships, Fisheries Research and Protection ships, Department of Transport icebreakers, and the Canadian Naval Auxiliary vessels. The services of the MV *E. E. Prince,* the MV *Sigma-T,* and the MV *Navicula,* all of the Fisheries Research Board, were used in a number of small projects. Through the courtesy of the Department of Transport, Marine Division, the CCGS *C.D. Howe* was made available to support the submersible, *Shelf Diver,* operations; the *CCGS Labrador* and the CCGS *John A. MacDonald* were made available for reconnaissance surveys in the Arctic and the *MacDonald* escorted the *CSS Hudson* and the CSS *Baffin* through Viscount Melville Sound.

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S.H. Scott

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J.F. Greig
J. Guilderson[1]
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C.A. Webber[2]
D.B. Westhaver
S. Young'

During the period covered by this review the laboratory wing of the Institute was increased by 50%. In early fall of 1969 two new floors were added to the administrative wing providing much needed office space and a new 100-seat seminar hall.

In response to accelerating exploratory work off the east coast, particularly the increasing number of exploratory drilling programs, the Resource Administration Division, Department of Energy, Mines and Resources, completed a 5600 square foot office-laboratory building in 1970. This building provides a base for conservation engineers involved in the supervision and regulation of east coast off-shore exploration programs, and it includes laboratory facilities for the processing, storing, and curating of cores.

Ten new laboratory trailers were combined with existing units to provide a 14-unit complex as a Marine Ecology Laboratory pollution study centre. More fish holdings and laboratories are now being constructed as an extension to present facilities.

[1] Joined AOL

[2] Left AOL

[3] Transferred within AOL

Extensions to the Depot provided much needed stores space and additional workshop area with overhead cranes.

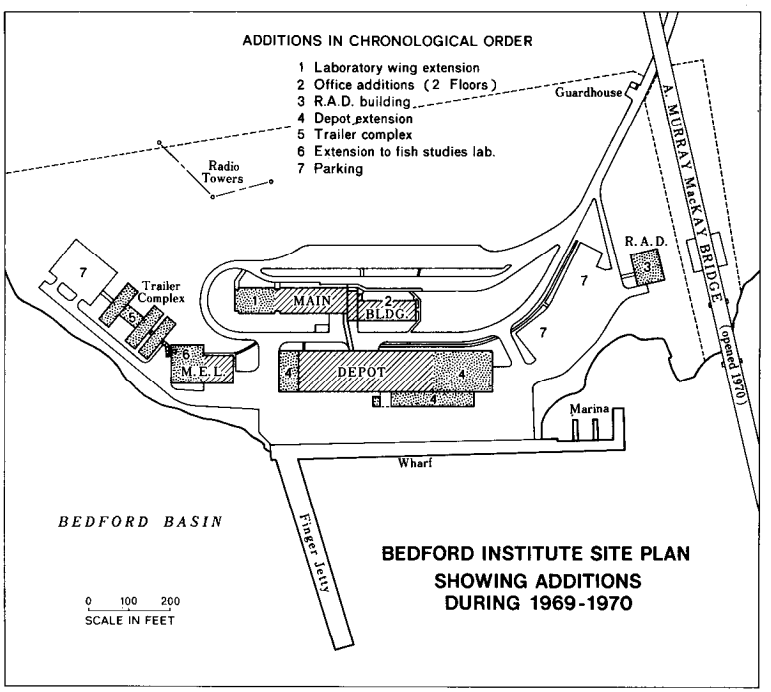
Landscaping and parking space for an additional 100 cars were included in the new construction.

Treatment of sanitary sewage and lab wastes were examined during this period and a new extended aeration, sanitary sewage treatment plant was installed. This plant includes sludge removal and chlorination and provides for a reduction in solids and B.O.D. of about 90% on effluent being discharged into the Bedford Basin.

Another highlight of great interest was the construction, over a three-year period, of the A. Murray MacKay Bridge crossing Halifax Harbour. The bridge extends from the southern limit of Institute property (see diagram). The bridge was opened for traffic in the summer of 1970.

Visits by tourists continued to be very popular during July and August: about 3000 in 1969 and 3600 in 1970. There were also many visits by foreign dignitaries, Canadian Government Parliamentary groups, scientific groups, student groups and individuals.

S.H. Scott



Personnel

P.H. Sutherland

P.L. Barnbury
G.W. Booth[2]
K.J. Conrod[1]
S.J. Corkery[2]
M.D. Dalzell
S.G. Furlong[3]
M.L. Hachey[1]
G.P. Hendsbee[3]
S.J. Jones
M.O. Kotlar[1]
J.A. Lake[2]
F.G. MacLaren[3]
S.J. McMullen[2]
L.F. Matheson[2]
R.N. Pettipas[2]
R.H. Stone[3]

The Personnel Section of the Atlantic Oceanographic Laboratory is responsible for providing a complete personnel administration and advisory service to the management of the Laboratory. This service includes staffing, staff relations, manpower planning, classification, personnel services and training.

The Laboratory has employed, over the past two years, an average of 490 full-time continuing employees in 23 occupational groups and has utilized an average of 625 man-years per annum. At present the section provides advice on the administration of 24 collective agreements.

P.H. Sutherland

During the summer of 1969 the student employment program was reviewed by the Public Service Commission in an effort to bring to the program a more meaningful approach to career orientation through summer employment. To this end the Career Introduction Program was introduced in 1969. Prior to the inception of C.I.P. the selection of students for summer employment in positions requiring training in the biological, chemical and physical sciences was generally made without personal contact with the students and involved the screening and rating of an extremely large number of applications. Selection, therefore, did not always provide opportunities for outstanding students, nor did it ensure a match of student to job in terms of skill, knowledge, and interest. The previous programs did not attempt to distinguish between positions offering meaningful work assignments of a professional or career-oriented nature and those non-specialized positions providing little challenge. In establishing C.I.P. the primary concern was, therefore, to develop a program that would: facilitate the identification of promising and deserving students who would most likely get the maximum benefit from the work assignments; provide meaningful and challenging work assignments that would complement

[1] Joined AOL

[2] Left AOL

[3] Transferred within AOL

or augment academic training and development; provide more meaningful matching of the students' special training and career interests with particular jobs; and encourage greater liaison amongst university students and faculty, departmental scientists, and the Public Service Commission officers. To meet these objectives C.I.P. provided for the selection of students based on nomination. In adopting the nomination method of selection, considerable emphasis was placed on position quality to ensure that students were provided with assignments of value from an educational and career development standpoint.

In addition to C.I.P. the Department continued to employ students through the Applied Sciences and Bio-Physical Sciences Programs which invite applications from students attending universities, community colleges and institutes of technology.

In the summer of 1969, 33 students were employed. This number rose to 63 in 1970.

M.D. Dalzell

Appendix B-1
Publications and Reports 1969/70

Publications (B.I. Contributions)

AUMENTO, F. 1969. The Mid-Atlantic Ridge near 45°N. V. Fission-Track and Ferro-Manganese Chronology. *Cdn. Jour. Earth Sci., 6:* 1431-1440. BI Contrib. No. 168.

Specimens from 42 dredge stations taken over a 120 x 220 km area across the axis of the Mid-Atlantic Ridge were dated by a combination of fission-track and ferro-manganese deposition rate methods, and results were compared with previous K-Ar determinations.

AUMENTO, F., and **LONCAREVIC, B.D.** 1969. BI Contrib. No. 137. (see 81 Biennial Review 1967-1968).

BARRETT, D.L., and **AUMENTO, F.** 1970. The Mid-Atlantic Ridge near 45°N. XII. Velocity, Density and Layering of the Crust. *Cdn. Jour. Earth Sci., 7:* 1117-1124. BI Contrib. No. 193.

Compressional wave velocities at pressures to 1000 kg/cm^2 and densities are given for a representative suite of rocks selected from 46 dredge hauls on the Mid-Atlantic Ridge near 45°N. Evidence is presented for block faulting of an originally continuously layered crust of vesicular basalt and massive basalt underlain by a metamorphosed basalt and gabbro sequence.

BARTLETT, G.A., 1969. Cretaceous Biostratigraphy of the Grand Banks of Newfoundland. *Maritime Sediments, 5:* 4-14. BI Contrib. No. 163.

Several hundred feet of Cretaceous (Neocomian-Maestrichtian) strata deposited in shallow warm waters underlie the Grand Banks of Newfoundland. Planktonic foraminifera enable a general intercontinental correlation of these Grand Banks sediments. Periodic tectonic activity is suggested by major unconformities that are recognizable on a world-wide scale.

BARTLETT, G.A., and **GREGGS, R.G.** 1969. Carbonate Sediments Oriented Lithified Samples from the North Atlantic. *Science, 166:* 740-741. BI Contrib. No. 187.

Indurated carbonate samples, obtained from the North Atlantic Sea floor with a deep-sea drill coring apparatus, suggest that the phenomenon of deep-sea carbonate lithification is more complex than had been thought previously. Lithified-nonlithified couplets can now be related in age and orientation. Age determinations based on the method of carbon-14 dating show that adjacent nonlithified-lithified layers may differ in age by more than 30,000 years.

BARTLETT, G.A., and **GREGGS, R.G.** 1970. The Mid-Atlantic Ridge near 45°N. VIII. Carbonate Lithification on Oceanic Ridges and Seamounts. *Cdn. Jour. Earth Sci.,* 7: 257-267. BI Contrib. No. 182.

Deep sea *carbonate lithification and the interbedding of carbonate and ferro-manganese are common processes on oceanic ridges and seamounts. Temperature and salinity changes caused by climatic fluctuations or heat emanations and manganese substitution for calcium in the calcite lattice are believed to be responsible for these inorganic processes. Lithification and solution of the carbonate take place at the sediment-water interface and can occur in ocean depths of at least 3,000 metres.*

BARTLETT, G.A., and **GREGGS, R.G.** 1970. A Re-Interpretation of Stylolitic Solution Surfaces Deduced from Carbonate Cores from San Pablo Seamount and the Mid-Atlantic Ridge. *Cdn. Jour. Earth* Sci., 7: 274-279. BI Contrib. *No.* 183.

Processes associated with deep sea carbonate lithification suggest an alternative mechanism, other than pressure solution, for the formation of stylolites. Stylolites may also be formed by submarine solutional erosion following lithification, oxidation of the eroded surface, and renewal of carbonate deposition. This process is responsible for removing significant quantities of carbonate sediment in the marine environment without exposure to subaerial agencies.

BENNETT, A.S. 1969. Computer Data Display. *Trans. Applications of Seagoing Computers 1969, Mar. Tech. Soc.:* 99-103. BI Contrib. No. 144.

The hardware configuration of one of the Bedford Institute's PDP-8 computers is described. Display devices include an oscilloscope display and an X-Y chart recorder. Two instruments have been used with this system: a remote recording digital thermometer used off line, and an electronic bathythermograph connected on line to the computer. Programs have been developed which enable the operator to modify the visual display on the oscilloscope so as to display selected portions of the data. A permanent record of the selected portion may be made photographically from the oscilloscope display or by use of the X-Y chart recorder. Preliminary results are shown and possible further developments are discussed.

BENNETT. A.S., MASON, C.S., and **BENDELL, E.A.** 1969. The Bedford Insti- Institute Shipboard Data Logging System. *Trans. Applications of Seagoing Computers* 1969, *Mar. Tech. Soc.:* 63-69. BI Contrib. No. 143.

Since 1965 the Bedford Institute has been using a shipboard data logging system in which several parameters have been recorded, sequentially, up to ten times a minute on punched paper tape. The paper tape serves as a buffer store before the data is processed by a digital computer, which is considered to be a necessary part of the system. A data logging system built up at the Bedford Institute is described and the use of that system to control the data transfer from a basic instrument such as a magnetometer to a shipboard digital computer is discussed.

BROOKE, J., and **GILBERT, R.L.G.** 1969. A Hydrostatic Power System. *Oceanology International 69 Conf. Proc.,* Technical Sessions, Day 4, Session F, Paper 5. BI Contrib. No. 135.

A system has been developed to obtain power in the sea using fluid moving from the ambient hydrostatic pressure into a low pressure reservoir. The paper describes the methods used to control the energy for practical purposes.

BROOKE, J., IRVING, E., and **PARK, J.K.** 1970. The Mid-Atlantic Ridge near 45°N. XIII. Magnetic Properties of Basalt Bore-core. *Cdn. Jour. Earth Sci., 7:* 1515-1527. BI Contrib. No. 211.

The magnetic properties of three basalt cores, drilled from two peaks flanking the valley of the Mid-Atlantic Ridge, are described and the variations in coercivity are discussed.

BROOKE, J., and **MASON, C.S.** 1969. Some Instruments for Monitoring the Performance of Undersea Mechanical Devices. *Oceanology International 69 Conf., Proc.,* Technical Sessions, Day 1, Session A, Part 1, Paper 5. BI Contrib. No. 133.

The design of mechanical devices to operate at great depths in the ocean is made difficult by a lack of knowledge of how such instruments are performing. By recording or telemetering information regarding various aspects of a unit's performance, the design can be greatly expedited. This paper outlines the instrumentation used to monitor the performance of an hydraulically operated device designed to drill a core of rock from the sea floor.

BUDLONG, K.S. 1969. A Simplified Method for Predicting Satellite Passes. *Jour. Space and Rockets,* 6: 1341-1343. BI Contrib. No. 172.

A simplified method is presented for the prediction of rise and set times for a satellite in a circular, polar orbit, such as those of the Navy Navigation Satellite System.

FORRESTER, W.D. 1970. BI Contrib. No. 176. (see BI Biennial Review 1967-1968).

GARNER, D.M. 1969. Vertical Surface Acceleration in a Windgenerated Sea. *Deutsche Hydrog. Zeit.,* 22: 163-168. BI Contrib. No. 173.

The output of a small accelerometer buoy (diameter 12 cm), whose sensor axis was vertical when floating undisturbed, was recorded in the open ocean at four wind speeds ranging from 4.5 to 11.0 m/s. Records are discussed assuming they represent the vertical component of the sea surface acceleration.

GARNER, D.M., and **FORD, W.L.** 1969. Mid-Atlantic Ridge near 45°N. IV. Water Properties in the Median Valley. *Cdn. Jour. Earth Sci., 6:* 1359-1363. BI Contrib. No. 162.

Hydro stations were worked during August/September 1968 over six basins in the floor of the Median Valley of the Mid-Atlantic Ridge near latitude 46°N. and in the open Atlantic each side of the Ridge. Measurements were made of temperature, salinity, dissolved oxygen, reactive silica and dissolved fluoride.

GILBERT, R.L.G. 1970. The Bedford Institute Wave Recorder. *Jour. Geophys.* Res., 75: 5215-5224. BI Contrib. No. 199.

A new type of inexpensive accelerometer for the measurement of wave heights has been developed. It has been used in two modes: as a self-contained, free-floating unit; and as a part of a fixed system moored to a buoy. In the free-floating mode it has measured waves in any depth of water; in the fixed mode it has been used in wafer depths up to 180 m. It has measured wave heights up to 6 m, with periods from 3 to 10 seconds, and has telemetered the data to a recording station up to 16 km away. The measurement error appears to be comparable to or less than that exhibited by other wave recorders.

GILBERT, R.L.G., and **MASON, C.S.** 1970. Some Developments in Undersea Technology at the Bedford Institute. *Cdn. Aeronautics Space Jour., Undersea Technol. Supp., 16:* 17-20. BI Contrib. No. 150.

Aerospace technology has achieved great success in solving the extremely complex problems associated with high-speed flight, both within the atmosphere and beyond it. No doubt much more existing knowledge could be applied to problems in oceanography than is presently the case, if the communication between the two communities was improved. The paper indicates some areas where mutual benefits can be expected from cooperation, and describes three recent developments at AOL to indicate some recent technical problems in oceanography and the manner in which they are being solved. It is anticipated that this background material will provide the foundation for a profitable discussion to be held in the summer of 1969 between oceanographers and aerospace specialists.

GRANT, A.C. 1970. Recent Crustal Movements on the Labrador Shelf. *Cdn. Jour. Earth Sci.,* 7: 571-575. BI Contrib. No. 174.

The marginal channel on the Labrador Shelf appears to be an erosional feature, although in places there is evidence of associated structural disturbance, in part possibly of fairly recent origin.

GRANT, A.C., and **MANCHESTER, K.S.** 1970. Geophysical Investigations in the Ungava Bay-Hudson Strait Region of Northern Canada. *Cdn. Jour. Earth Sci., 7:* 1062-1076. BI Contrib. No. 192.

The Palaeozoic outlier in Ungava Bay extends northward across Hudson Strait, where it has been downfaulted to form a half-graben Structure, and a Palaeozoic outlier may also occur in northwestern Frobisher Bay.

IRVING, E. 1970. The Mid-Atlantic Ridge near 45°N. VI. Remanent Intensity, Susceptibility and Iron Content of Dredged Samples. *Cdn. Jour. Earth Sci., 7:* 226-238. BI Contrib. No. 179.

Rock samples from 27 dredge hauls show a variation of various magnetic properties with distance from the ridge axis. In the Median Valley, the natural remanent magnetization is large, with a geometric mean of nine samples of 57.4 x *10^{-3} cgs units.*

IRVING, E. 1970. The Mid-Atlantic Ridge at 45°N. XIV. Oxidation and Magnetic Properties of Basalt; Review and Discussion. *Cdn. Jour. Earth Sci., 7:* 1528-1538. BI Contrib. No. 212.

The oxidation and magnetic properties of 34 submarine basalt samples procured in a traverse across the accreting margin of a lithospheric plate are reviewed and interpreted.

IRVING, E., PARK, J.K., HAGGERTY. S.E., AUMENTO, F., and **LONCAREVIC, B.D.** 1970. Magnetism and Opaque Mineralogy of Basalts from the Mid-Atlantic Ridge at 45°N. *Nature,* 228: 974-976. BI Contrib. No. 215.

The magnetic properties and minerals of oceanic pillow basalts are very different from hose of sub-aerial flow basalts. The volcanic layer which is responsible for the magnetic anomalies of the Mid-Atlantic Ridge may be only 300 m thick.

KEEN, C., and TRAMONTINI, C. 1970. A Seismic Refraction Survey on the Mid-Atlantic Ridge. *Geophys. Jour., Roy. Astr. Soc., 20:* 473-491. BI Contrib. No. 197.

A detailed seismic refraction experiment has been performed on the Mid-Atlantic ridge near the median valley at 45°N.. using two ships and anchored sono-radio buoys. Both the slope-intercept and the time-term methods were used to interpret the data. The rime-term analysis indicated a continuous M discontinuity at a mean depth of 7.5 km with a mean velocity of 7.9 km s^{-1} for the underlying material. This result was substantiated by the time-distance plots with the exception of the line of shots nearest the median valley which gave a velocity of 7.5 km s^{-1}. Evidence for anisotropy of the 7.9 km s^{-1} material was found, the velocity deviation being ± 0.25 km s^{-1} and the azimuth of maximum velocity, 080°. Two crustal layers, the upper having velocities in the range 3.5 to 5.4 km s^{-1} and the lower velocities around 6.6 km s^{-1} were observed but one or both of these are absent on many of the time-distance plots.

KING, L.H. 1969. BI Contrib. No. 112. (see BI Biennial Review 1967-1968).

KING, L.H. 1970. Surficial Geology of the Halifax-Sable Island Map Area. *Marine Sciences Branch, Paper 1,* 16 pp. BI Contrib. No. 153.

This is a brief account of the surficial geology of the Halifax-Sable island map-area. It provides an interpretation of the map and indicates a number of potential uses.

KING, L.H., and **MACLEAN, B.** 1970. Pockmarks on the Scotian Shelf. *Geol. Soc. Amer. Bull., 81:* 3141-3148. BI Contrib. No. 200.

Pockmarks are coned-shaped depressions that occur in large numbers across the LaHave clay of the Scotian Shelf. They are possibly formed by ascending gas or subsurface water leakage from underlying coastal plain sediments.

KING, L.H., and **MACLEAN, B.** 1970. Continuous Seismic-Reflection Study of Orpheus Gravity Anomaly. *Am. Assoc. Petroleum Geologists, 54:* 2007-2031. BI Contrib. No. 204.

Mild folding of Cretaceous rocks within the area of the Orpheus gravity anomaly is attributed to movement along the Cobequid-Chedabucto fault system. The fault system appears to be much larger than previously thought and could extend across the Atlantic Ocean.

KING, L.H., and **MACLEAN, B.** 1970. Origin of the Outer Part of the Laurentian Channel. *Cdn. Jour. Earth Sci.,* 7: 1470-1484. BI Contrib. No. 206.

This paper describes the geology of the outer part of the Laurentian Channel and the evolutionary development of the feature.

KING, L.H., MACLEAN, B., JELETSKY, J.A., BARTLETT, G.A., and **HOPKINS, W.S.** Jr. 1970. Cretaceous Strata on the Scotian Shelf. *Cdn. Jour. Earth* Sci, 7: *145-155, 188-190.* BI Contrib. No. 170.

This paper describes and dates Cretaceous bedrock dredged from the Scotian Shelf north of Sable island.

LAKE, R.A., and **LEWIS, E.L.** 1970. Salt Rejection by Sea Ice During Growth. *Jour. Geophys.* Res., *75:* 583-597. BI Contrib. No. 131.

It is demonstrated that rejection of salt at a freezing ice-water interface takes place at least in part by cyclic convective processes occurring within the small interstitial spaces located in the first few centimeters of ice above the interface. This invalidates the assumption of the diffusive boundary layer utilized by previous authors and shows that near-interface temperatures are subject to cyclic variations. This result should be generally true for phase changes in aqueous solutions with floating ice, and it must be considered as a modification to current theories of solidification. It is shown that large vertical tubular structures attended by smaller tributary tubes exist within the growing sea ice sheet; this arrangement almost certainly indicates horizontal migration of brine toward preferred drainage areas in a manner analogous to the catchment area of a river and its tributaries.

LEWIS, E.L., and **WALKER, E.R.** 1970. The Water Structure Under a Growing Sea Ice Sheet. *Jour. Geophys.* Res., *75:* 6836-6845. BI Contrib. No. 202.

Data illustrating seasonal changes in the water structure beneath an annual sea ice cover are presented. The water column heat loss is related to ice growth. Time series temperature measurements taken over a month from thermistor chain depending from the ice sheet indicate probable mechanisms for these changes and are tentatively related to laboratory studies.

LONCAREVIC, B.D., FORD, W.L., and **MCMULLEN, R.M.** 1969. Atlantic Oceanographic Laboratory, Bedford Institute, the First Six Years. *Polar Record, 14:* 807-813. BI Contrib. No. 155.

This history of the Bedford Institute of Oceanography/Atlantic Oceanographic Laboratory during the first six years of its existence (1962-1968) is briefly reviewed. Included are lists of senior professional staff, 81 Contributions, representative cruises, and a table of statistics of the research ships used.

MANCHESTER, K.S., and **KEEN, M.** 1970. The Mid-Atlantic Ridge near 45°N. X. Sediment Distribution and Thickness from Seismic Reflection Profiling. *Cdn. Jour. Earth Sci.,* 7: 735-747. BI Contrib. No. 185.

The distribution of sediment on the crest mountains and high fractured plateau of the Mid-Atlantic Ridge at 45°N was studied by seismic profiling techniques which indicated that mean sediment thickness increased with distance from the median valley.

MANN, C.R. 1969. BI Contrib. No. 122. (see BI Biennial Review 1967-1968).

MANN, C.R. 1969. BI Contrib. No. 132. (see BI Biennial Review 1967-1968).

MARLOWE, J.I. 1969. A Succession of Tertiary Strata Off Nova Scotia, as Determined by Dredging. *Cdn. Jour. Earth Sci., 6:* 1077-1094. BI Contrib. No. 157.

Carbonate rocks dredged from a seamount on Aves Swell in depths from 340 to 730 m are phosphatic micrite, altered calcirudite, and calcarenite. Data from thin section, X-ray, and chemical analyses show that several processes of diagenesis including submarine dolomitization and cementation have affected these rocks.

MARLOWE, J.I. 1969. High-Magnesian Calcite Cement in Calcarenite from Aves Swell, Caribbean Sea. *Bermuda Biol. Stn. for Research, Spec. Pub. No. 3 - Carbonate Cements:* 79-83. BI Contrib. No. 164.

Petrographic investigations on calcarenite dredged from a seamount on Aves Swell, in the Caribbean Sea, show that component grains of the rock have been cemented by high-magnesian calcite. The occurrence is unusual in two respects: 1) the calcarenite appears to have been cemented under sub-marine conditions; and 2) the cementing carbonate is rich in magnesium. A comparison between-this occurrence and a previously reported occurrence on Atlantis Seamount, on the Mid-Atlantic Ridge, is drawn.

MARLOWE, J.I. 1969. Petrologia de Rotas Carbonaticas de la Prominencia de las Aves (un Informe Preliminar). *Bol. Inform. Asoc. Venez. Geol. Min. Petroleo, 12:* 275-287. BI Contrib. No. 160.

Outcrops of strata ranging in age from Oligocene to Miocene occur on the sides of The Gully, a large submarine canyon near Sable Island. Data from dredge-sampling operations suggest that the exposed stratigraphic section may be as much as 1400 m thick. Analysis of dredge samples show that the rocks collected are dominantly mudstone with minor components of sand.

MARLOWE, J.I. 1970. Weddellite in Bottom Sediment from the St. Lawrence and Saguenay Rivers. *Jour. Sed. Pet., 40:* 499-506. BI Contrib. No. 178.

Weddellite (a hydrated calcium oxalate), previously reported from the central Weddell Sea, Antarctic has been identified from bottom sediments of the Saguenay and St. Lawrence Rivers, Canada.

PAGDEN, I.M.H., and **SUTHERLAND, J.C.** 1970. BI Contrib. No. 115. (see BI Biennial Review 1967-1968, Pagden, I.M.H.).

PARK, J.K., and **IRVING, E.** 1970. The Mid-Atlantic Ridge near 45°N. XII. Coercivity, Secondary Magnetization, Polarity, and Thermal Stability of Dredge Samples. *Cdn. Jour. Earth Sci., 7:* 1499-1514. BI Contrib. No. 210.

In this paper the description of the remanent magnetic properties of 34 dredge samples from the Mid-Atlantic Ridge is completed particular attention being paid to the coercivity of remanence and to the changes in intensity and blocking temperature produced by mild heating.

PHIPPS, C.V.G., and **KING, L.H.** 1969. BI Contrib. No. 114. (see BI Biennial Review 1967-1968, King, L.H.).

PRAKASH, A., and **RASHID, M.A.** 1969. BI Contrib. No. 107. (see BI Biennial Review 1967-1968).

QUON, C. 1969. Bl Contrib. No. 136. (see BI Biennial Review 1967-1968).

RASHID, M.A., and KING, L.H. 1969. BI Contrib. No. 109. (see BI Biennial Review 1967-1968).

ROSS, D.I. 1969. Experience with A Shipboard PDP-8 Computer. *Oceanology International* 69 *Conf., Proc.,* Technical Sessions, Day 2, Session A, Part I I, Paper 6. BI Contrib. No. 142.

Increased sophistication and reliability of modern electronic instrumentation has made the automatic acquisition of oceanographic data both feasible and desirable. The inevitable increase in data obtained has led to the use of computers on board ship to carry out preliminary data reduction. This in turn has greatly increased the efficient use of ship time by providing facilities for checking data, and delineating clearly the areas of importance where measurements should be made. The development of a shipboard installation for the acquisition and processing of data on a routine basis is discussed. Experience with the computers at sea has proved their versatility and indicated instances where they may be incorporated as an integral part of the data acquisition system to control both the quantity and the quality of the data obtained. The future role of the computer at sea as a powerful tool in oceanography is suggested.

RUFFMAN, A., and **WOODSIDE, J.** 1970. The Odd-Twins Magnetic Anomaly and Its Possible Relationship to the Humber Arm Klippe of Western Newfoundland, Canada. *Cdn. Jour. Earth Sci., 7:* 326-337. BI Contrib. No. 180.

A distinctive twin-peaked magnetic anomaly has been traced for a distance of 65 km parallel to the coast of western Newfoundland about 10 km offshore. The magnetic anomaly is associated with a bathymetric high in some areas.

SANDSTROM, H. 1969. BI Contrib. No. 84. (see BI Biennial Review 1967-1968).

SEN GUPTA, B.K., and **MCMULLEN, R.M.** 1969. BI Contrib. No. 134. (see BI Biennial Review 1967-1968).

SMITH, S.D. 1970. Wind Stress and Turbulence Over Ice in the Gulf of St. Lawrence. *Jour. Geophys. Res., 75:* 2803-2812. BI Contrib. No. 184.

Field measurements of wind turbulence over ice floes were used to compute Reynolds stress, velocity spectra and drag coefficients.

SMITH, S.D. 1970. Thrust-Anemometer Measurements of Wind Turbulence, Reynolds Stress, and Drag Coefficient over the Sea. *Jour. Geophys. Res., 75:* 6758-6770. BI Contrib. No. 205.

A thrust anemometer has been used on a stable platform off the approaches to Halifax Harbour to study wind stress and turbulence. The mean drag coefficient of the sea is 1.35 x 10^{-3} ±0.34 x 10^{-3} (standard deviation) at wind speeds from 7 to 16 m/sec.

VILKS, G. 1969. BI Contrib. No. 93. (see BI Biennial Review 1967-1968).

VILKS, G. 1970. Circulation of Surface Waters in Parts of the Canadian Arctic Archipelago Based on Foraminiferal Evidence. *Arctic,* 23: 100-111. BI Contrib.

Planktonic foraminifera are present both in bottom sediments and surface waters on the continental shelf off M'Clure Strait, N. W. T., but only in surface waters in the Strait. The evidence is used to suggest a *slow net movement of water from the ocean through M'Clure Strait in the past with increased rates at the present.*

VILKS, G. 1970. New Method for Separation of Skeletal Material from a Plankton Sample. *Maritime Sediments, 6:* 72-73. BI Contrib. No. 218.

Plankton samples for foraminiferal analysis are processed using a TRACERLAB low temperature asher. By this method all organic material is removed from the sample, leaving the calcareous foraminiferal tests undamaged.

WALKER, D.A. 1969. Observations of the Regeneration of a New Test by the Foraminifera Discorbis Sp. *Cdn. Jour. Zool., 47:* 543-545. BI Contrib. No. 147.

A specimen of Discorbis sp., while maintained in culture for several weeks, was accidentally crushed, resulting in definite damage to the test, but unrecognizeable (although possible) damage to the cytoplasm. Within a week cytoplasm protruded from beneath the test and new test material was being constructed. During the following two weeks a new test was *completely constructed, but attached to the original tests. Chamber arrangement of the regenerated test was extremely irregular for a Discorbis.*

WELLS, D.E. 1969. The Automatic Real-Time Plotting of Ship's Tracks. *Trans. Applications of Seagoing Computers* 1969, *Mar. Tech. Soc.:* 131-139, BI Contrib. No. 145.

Equipment to digitally record ship' s head and log, and either Navigational DECCA (hyperbolic mode) or DECCA Lambda (two range model, in conjunction with a plotter-equipped PDP-8 computer, is used to provide plots of ship' s tracks. The data is logged on paper tape using the Bedford Institute Shipboard Data Logging System, and processed on board in real time plus ten minutes. Tracks plotted from ship' s head and log are compared with plots from DECCA to improve the reliability of the digitized record of ship' s track. An interface between the data logging system and the PDP-8 has been developed, and on-line track plotting demonstrated.

WELLS, D.E. 1969. Experience with Satellite Navigation During the Summer of *1968. The Canadian Surveyor, 23:* 334-348. BI Contrib. No. 152.

The U.S. Navy Navigation Satellite System is described. Factors which affect the accuracy of positions determined with this system are discussed. An analysis of satellite navigation positions obtained at the Bedford Institute is presented, indicating that fixes from individual satellite passes are scattered about a mean position with a root-mean-square radial scatter of 55 metres, and that the mean position is displaced by 43 metres from a surveyed position referenced to the 1927 North American Datum. Considerations involved in the use of this system at high latitudes are discussed, and some results from Bedford Institute experience in northern Greenland are presented. The problems involved in effectively using this system at sea are discussed.

Collected Contributions of the Bedford Institute, volume I, 1968, and volume II, 1969, are available.

Publications (Others)

BEWERS, J.M., and **FLACK, F.C.** 1969. Determination of Fluorine by Prompt r-Radiation from Proton Bombardment. Part I Theory and Experimental Method. *Analyst 94:* 1-6.

BEWERS, J.M., and **FLACK, F.C.** 1969. Determination of Fluorine by Prompt r-Radiation from Proton Bombardment. Part **II** Results. *Analyst 94:* 7-14.

BROOKE J., and **PELLETIER, B.R.** 1970. Sea Drilling Techniques of the Bedford Institute. *Underwater Sci. and Tech. Jour. (U.K.) 2:* 165-167.

BUCKLEY, D.E. 1970. A Contribution to Trace Element Intercalibration Study - Report of 11 Elements. *Report No. 70-62, Woods Hole Oceanographic Institution, Eds. P. G. Brewer, and O. W. Spencer.*

DINN, D.F., WINTER, D.A., and **TRENHOLM, B.G.** 1970. CINTEL - Computer Interface for Television. *I.E.E.E. Trans., On Computers,* C-19: 1091-1093.

FORRESTER, W.D. 1970. Geostrophic Approximation in the St. Lawrence Estuary. *Tellus, 22: 53-65.*

KEYS, J., and **SMITH, S.D.** 1970. Frictional Resistance to a Ship's Passage Through Converging Ice. *Arctic 23: 284-285.*

KING, L.H., and **MACLEAN, B.** 1970. A Diapiric Structure near Sable Island - Scotian Shelf. *Maritime Sediments, 6: 1-4.*

LEVY, E.M. 1969. Nickel-Iron Alloys Electrodeposited from a Sulfate-Chloride Electrolyte: The Effects on Mechanical Properties and Microstructure of Stress-Reducing Agent, Heat Treatment, pH and Chemical Compositions. *Plating* 56: 903.

LEVY, E.M. 1970. The Significance of the Third Figure Following the Decimal Point in Salinity Data. *Conseil International pour l'Exploration de la Mer - Information on Techniques and Methods for Sea Water Analysis.* An Interlaboratory Report No. 3, 37-49. (Written on invitation).

LEVY, E.M., MACINNIS, R.D., and **COPPS, T.P.** 1969. Iron Electrodeposited from a Sulfate-Chloride Electrolyte: Effects on Microstructure and Microhardness of Current Density, Temperature, pH and Chloride ton Concentration. *Plating 56:* 533.

LOUCKS, R.H. 1969. Particle Size Distribution of Chlorine and Bromine in Mid-Continent Aerosols from the Great Lakes Basin. *Tech. Rep. Dept. of Metrology and Oceanography, College of Engineering, University of Michigan,* Ann Arbor, 168 p.

LOUCKS, R.H., and **WINCHESTER, J.W.** 1969. Pollution Contributions to the Atmospheric Inventory of Chlorine and Bromine in Aerosols over Continental U.S.A. in *Trace Substances in Environmental Health - Ill, Proc. Third Annual Conference* - June, 1969, University of Missouri, Columbia.

LOUCKS, R.H., and **WINCHESTER, J.W.** 1970. Some Features of Cl and Br in Aerosols. *Jour. Geophys. Res., 75: 2311-2315.*

LOUCKS, R.H., WINCHESTER, J.W., MATSON, W.R., and **TIFFANY, M.A.** 1969. The Halogen Composition of Aerosol Particles over Lake Michigan. *Modern Trends in Activation Analysis,* I, U.S. Nat. Bur. Stds. Special Publication 312: 36-42.

LUMSDEN, D.N., and **PELLETIER, B.R.** 1969. Petrology of the Grimsby Sandstone (Lower Silurian) of Ontario and New York. *Jour. of Sed. Pet., 39:* 521-530.

NEU, H.J.A. 1969. Salinity Variations, Density Currents, and Silt Transport in the Saint John Estuary. *Proc. 13th Congress of the Internat. Assoc. for Hydraulic Res.. Science Council of Japan, 3:* 241-248.

PAGDEN, I.M.H., PEARSON, G.J., and **BECK, V.N.** 1969. A Semi-Automated Computer System for Gamma-Ray Spectrum Analyses of Thermal Neutron Activated Samples. *I.E.E.E. Trans. Nucl. Sci. 17: 211-217.*

PELLETIER, B.R., and **GODDEN, C.A.** 1970. A Submersible Electric Coring Drill for Geological Exploration on the Shelf. *Mining in Canada, August: 34-40.*

QUON, C. 1970. Effects of Boundary Conditions on Thermal Convection in an Enclosure. *Proc. of the Conference on Computational Phys.* The Inst. of Phys. and the Physical Soc. of Britain: 80-83.

RASHID, M.A. 1969. Contribution of Humic Substances to the Cation Exchange Capacity of Different Marine Sediments. *Maritime Sediments, 5: 44-50.*

ROSS, D.I. 1970. Marine Geophysics, in *Background Papers on the Earth Sciences in Canada. Geophysical Survey of Canada paper 69-56:* 180-186.

ROSS, D.I., and **CHRISTOFFEL, D.A.** 1970. A Fracture Zone in the Southwest Pacific Basin South of New Zealand and Its Implications for Sea Floor Spreading. *Earth and Planetary Sci. Letters, 8:* 125-130.

SCHAFER, C.T. 1969. Distribution of Sediments on the Tops of Mid-Atlantic Ridge Mountains. *Maritime Sediments, 5:* 51-55.

SCHAFER, C.T. 1969. Distribution of Foraminifera along the West Coasts of Hudson and James Bay, A Preliminary Report. *Maritime Sediments, 5; 90-94.*

SCHAFER, C.T. 1970. Lock-Out Diving in Gulf of St. Lawrence for Geological Samples. *Sea Harvest and Ocean Sci., December 1969 - January 1970: 26-27.*

SCHAFER,C.T., and **BROOKE, J.** 1970. Cores from the Crest of the Mid-Atlantic Ridge. *Geotimes, 17:* 14-16.

TIFFANY, J.A., WINCHESTER, J.W., and **LOUCKS, R.H.** 1969. Natural and Pollution Sources of Iodine, Bromine and Chlorine in the Great Lakes. *Jour. Water Pollution Control Federation,* 41: 1319-1329.

VILKS, G. 1970. New Method for Separation of Skeletal Material from a Plankton Sample. *Maritime Sediments, 6: 72-73.*

WAGNER, F.J.E. 1970. Marine Pleistocene Faunas of Canada. *Geol. Survey of Canada, Economic Geol. Report, 1, 5th ed:* 671-674.

WAGNER, F.J.E. 1970. Faunas of the Pleistocene Champlain Sea; *Geol. Survey of Canada Bulletin 181: 104* pp.

WALKER, D.A., and **BUCKLEY, D.E.** 1969. Some Techniques and Applications of Scanning Electron Microscopy in the Fields of Marine Science, *Maritime Sediments, 5:* 113-118.

WOODSIDE J.M., PHILLIPS, J.D., and **BOWIN, C.W.** 1969. Magnetic and Gravity Anomalies in the Central Red Sea, in *Hot Brines and Recent Heavy* Metal *Deposits in the Red Sea.* Ed. E.T. Degens and D.A. Ross. Springer Verlag, N.Y.: 98-113.

WOODSIDE, J.M., and **BOWIN, C.O.** 1970. Gravity Anomalies and Inferred Crustal Structure in the Eastern Mediterranean Sea. *Geol. Soc. Amer. Bull., 81:* 1107-1122.

AOL Reports

69-l SCHAFER, C.T., and **SEN GUPTA, B.K.** Foraminiferal Ecology in Polluted Estuaries of New Brunswick and Maine.

Eighteen benthonic species constitute the total foraminiferal assemblage in the St. John, Penobscot and Kennebec estuaries, all of which are polluted. Miliammina fusca *is the most widespread species. In the St. John River, the absence of living Foraminifera at certain stations may be due to the toxic nature of a paper-mill waste. In some parts of the Penobscot the relatively low pH and oxygen values of nearshore waters may be causing a barrier to the establishment of foraminiferal species. In the Kennebec River,* Trochammina inflata *is apparently the most pollution-tolerant species. A plot of bioindex values against numbers of species indicates that the St. John and Kennebec estuaries are relatively more polluted than the Penobscot.*

69-2 FORRESTER, W.D. Tidal Transport and Streams in the St. Lawrence River and Estuary.

The principle of continuity is used to calculate transports through various cross-sections of the St. Lawrence channel between Lake St. Peter and Pte. des Monts. This has been done for tidal constituents M_2, S_2, N_2, K_1, O_1, M_4, and MS_4 and for the river discharge. The transports are also converted to average currents and tidal streams by dividing by the measured cross-sectional areas. Excellent agreement is found with corresponding tidal constituents obtained from direct current measurements near Pte. des Monts and Pte. au Pere.

69-3 BUCKLEY, D.E. Sedimentological Studies at Malpequa Bay, Prince Edward Island.

Studies of recent sedimentation in a part of Malpeque Bay indicate that the area has been accumulating erosion products at an accelerating rate over the past 100 years. Part of the Bideford River estuary received an average of ten inches of sediment per year between the years 1958 and 1963. Some fertilizer and pesticide residues are being retained in the recent sediments.

69-4 SMITH, S.D. A Sensor System for Wind Stress Measurement.

A sensor system for air-sea interaction studies consists of a three-component Doe Thrust Anemometer (Mk. VI), a two-component modified Bendix Aerovane anemometer, and associated electronics. The system was designed for operation on a stable floating platform by remote control, and its output signals are suitable for radio telemetry and magnetic tape recording.

The system was calibrated in the B.I. wind tunnel. A CDC 3100 computer was used to process the data obtained.

69-6 SMITH, S.D., DOE, L.A.E., and **STEVENS, R.G.** Thrust Anemometer Measurement of Reynolds Stress over the sea off Chebucto Head, Nova Scotia.

Reynolds stress over the sea surface has been measured using a thrust anemometer at a stable floating platform moored off Chebucto Head, N.S. The purpose of the experiment is to determine values of the drag coefficient of the sea surface as a function of wind speed, atmospheric stability, and other parameters. Some preliminary results are discussed.

69-6 ROSS, D.I., and **WELLS, D.E.** Experience with Satellite Navigation Equipment during Summer 1968.

The operation of the U.S. Navy *Navigation Satellite* system *on land, at high latitudes and at sea is described. An analysis of satellite navigation positions obtained with Magnavox and I.T.T. receivers at the Bedford Institute indicates that on land a repeatability of 200 meters between individual fixes* can *be reliably achieved by adequate screening of poor data. At sea the repeatability depends on an independent accurate knowledge of ship's motion during satellite passes. Details of the receiver configurations, satellite data formats and software requirements are included as appendices.*

69-8 LARSEN, E. Design of an Integrating, Submersible Radiometer.

To determine the relationship between the rate of production of ply to plankton and the mean solar radiation, the solar energy per unit area at a given depth should be measured. This report deals with the design of the electronics: the construction, testing and calibration of an instrument to measure this quantity in absolute units.

69-9 PAGDEN, I.M.H., PEARSON, G.J., and **BECK, V.N.** A Semi-automated Computer System for Gamma Ray Spectrum Analysis of Thermal Neutron Activated Samples.

A set of consecutively executed computer programmes have been developed for the quantitative interpretation of gamma ray spectra obtained with Ge (Li) detectors.

69-11 JOLLYMORE, P.G. A Portable Digital Sounding System for Arctic Use.

A deep-water, portable, digital sounder has been designed to sound through the ice. It was developed for the Canadian Polar Continental Shelf Project.

70-1 BEWERS, J.M. An Investigation into Fluoride Concentration Profiles in the North Atlantic.

High density fluoride profiles have been obtained for 9 stations in the North Atlantic. No anomalies, as reported by other authors, were found, the fluoride concentration being effectively constant at 1.32 µg/g.

70-2 ROSS. D.I., WELLS, D.E., and **EATON, R.M.** Navigation at Bedford Institute.

This report presents a survey of the navigational requirements for work at Bedford Institute, summarizes the existing navigational facilities available in the Institute, considers the alternative currently-available programs, and defines areas where further development is essential or advantageous.

70-3 HOOPER, K. Recent Foraminifera of the Continental Shelf off Eastern Canada: A Preliminary Report.

Foraminifera of 40 bottom sediment samples collected from depths ranging from 5 to 457 metres between English Point, Quebec, and Flemish Cap, 360 miles east of Newfoundland were analysed for foraminiferal content; 318 species and varieties are recognized. Raw data of foraminiferal counts were processed by computer to produce data matrices that were used as input for a factor-vector analysis, the results of which indicated that seven benthonic foraminiferal assemblages exist in the region of the continental shelf off eastern Canada.

70-4 THORBURN, J.P., SMITH, S.D., and **DOBSON, F.W.** Bedford Institute Wind Tunnel.

The tunnel has a 2 x 2 foot cross section and flow rates from 0 to 32 m/sec. It is being relocated in the Hydrodynamics Laboratory, Depot extension.

70-5 FARQUHARSON, W.I. Tides, Tidal Streams and Currents in the Gulf of St. Lawrence. Second Edition Pt. 1 - Tides and Tidal Currents.

This presentation in general consists of data in diagrammatic and tabulated forms and comments on features which appear to be of significance.

70-6 NEU, H.J.A. The Hydrodynamics of Head of Chedabucto Bay and Its Influence on the *Arrow* Oil Disaster.

Major meteorologic and hydrodynamic factors which could have influenced the grounding of the tanker "ARROW", the movement of the oil spills and the recovery of the oil from the wreck are analyzed and described. The results of a number of surveys, made during the salvage operation, are discussed.

70-7 MACPHEE, S.B., and **AWALT, G. An** Evaluation of Digital Depth Tracking Systems.

This report deals with the evaluation of various systems to interface to a sounding system and present bathymetry in digital form.

70-8 BEWERS, J.M., and **PEARSON, G.J.** Effects of Pulp Mill Effluent on Water Quality and Biota Trace Element Characteristics.

Trace element concentrations have been determined in marine fauna obtained from the receiving area of pulp mill effluent. Studies of the behaviour of suspended sediments have indicated an economic method of reducing both colour and particulate loading in the receiving coastal waters.

70-9 NEU, H.J.A. A Study on Mixing and Circulations in the St. Lawrence Estuary up to 1964.

The effect of fresh water regulations on the St. Lawrence Estuary (e.g. due to hydro power developments and water diversions) was studied by analyzing the 1963 salinity and temperature distributions and the dynamics of the system during a fresh water runoff of 11,000 m^3/s in February and 17.000 m^3/s in May. From the results it follows that man-made modifications alter the flow regime, particularly that of the Gaspé Current and with it the salinity and temperature structure of the system. The most obvious change would be in temperature with consequences likened to large-scale heat pollution. The report is an abbreviated version of a 1964 manuscript which has not been published.

AOL Internal Notes

69-1-I MACPHEE, S.B. Digital data logging system MK. II. (2 volumes).

69-2-I SCHAFER, C.T. Is there a submersible in your life? An informative questionnaire.

69-3-I DEGRASSE, F.L. The hydrographers' role in offshore hydrographic-geophysical surveys.

69-4-I SRIVASTAVA, S.P. Importance of phase angle when determining anisotropic conductivity by magnetotelluric method.

69-5-I DOUGLAS, G.R. Notes on visits to European hydrographic offices and the International Congress of Surveyors.

69-6-I DOUGLAS, G.R. Progress report and five year program for hydrographic development group A.

69-7-I HEMPHILL, M.A. The use of continuous seismic profiler equipment on future hydrographic surveys.

69-8-I MACNAB, R.F. Gravity computations on a spherical earth.

69-9-I AWALT, G. Data logging system power supplies MK. I I. Operation and Maintenance manual.

69-10-I MCMULLEN, R.M. Guide to authors of B.I. contributions to the published literature.

69-11-I BENDALL, E.A. Synchronous clock amplifier. (Operating Manual).

69-12-I BENDALL, E.A. Time-mark generator (Operating Manual).

69-13-I MANCHESTER, KS. Anschutz gyro-table repair and overhaul manual.

69-14-I NICHOLSON, K.M. Real time computer graphics display with light pen.

69-15-I SIMO-PLA, J. Sonobuoy for scientific work.

69-16-I MCKEOWN, D.L. A guide to the services provided by the metrology section.

69-17-I BENNETT, A.S. A note on the potential sensitivity of the Electromagnetic Current Meter.

69-18-1 PHI, D.T. Notes on the Applications of Sea-going Computers Symposium held January 13-14, 1969, at Scripps Institution of Oceanography.

69-19-I SRIVASTAVA, S.P., WILLIAMS, G.I., and **MASON, R.G.** A system for measuring magnetotelluric signals at the sea bottom.

69-20-1 KEEN, C.E. Seismic refraction studies on the Mid-Atlantic Ridge near 45°N.

69-21-I FENERTY, N.E. A proposal for a free-floating ocean bottom camera.

69-22-I MCKEOWN, D.L. A progress report on the radio-controlled launch project.

69-23-I BROOKE, J. A corer drill - a proposal.

69-24-I RENDELL, E.A. Telemetering analogue thermometer.

69-25-I BETLEM, J.J. AOL standards laboratory.

69-26-I SMITH, S.D., BANKE, E., and **JOHANNESSEN, D.M.** Some measurements of Reynolds Stress over ice in the Gulf of St. Lawrence. A preliminary note.

69-27-I SMITH, S.D. Program review and proposals for wind stress measurements.

69-28-I KINGSTON, P.F., and **HARVEY, D.R.** An incremental digital tape recorder.

69-29-I CARSON, B.D. Electronic salinity, temperature, depth recording.

69-31-I BENNETT, A.S., and **BENDELL, E.A.** Data telemetering system for porpoising towed body.

69-32-I BENNETT, A.S. Practical considerations for an electro-magnetic current meter.

69-33-I PARKER, R.L. A report on computing at Bedford Institute.

69-34-I DRAPEAU, G. Proposal for storage and retrieval of geological data.

69-35-I BETLEM, J.J. Report of visit to the National Research Council, Applied Physics Division, September 23-25, 1969.

69-36-I BROWN, L.C. Tumbling apparatus used in sedimentology laboratory.

69-37-I GRANTHAM, R.E. Notes on Kalman filtering.

69-38-I PIERIES, R.C.K. To investigate pulsed sieve-plate extraction column for preconcentrating trace metal ions by solvent extraction.

69-39-I PAGDEN, I.M.H., and **PEARSON, G.J.** A catalogue of the nuclear parameters of the isotopes.

70-1-I LEVY, E.M. The production and analysis of I.A.P.S.O. standard sea water.

70-2-I LEVY, E.M. A search for the ideal salinity sample box.

70-3-I BEWERS, J.M. Some notes concerning effluent from the chlor-alkali plant now under construction at Abercrombie. Pictou County, Nova Scotia.

70-4-I BETLEM, J.J. Evaluation of tape recorders.

70-5-I NEU, H.J.A. Equipment for calibrating current meters in the Bedford Institute.

Series Discontinued.

AOL Computer Notes

69-1-C **RICHARDSON. A.** Programmes used to study lineations in magnetic anomaly map of Mid-Atlantic Ridge between 45°N and 46°N

69-2-C **BUDLONG, K.S.** Program to calculate geoidal height.

69-3-C **BEWERS, J.M.** Published article and data source reference catalogue and search program for the CDC 3100.

69-4-C **BUDLONG, K.S.** Fortran subroutines for supplement to control data manuals.

69-5-C **BUDLONG, K.S.** Bathysonde calibration programs.

69-6-C **BUDLONG, K.S.** Calibrations of bathysonde data sheet axes.

69-7-C **PARSONS, D.S.F.** HYPERMAP for the CDC 3100.

69-8-C **PARKER, R.L.** A format-free reading function.

69-9-C **WHALEN, P.R.** Power spectra program used on CDC 3100.

69-10-C **HERMAN, D.H.** Voltage to velocity: a computer program to digitise and analyse thrust, sonic, and aerovane anemometer date.

69-11-C **HERMAN, D.H.** A set of subprograms to digitise and analyse multi-variable time-series data.

69-12-C **HERMAN, D.H.** A computer program to calculate power spectra.

69-13-C **PARSONS, D.S.F.** I.G.R.F. defines a polynomial for the north Atlantic.

70-1-C **SCOBEY, P.** Three-dimensional histograms.

70-2-C **STEVENS, R.G.** The multi-variable data sampling program MVDS (II).

70-3-C **STEVENS, R.G.** Users' manual for multi-variable data analysis system. Indices MB DSTC.

70-4-C **SCOBEY, P.** Program CONTOUR and program CONTPLOT (with picture option).

70-5-C **SHIH, K.G.** Computation of the Bouguer anomaly at sea with a PDP-8 computer.

70-6-C **LAWRENCE, D.J.** Processing data from Plessey digital instruments.

70-7-C **SHIH, K.G.** Investigation of the third degree polynomial describing the IGRF values at sea.

70-8-C **MACLEAN, L.** Programs for editing and analyzing Air/Sea interaction data: COPY, COPYRUN, SELRUN, HISTOGRAM and TIMSERES.

70-9-C **KEYTE, G.K.** Processing STD magnetic tapes.

70-10-C **VANDALL, P.** Jr. Description of a computer program to generate surface wave diffraction diagrams.

70-11-C **RICHARDS, R.** Computing services users manual.

70-12-C **BENNETT, A.S.** Curve fitting for thermistors,

70-13-C **BENNETT, A.S.** Focal language programs for salinity-temperature-depth data acquisition and processing.

70-14-C **BENNETT, A.S.** Versions of FOCAL for use with A 4K PDP-8 with dectapes.

70-15-C **RUDDERHAM, D.,** and **LIVELY, R.R.** Current meter reduction programs for the CDC 3100.

AOL Data Reports

69-1-D **SRIVASTAVA, S.P.** Magnetics and bathymetry on the Nova Scotia shelf.

69-2-D **LAWRENCE, D.J.** An index of current meter records at the Bedford Institute, 1958-1966.

69-3-D **SRIVASTAVA, S.P., LOCKE, D.R.,** and **LEBLANC, A.V.** Magnetic variations for ground station, B.I., for October, November, December, 1968.

69-4-D **SRIVASTAVA, S.P.. LOCKE, D.R.,** and **LEBLANC, A.V.** Magnetic variations for ground station, B.I., for January, February, March, 1969.

69-5-D **WILLIAMS, C.A.,** and **PORTEOUS, D.M.** North Atlantic. March to May. 1965.

69-6-D **SRIVASTAVA, S.P., LOCKE, D.R..** and **LEBLANC, A.V.** Magnetic variations for ground station, B.I., for April, 1969.

69-7-D **SEIBERT. G.H..** and **REDDY, M.P.M.** Petit Passage tide and current survey, 1966.

69-8-D **SRIVASTAVA, S.P., LOCKE, D.R.,** and **LEBLANC, A.V.** Magnetic variations for ground station, B.I., for May, 1969.

69-9-D **SRIVASTAVA, S.P., LOCKE, D.R.,** and **LEBLANC, A.V.** Magnetic variations for ground station, B.I., for June 1969.

69-10-D **STEWART, J.M.,** Sediment-core data synopsis, cruise number BIO 19-66 Hudson, Mid-Atlantic Ridge at 45 degrees north latitude

69-11-D **SRIVASTAVA, S.P., LOCKE, D.R.,** and **PARSONS, A.V.** Magnetic variations for ground station, B.I., for July, August, September, 1969.

69-12-D **CLARKE, N.H., MCMULLEN, R.M.,** and **ALLAN, C.S.** Listing of periodicals, serials, and reports held in the Bedford Institute Library.

70-1-D **SRIVASTAVA, S.P.. LOCKE, D.R.,** and **PARSONS, A.V.** Magnetic variations for ground station, B.I., for October, November, and December, 1969.

70-2-D **SRIVASTAVA, S.P., LOCKE, D.R.,** and **PARSONS, A.V.** Magnetic variations for ground station, B.I., for January, February, March, April, 1970.

70-3-D **HOFFMAN, T.M.** Geochemical data report (geochemistry of Scotian shelf sediments).

70-4-D **SRIVASTAVA, S.P., LOCKE, D.R.,** and **PARSONS, A.V.** Magnetic variations for ground station, B.I., for May, 1970.

70-5-D **AUMENTO, J.** Petrological, geochemical and geophysical studies of rocks dredged from the Mid-Atlantic Ridge at 45°N.

70-6-D **GRANT, A.C.,** and **MANCHESTER, K.S.** Seismic reflection profile from the continental margin off Nova Scotia, Canada.

70-7-D **FARQUHARSON, W.I.** Information on currents for Chart International 109.

70-8-D **SRIVASTAVA, S.P., LOCKE, D.R.,** and **PARSONS, A.V.** Magnetic variations for ground station, B.I., for June, July, August, September, 1970.

70-9-D **GRANT, A.B.,** and **REINIGER, R.F.** Current meter and thermograph observations on the Scotian shelf.

70-10-D **SRIVASTAVA, S.P., LOCKE, D.R.,** and **MACINTYRE, J.B.** Magnetic variations for ground station, B.I., for October, November, 1970.

Appendix B-2
Lectures and Talks

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

BANKE, E.G. "Ice Drift". Workshop on Structures in Force, Ottawa, November 1970.

BARRETT, D.L., and **MANCHESTER, K.S.** "Crustal Structure in Baffin Bay and Davis Strait from Magnetometer Surveys". Meeting of Am. Geophys. Union, Washington, April 1969.

BARTLETT, G.A. "Geological Report on Grand Banks Drill Cores". Offshore Information Seminar. Bedford institute, January 1969.

BENNETT, A.S. "Computer Data Display". Applications of Sea Going Computers Symposium, La Jolla,Calif., January 1969.

BENNETT, A.S., MASON, C.S., and **BENDELL, E.A.** "The Bedford Institute Shipboard Data Logging System". Applications of Sea Going Computers Symposium, La Jolla, Calif., January 1969.

BEWERS, J.M. "Mercury and its Behavior in the Environment". Northumberland Strait Pollution Control Committee, Pictou, N.S., May 1970.

BROOKE, J., and **MASON, C.S.** 1969. "Some Instruments for Monitoring the Performance of Undersea Mechanical Devices". International Oceanology Conference, Brighton, U.K., February 1969.

BROOKE, J., and **GILBERT, R.L.G.** "A Hydrostatic Power System" - an invited paper. International Oceanology Conference, Brighton, U.K., February 1969.

BROOKE, J. "*Hudson* 70 and Engineering in Oceanography". Annual Meeting of Ottawa Branch, Engineering Inst. of Canada, Ottawa, May 1970.

BUCKLEY. D.E. "Marine Geological Research in Alaska". Dalhousie Dawson Geology Club, January 1969.

BUCKLEY, D.E. Seminar on marine inorganic geochemistry to the University of New Brunswick. February 1969.

BUCKLEY, D.E. "General Marine Geology and Oceanography". Mount Allison University Teachers Science Course, Sackville, N.B., July 1970.

BUTLER, D.W. "*Hudson* 70" Dartmouth Rotary Club, Dartmouth, November 1970.

DEGRASSE, F.L. "Atlantic Operations". Eighth Annual Canadian Hydrographic Conference, Victoria, B.C., March 1969.

DESSUREAULT, J.G. "A Porpoising Towed Body". C.C.D. Meeting, Victoria, B.C., November 1969.

DESSUREAULT, J.G. "Oceanography in Canada and Mechanical Engineering in Oceanography". Laval University, Montreal, February 1970. In the French Language.

DESSUREAULT, J.G. "Oceanography in Canada and Mechanical Engineering In Oceanography". University of New Brunswick, Fredericton, February 1970. In English.

DESSUREAULT, J.G., and **HYMAN, R.** "Living, Work and Equipment on the French Ship *Jean Charcot*". Fall 1969.

DOBSON, F. "Pressure Measurements on Wind Driven Waves". An invited lecture at the John Hopkins University, Baltimore, Maryland, U.S.A., April 1970.

DOUGLAS, G.R. "Development Group Activities". Eighth Annual Canadian Hydrographic Conference, Victoria, B.C., March 1969.

EWING, G.N. "Future of Marine Sciences in Canada". Panel member. Science Council Study on Marine Sciences and Technology, Halifax, N.S., August 1969.

EWING, G.N. "A Brief on Marine Sciences and International Activity in the Offshore Areas of Canada's Atlantic Seaboard." Science Council Study of Marine Sciences and Technology at the Nova Scotia Technical College, August 1969.

EWING, G.N. "A Geophysical Interpretation of Large Scale Geological Features of Our Eastern Seaboard." The Regina Branch, Alberta Association of Petroleum Geologists, September 1969.

EWING, G.N. "A Geophysical Interpretation of Large Scale Geological Features of Our Eastern Seaboard." The Edmonton Branch, Alberta Association of Petroleum Geologists, September 1969.

EWING, G.N. "Geophysical Interpretation of Large Scale Geological Features of Our Eastern Seaboard." The Calgary Branch, Alberta Association of Petroleum Geologists, September 1969.

EWING, G.N. "The Historical Development and Future Trends in Multi-Disciplinary Marine Surveys." The Canadian Hydrographic 1970 Conference, Ottawa, January 1970.

EWING, G.N. "Multidiscipline Surveys Conducted by the Canadian Hydrographic Service." Atlantic Oceanographic Laboratory, C.I.S. Convention, Halifax, N.S., April 1970.

EWING. G.N. "Brief on the Status of Survey Activity in the Atlantic Region." Presented to the Parliamentary Committee on National Resources during a recent visit to the Bedford Institute, Dartmouth, Nova Scotia, May 1970.

FORD, W.L. "Trends in Ocean Exploration." Dinner talk at Third Canadian Fuel Cell Seminar, Toronto, February 1969.

FORD, W.L. "Objectives and Program in Marine Research." Talk to Canadian Research Management Association meeting in Halifax, October, 1969. This talk was read by Dr. B.D. Loncarevic as Dr. Ford was unable to attend.

FORD, W.L. "Project Oil." Seminar at Institute of Oceanography, Dalhousie University, Halifax, N.S., November, 1970.

FORD, W.L. Panel Member regarding the future course of marine science and technology in Canada. Nova Scotia Technical College, Halifax, August 1969.

GRANT, A.C. "Seismic Reflection Profiling on the Continental Shelf and Slope off Labrador and Northeast Newfoundland." Offshore Information Seminar, Bedford Institute, January 1969.

GRANT, A.C. "Seismic Profiler Investigations on the Labrador Shelf." DEMR Symposium on Recent Crustal Movements, Ottawa, March 1969.

GRANT, A.C. Talk on the Bedford Institute's earth science project on the Atlantic Seaboard, Meeting of the Mining Society of Nova Scotia, Keltic Lodge, N.S., June 1969.

GRANT, A.C., and **MANCHESTER, K.S.** "Geophysical Investigations in the Ungava Bay-Hudson Strait Region." Meeting of Am. Geophys. Union, Washington, April 1969.

HAWORTH, R.T. "Cross-Coupling Errors as a Function of Gravimeter Orientation." Meeting of Am. Geophys. Union, Washington, April 1969.

HEMPHILL, M.A. "Bathymetric Seismic Profiling Surveys." Eighth Annual Canadian Hydrographic Conference, Victoria, B.C., March 1969.

KEEN, C.E., and **BARRETT, D.L.** "Seismic Structure on the Mid-Atlantic Ridge near 45°N" Meeting of Am. Geophys. Union, Washington, April 1969.

KING, L.H. "The Geology of the Scotian Shelf." Teachers College of Truro at Bedford Institute, Dartmouth, N.S., July 1970.

KING, L.H. "Map and Geology of Scotian Shelf." Interviewed on CBHT-TV "Gazette" Program, Halifax, N.S., April 1970.

KING, L.H. "On the Origin of the Laurentian Channel." Meeting of Canadian Association of Geographers, St. John's, Nfld., August 1969.

KING, L.H., and **MacLEAN, B.** "The Origin of the Laurentian Channel." Pleistocene problems in the Atlantic Provinces, Canadian Association of Geographers in St. John's, Nfld. 1969.

KING, L.H., and **MARLOWE, J.I.** "Geology of the Scotian Shelf and Adjacent Slope." Offshore Information Seminar, Bedford Institute, January 1969.

KRANCK, K.M. "Post Glacial History of Northumberland Strait." Meeting of Canadian Association of Geographers, St. John's, Nfld., August 1969.

KRANCK, K.M. "Marine Geological Research in the Grenadines, West Indies." Geographical Society of Finland, Helsingfors, Finland, November 1969.

KRANCK, K.M. "Oil Pollution." Faculty of Engineering and Applied Science, Memorial University, St. John's, Nfld., October 1970.

LAWRENCE, D.J. "Water Pollution Survey in the Strait of Canso." C.C.O. meeting, Victoria, B.C., November 1969.

LEVY, E.M. "A Shipboard Method for the Estimation of Bunker C in Sea Water." Chemical Institute of Canada, Charlottetown, P.E.I., August, 1970.

LEVY, E.M. "Some Factors Affecting the Precision of Accuracy of Salinity Data." C.C.O. Meeting, Victoria, B.C., November 1969.

LONCAREVIC, B.D. Keynote address. Institute of Electrical and Electronic Engineers Symposium, Nova Scotia Technical College, March 1970.

LONCAREVIC, B.D. Science Council Working Group on Basic Science, Ottawa, March 1970.

LONCAREVIC, B.D. "Why the Bedford institute?" - an argument for basic research in government laboratories. Physics Department Seminar, Dalhousie University, March 1970.

LONCAREVIC, B.D. "New Directions in Education in Engineering." Nova Scotia Technical College, May 1970.

LONCAREVIC, B.D. Panel Discussion "The Future of Geology in the Oceans." Central Canada University Geological Conference, Queen's University, Kingston, Ontario, October 1970.

LONCAREVIC, B.D. "Marine Geology is Really Geophysics." Central Canada University Geological Conference, Queen's University, Kingston, Ontario, October 1970.

LONCAREVIC, B.D. "Mid-Atlantic Ridge Geophysical Aspects". N.A.C.G.S., A.C.G.G. Geodynamics Symposium, Ottawa, October 1970.

LONCAREVIC, B.D. "With *Hudson's* Scientists through the Northwest Passage". Arctic Circle Group, Ottawa, December 1970.

LONCAREVIC, B.D., ROSS, D.I., MANCHESTER, K.S., WOODSIDE, J.M., and **AUMENTO, F.** "The Mid-Atlantic Ridge Near 45°N". Meeting of Am. Geophys. Union, Washington, April 1969.

LOUCKS, R. "Oceanography at Bedford Institute". New Brunswick Teachers Association, St. John, N.B., May 1970.

MCKEOWN, D.L. "Oceanographic Sensors". Marine Applications Council, Hermes Plant, Dartmouth, N.S., December 1970.

MANN, C.R. "Sources of the Deep Water of the North Atlantic". An invited lecture, McGill University, Montreal, March 1969.

MANN, C.R. "Sources of the Deep Water of the North Atlantic". Students at McGill University, Montreal, March 1969.

MANN, C.R. "*Hudson* 70". Dartmouth Rotary Club, Dartmouth, N.S., May 1970.

MANN, C.R. "*Hudson* 70". Halifax Rotary Club, Nova Scotian Hotel, Halifax, November 1970.

MARLOWE, J.I. "Geochemistry of Carbonate Rocks". Seminar on the Ecology of Carbonate Reefs, Dalhousie University, 1969.

MARLOW, J.I. "Geological Aspects of Exploration and Development of Mineral and Fuel Resources in Cold or Ice Covered Water". McGill University, Montreal, May 1969.

MASON, C.S. "Some Developments in Undersea Technology at the Bedford Institute". Meeting of Canadian Aeronautics and Space Institute, Halifax, Nova Scotia, May 1969.

MASON, C.S. "Results of Oil Pollution". Joint paper with Dr. A.Y. MacLean at NATO Colloquim, Brussels, November 1970.

MAUNSELL, C.D. "Preliminary Plan for Hudson 70 Geophysical Cruise off British Columbia Coast". C.C.O. Meeting, Victoria, B.C., November 1969.

MELANSON, R.C. "General Hydrography". Offshore Information Seminar, Bedford Institute, Dartmouth, January 1969.

MELANSON, R.C. "Tidal Current Measurements by Hydrographers at AOL". Eighth Annual Canadian Hydrographic Conference, Victoria, B.C., March 1969.

MELANSON, R.C. "The Bedford Institute With Particular Reference to Hydrography". Members of Kiwanis Club, Halifax, N.S., March 1969.

MELANSON, R.C. "Regional Hydrographer's 1968 Report and Proposed 1969 Program". Eighth Annual Canadian Hydrographic Conference, Victoria, B.C., March 1969.

MELANSON, R.C. "Hydrography - General". Presented to Subcommittee on Maritime Command of Parliamentary Committee on External Affairs and National Defence, Dartmouth, September 1969.

MELANSON, R.C. "Undertakings at Bedford Institute Appropriate to Offshore Explorations". Mapping Colloquim for the Petroleum Industry, Banff Springs, Alberta, October 1969.

MELANSON, R.C. "A Lambda Evaluation". Mapping Colloquim for the Petroleum Industry, Banff Springs, Alberta, October 1969.

MELANSON, R.C. "*Hudson* 70". Interview on CBC-TV Halifax "Gazette", November 1970.

MELANSON, R.C. "*Hudson* 70". Interview on CBC Radio Halifax, November 1970.

PECK, C.R. "The Place for Electronic Technicians at Atlantic Oceanographic Laboratory". Dartmouth Regional Vocational School, Dartmouth, N.S., May 1970.

PECK, C.R. "The Atlantic Oceanographic Laboratory of the Bedford Institute". Address to 32 teenagers at Lawrencetown, N.S., March 1969.

PELLETIER, B.R. Talks on the earth sciences program of the Bedford Institute, as well as seminars on the subject of the Migration of Clastic Sediments to the Geology Departments at Memorial University of Newfoundland and Queens University, Kingston, March 1969.

PELLETIER, B.R. "Geological Exploration and Petroleum Potential in the Eastern Canadian Offshore". American Association of Petroleum Landmen, Banff, Alberta, June 1969.

PELLETIER, B.R. "Marine Geology: A Look into the Past and into the 70's". Central Canada University Geological Conference, Queens University, Kingston, Ontario, October 1970.

PELLETIER, B.R. "Marine Geological Explorations and its Reference to Minerals and New Marine Technologies". Canadian Institute of Mining and Metallurgy. Calgary, Alberta, December 1970.

PELLETIER, B.R. "Migration of Clastic Sediments Under Prograding Conditions" Department of Geology, University of Calgary, Calgary, Alberta, December 1970.

PELLETIER, B.R., and **MCMULLEN, R.M.** "Models of Sediment Transport in Minas Basin and Bay of Fundy". International Tidal Conference, N.S. Technical College, Halifax, N.S., June 1970.

QUON, C. "Effects of Boundary Conditions on Thermal Convection in an Enclosure". Conference at Imperial College, London, England, September 1970.

RANALLI, G. "Theology of the Tectonosphere as Inferred from Seismic Aftershock Sequences". American Geophysical Union, Washington, U.S.A., April 1970.

RASHID, M.A. "Humic Acids of Marine Sediments and Organo-Clay Interactions". Gordon Research Conf. Organic Geochemistry, Plymouth, N.H. September 1970.

ROSS, D.I. "Data Storage and Retrieval for Offshore Geophysical Survey". C.C.O. Meeting, Victoria, B.C., November 1969.

SCHAFER, C.T. Talk on Submersible *Shelf Diver* on CBHT-TV "Gazette", October 1969.

SCHAFER, C.T., and **BROOKE, J.** "Hard Rock Cores from the Mid-Atlantic Ridge at 45°N." Am. Geophys. Union, Fall Meeting, San Francisco, U.S.A., December 1969.

SEIBERT, G. "Tidal Circulation in Petit Passage, Nova Scotia". C.C.O. Meeting, Victoria, B.C., November 1969.

SMITH, S.D. "Some Measurements of Reynolds Stress over Ice in the Gulf of St. Lawrence". McGill University, Montreal, March 1969.

SMITH, S.D. "Some Measurements of Reynolds Stress over Ice in the Gulf of St. Lawrence". C.C.O. Meeting, Victoria, B.C., November 1969.

SMITH, S.D. Seminar, "Recent Wind Stress Measurement Over the Sea" and Lecture, "Stable Platforms for Air-Sea Interaction Studies". U.S. Naval Postgraduate School, Monterrey, Calif., July 1970.

SMITH, S.D. "Thrust and Sonic Anemometers". Arctic Ice Dynamics Joint Experiment Planning Meeting San Diego, Calif., July 1970.

SMITH, S.D., BANKE, E.G., and **JOHANNESSEN, O.M.** "Wind Stress Measurement over Ice by Sonic Anemometer". Workshop Seminar on Ice Drift and Related Studies; McGill University, Montreal, March 1969.

SMITH, T.B. "Hydrodist MRB-2". Eighth Annual Canadian Hydrographic Conference, Victoria, B.C., March 1969.

STEVENS, R.G. "Wind Stress Studies". Twelfth Conference on Great Lakes Research at Detroit, Michigan, May 1969.

STEVENS, R.G. "Generation and Travel of Surface Waves". McGill University, Montreal, March 1969.

STEVENS, R.G., and **SMITH, S.D.** "Wind Stress Measurements over the Open Sea". 12th Conference Great Lakes Res., Ann Arbor, Michigan, May 1969.

VILKS, G. "Foraminiferal Ecology in the Canadian Arctic". Mount Allison University, Sackville, N.B., February 1969.

WAGNER, F.J.E. "*Hudson* 70 Expedition". Eastern Shore District High School, Musquodoboit Harbour, N.S., December 1970.

WELLS, D.E. "Experience with Satellite Navigation during Summer of 1968". Eighth Annual Canadian Hydrographic Conference, Victoria, B.C., March 1969.

WELLS, D. "Surveys for Offshore Resources Development", TV Panel - C.I.S. Convention, Halifax, N.S., April 1970.

WILLIAMS, R.K. "What Can Service Clubs Contribute to the Pollution Problem". Members of Kinsmens' Club, Edmundston, N.B., March 1969.

Appendix B-3
Affiliations

During the years 1969-70 some staff members of the Atlantic Oceanographic Laboratory were affiliated in various ways with the academic community.

At Dalhousie University several staff members were associate members of the Faculty of Graduate Studies. These included Dr. C.R. Mann who is an Associate Professor in the Physics Department and has been lecturing in fluid dynamics and supervising graduate students, Dr. B.D. Loncarevic who is also an Associate Professor in the Physics Department, Drs. B.R. Pelletier and L.H. King who are Special Lecturers in the Geology Department, and Drs. G.T. Needler and H. Sandstrom who are Research Associates in the Institute of Oceanography and have given courses in dynamical oceanography. In addition, Drs. C. Quon and S.D. Smith gave lecture series in fluid mechanics and Drs. D. I. Ross, S.P. Srivastava, and C. Keen served on students' thesis committees.

At the Nova Scotia Technical College, S.B. MacPhee and D.F. Dinn gave courses in electronic design and Dr. A. Bennett has served as associate supervisor of a student. Dr. W. Forrester is supervisor of a Ph.D. candidate at the Marine Sciences Centre, McGi!l University, and Dr. A. Walton is supervising Ph.D. students at the Chemistry Department, University of Glasgow.

During the winter term 1969, Dr. B. D. Loncarevic was a visiting lecturer at the University of California at San Diego and, for the year 1970, Dr. G. T. Needler was the Rossby Fellow at the Woods Hole Oceanographic Institution. Dr. B.R. Pelletier is the editor of Maritime Sediments and Dr. Loncarevic is on the editorial board of Marine Geophysical Researches.

ToC

Appendix B-4
Lists of Publications by Bedford Institute Contribution Number

1 PELLETIER, B.R. 1963. Triassic Stratigraphy of the Rocky Mountain Foothills Between Peace and Muskwa Rivers, Northeastern British Columbia. *Geol. Surv. Can., Paper 63-33: 89* pp.

2 LESLIE, R.J., 1963. Sedimentology of Hudson Bay, District of Keewatin. *Geol. Surv. Can., Paper 63-48: 31* PP.

3 LONCAREVIC, B.D. 1963. Accuracy of Sea Gravity Surveys. *Nature, 198:* 23-24.

4 PLATFORD, R.F. 1964. The Activity Product of Ferric Hydroxide by Turbidimetry. *Cdn. Jour. Chem., 42: 131-183.*

5 CAMPBELL, N.J. 1964. The Origin of Cold High Salinity Water in Foxe Basin. *Jour. Fish. Res. Bd. Can., 21: 45-55.*

6 COLLIN, A.E., and **DUNBAR, M.J.** 1964. Physical Oceanography in Arctic Canada. *Ann. Rev. Ocean. and Mar. Biol., 2: 45-75.*

7 BARRETT, D.L., BERRY,M., BLANCHARD, J.E., KEEN,M.J., and **MCALLISTER, R.E.** 1964. Seismic Refraction Studies on the Nova Scotian Shelf. *Travaux scientifiques de l'Association Internationale de Seismologie, Serie A, Fafcicule 23: 99-102.*

9 DRAKE,C.L., CAMPBELL, N.J., SANDER,G., and NAFE, J.E. 1963. A Mid-Labrador Sea Ridge. Nature, 200: 1085-1086.

10 BARTLETT, G.A. 1964. A Preliminary Study of Foraminifera Distribution on the Atlantic Continental Shelf, Southeastern Nova Scotia. *Geol. Surv. Can., Paper 64-5: 19* pp.

11 FORRESTER, W.D. 1964. Thermocline Structure in the Equatorial Pacific. *Jour. Mar. Res., 22:* 142-151.

12 LONCAREVIC, B.D. 1964. Geophysical Studies in the Indian Ocean. *Endeavour, 23: 43-47.*

13 MACINTYRE, W.G., and **PLATFORD, R.F.** 1964. Dissolved Calcium Carbonate in the Labrador Sea. *Jour. Fish. Res. Bd. Can. 21: 1475-1480.*

14 BARRETT, D.L., BERRY, M., BLANCHARD, J.E., KEEN, M.J., and **MCALLISTER, R.E.** 1964. Seismic Studies on the Eastern Seaboard of Canada - The Atlantic Coast of Nova Scotia. *Cdn. Jour. Earth Sci., 1:* 10-22.

15 NOTA, D.J.G., and **LORING, D.H.** 1964. Recent Depositional Conditions in the St. Lawrence River and Gulf - A Reconnaissance Survey. *Mar. Geol., 2: 198-235.*

16 VILKS. G. 1964. Foraminiferal Study of East Bay, MacKenzie King Island, District of Franklin. Geol. Surv. *Can., Paper 64-53: 26* pp.

17 GILBERT, R.L.G., and **OAKEY, N.S.** 1965. A Graphic-Analogue *to* Digital Convertor. *Electron. Engng., 37:* 98-101.

18 PLATFORD, R.F. 1965. Activity Coefficient of the Magnesium Ion in Sea Water. *Jour. Fish. Res. Bd. Can., 22:* 113-116.

19 PELLETIER, B.R. 1965. Paleocurrents in the Triassic of Northeastern British Columbia. In *Soc. Econ. Paleot. Mineral. Spec. Pub. No. 12,* Ed. G.V. Middleton: 233-245.

20 MARLOWE, J.I. 1965. The Geology of Part of the Continental Slope Near Sable Island, Nova Scotia. *Geol. Surv. Can., Paper 65-38: 30* pp.

21 LORING, D.H. 1965. Resume of Marine Geological Investigations Carried *Out* by the Atlantic Oceanographic Group in the Gulf of St. Lawrence, 1961-1964. *Maritime Sediments, 1: 8-9.*

22 KRANCK, K. 1966. Sediments of Exeter Bay, Baffin island, District of Franklin. *Geol. Surv. Can., Paper 66-8: 60* PP.

23 PELLETIER, B.R. 1966. Hudson Bay and Approaches, B-Bathymetry and Geology, In *Encyclopedia of Oceanography,* Ed. R.W. Fairbridge: 359-363.

24 COLLIN, A.E. 1966. Canadian Arctic Archipelago. A. Introduction and Oceanography. Hudson Bay and Approaches. A. Introduction and Oceanography. In *Encyclopedia of Oceanography,* Ed. R.W. Fairbridge: 157-160, 357-359.

26 PELLETIER, B.R. 1966. Canadian Arctic Archipelago. B.Bathymetry and Geology. In *Encyclopedia of Oceanography,* Ed. R.W. Fairbridge: 169-166.

27 LONCAREVIC, B.D. 1967. Gravity Measurements at Sea, Techniques of. In *International Dictionary of Geophysics: 694-700.*

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30 BULLARD, E.C., MASON, C.S., and **MUDIE, J.D.** 1964. Curious Behaviour of a Proton Magnetometer. *Proc. Camb. Phil. Soc., 60:* 287-293.

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32 MARLOWE, J.I. 1965. Probable Tertiary Sediments from a Submarine Canyon Off Nova Scotia. *Marine Geology, 3:* 263-268.

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35 MASON, C.S. 1966. A Geophysical Data Logging System for Shipboard Use. *Jour. Ocean. Tech., 1: 35-44.*

37 DOE, L.A.E., and **BROOKE, J.** 1965. A Moored Stable Platform for Air-Sea Interaction Studies. In *A.C. Redfield Volume, Suppl. To Vol. 10, Limnol. and Oceanog.:* R79-R86.

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40 POTTIE, B.G. 1967. A Fast-Response Thermistor Thermometer. *Proc. First Cdn. Conf. Micromet., Pt. 1:* 82-89.

41 BECK, V.N. 1967. Tests of a Miniature Electrical Humidity Sensor. *Proc. First Cdn. Conf. Micromet., Pt. 1:* 93-104.

43 LOUCKS, R.H. 1967. Measurements Required for Momentum and Energy Flux Determinations Over the Sea. *Proc. First Cdn. Conf. Micromet., Pt. 1:* 257-260.

44 EWING, G.N., KEEN, M.J., DAINTY, A.M., and BLANCHARD, J.E. 1966. Seismic Studies on the Eastern Seaboard of Canada - The Appalachian System. *Cdn. Jour. Earth Sci., 3:* 89-109.

45 KEEN. C.. and **LONCAREVIC, B.D.** 1966. Crustal Structure on the Eastern Seaboard of Canada - Studies on the Continental Margin. *Cdn. Jour. Earth Sci., 3: 65-76.*

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Marine Ecology Laboratory
Fisheries Research Board
of Canada

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Director's Remarks

" Peace, population, pollution and resources are the central interlocking variables whose unsatisfactory management threatens our options" .
-Preston Cloud in preface to report of Committee on Resources and Man.

It is a truism to say that animals and plants regularly occur in nature only in those areas which are suitable for them. The identification of "ecology" as a special field of biology has been an expression of our need for a better understanding of how animals and plants interact with their environmental settings to determine their distribution and occurrence. Ecology, of which marine ecology is an important part, was thus originally conceived as a study of the "homes" (oikos) or habitations of animals.

It is in this context that the word "ecology" has over the past two or three years risen from the obscurity of a technical term describing the work of a few scientific specialists, to the position of a byword, recognized by most of the literate of modern society. But this emergence has depended on at least two factors. The first has been the evolution of the field itself, from the description of natural systems by curious scientists, to the anticipation of a predictive theory which can deal with the interactions of "populations, pollution and resources". The second is the rapid growth of the realization that the impact of civilization on natural ecosystems is so great that prediction and the better management dependent on it is a necessity for survival, not a luxury to be purchased as a cultural frill.

In the essay, *Analysis of Marine Ecosystems,* which is presented earlier in this review, Dr. Mann gives an appreciation of the technical complexities which we face in our attempts to make predictions of complex natural systems. The methods of science have traditionally depended upon the framing of hypotheses which could be tested in simplified systems, subjected to deliberate manipulation. This experimental method, developed as an important tool by the physical and chemical sciences, has also been available in limited form to students of ecology of terrestrial and small aquatic systems. However, it is in the marine systems that we encounter scales of natural phenomena which are so large or so complex that special adaptations of these techniques are necessary. In these important large environmental systems, simplification and experiment depends upon the construction of mathematical or analogue models from which deductions can be made about the simultaneous operation of a number of important variables. "Experiments" performed with the models predict consequences which become the source of hypotheses which can often be tested only by observations in special situations or areas. These in turn lead to further generalizations or refinements of the models, and so on.

The recent activities of the Marine Ecology Laboratory, reported by the scientists in this review, give many examples of this method of study. They also indicate the ways in which the science of ecology is beginning to close some of the important gaps in our knowledge, and the utility of this new-found power to serve our immediate needs.

From its beginnings as a description of the adaptations of animals and plants to changing environments, ecology has thus become the study of ecosystems. At its base however it is still the study of the physiological and behavioural characteristics of the organisms themselves, their dependence on food for growth and reproduction, and the effects of physical conditions on the transfer rates. The problems to be solved are many, and have been aggravated by growing urgency to predict the effects of the many pollutants being poured into the environment, to end up, by one route or another, in the ultimate "sink", the seas. In the reports which follow we include accounts of a number of studies undertaken to examine the toxicity of specific compounds. Some of these studies are of compounds proposed for new use. Some of the studies have been undertaken to explain observed mortalities from accidental spills of pollutants such as the release of elemental phosphorus into Long Harbour, Newfoundland. Other studies have attempted to understand some of the more immediate effects of Bunker C spilled into the waters of Chedabucto Bay following the wreck of the oil-tanker *Arrow.* In a similar class are studies which are outlining the condition? which promote growth of the phytoplankton organisms responsible for paralytic shellfish poisoning. PSP has been known for some years from the East Coast of Canada, and has recently been detected along the shores of the North Sea in Europe. The laboratory staff have participated in preparation of a definitive review of our knowledge of this phenomenon.

A knowledge of the physiology and behaviour of the organisms is important to ecology in other ways. As our exploitation of fish populations has grown, and the rate of increase in catching has begun to slow down, we have become conscious of differences in mean productivity among various species of fish or differences in the stability of the mean production levels. While the overall catches of fish have fluctuated little about the overall trends, there have been larger variations among the individual species or stocks in various areas. Increased fishing has decreased the average life-spans of our prey so that these fluctuations increasingly affect the Industry. We are beginning to understand that the scales of variation are linked not only to the pattern of environmental change, but to the "design-constraints" of the species themselves. A predictive theory of multi-species fishing will have to explain the relation between these animal designs and the productivity and stability of their populations. It is in this context that we report our studies of the feeding, growth and respiration of a number of our important commercial species.

One of the most important ecosystem problems with which we must learn to deal, is the prediction of the total yields which can be expected, and the influence of the rates of fishing on it. This problem has increasingly occupied the attention of fisheries biologists, and there have been a number of recent attempts to summarize what we know. There is a growing consensus that on a world scale, the total potential yield may not be more than a few, perhaps two to four, times the present. The practical need for accurate prediction becomes large indeed when it is understood that in certain areas, at present rates of growth of the fisheries, the more conservatively estimated upper limit of fisheries yields could be reached within the life-time of a fishing vessel constructed today.

There are many reasons why we cannot rely on our present information as a basis for prediction. Among the most important of them is the simple fact that we do not yet have a method of fish population inventory which can give an estimate of total population size accurate to within perhaps an order of magnitude. It may be argued that our assessment of the abundance of the commercial sizes is better than this. However, the abundance of smaller sizes of fish, generally during their first three or four years of life, is hardly known at all, and it is among these sizes that most of the natural production takes place. Thus, while the commercial catches of large sizes are beginning to level off, we find that the seals and whales, which generally depend on young fish, eat almost as much as the commercial fishermen catch. In the face of such knowledge, it is difficult to believe that our fisheries are yet limited by the overall natural production. A significant proportion of the effort of the laboratory is therefore devoted to the development of both direct and indirect methods of measuring and enhancing natural production. For example, in the following reports are accounts of the development of acoustic systems for improving our methods of inventory of the stocks. This equipment,, which certainly would be useful for inventory, is also likely to find application for increasing the searching efficiency of fishing vessels. In other studies the acoustical systems of whales are being examined as part of a general exploration of the use of sound waves to understand marine phenomena.

Perhaps the greatest problem in marine production studies however, is to be found in the measurement of the primary plant production of the sea, and understanding how this basic energy becomes available to commercial species through the food chains. Workers in the laboratory have found, for example that our present methods are not uniformly reliable for measuring productivity in different areas of the sea, nor for measuring the fraction of the primary production which enters and is distributed through higher stages of the food chains. During late 1969 and 1970 the cruise of the CSS *Hudson* around the Americas provided a unique opportunity for testing some of the hypotheses about production rates by comparing conditions over a variety of temperate and

tropical water masses in both the Atlantic and Pacific Oceans.

Near home, the laboratory has undertaken the synthesis of much of our knowledge of production mechanisms in St. Margaret's Bay. This study has demonstrated for the first time the importance of the sea-weed production in cold temperate waters. It has also provided our first opportunity to study the influence of the sea-weed production on food-chain transfers leading to lobsters, our most valuable single commercial species.

While we are concerned with obtaining an understanding and prediction of fish production to provide a firm base for the management of the fish stocks of the continental shelves, underlying all such studies is our growing concern with the effects of pollutants on the production system, and its occurrence in our food. Of critical importance here is the production of the amazing array of pelagic shrimp-like or benthic mollusc-like filter feeders which feed on the plant materials and detritus, and form the important food links to the surface and bottom-feeding fishes. In various experiments it has been demonstrated that the surface zooplankton, by their grazing, may be responsible for removing about 30% of the daily plant production from the water column. In special experiments following the massive oil-spill from the tanker *Arrow,* it was found that these same zooplankton were the most important natural agent in clearing the water column of the finely dispersed oil particles. The bunker C oil did not appear to affect the animals, but their faeces, containing oil and a rich bacterial flora, settle to the bottom where the extra bacterial load probably enhances the oil degradation. The effects on the bottom communities are still unknown.

The biological production budgets of small coastal embayments are of special importance, partly because of the conflicting consequences of our actions with respect to them. It appears in the first place that these embayments are singularly rich producers. The fact that along the entire east coast of Canada the small bays throng with the larvae, juveniles and young of the species we catch as adults at sea, suggests that they may be vital links in the production chains supporting the continental shelves fisheries. But more than this, man has long recognized the natural beauty and advantages of living on the coastlines. Yet his haphazard conurbations are pouring vast amounts of municipal and industrial effluents into these areas. Until recently we have been oblivious of the consequences. Studies conducted from our laboratory have indicated that this has probably already led to significant "deterioration" of some areas, such as Bedford Basin and Halifax Harbour. It is in the coastal inlets that, as a society, we are seriously beginning to consider the development of aquaculture to enhance the production of sea-foods. The various purposes for which we plan to use the coast-lines are potentially in direct conflict and require careful knowledge-based management.

In order to understand better the role of these coastal inlets in marine production the laboratory has used the expertise built up in our St. Margaret's Bay program, to make an intensive study of production in the Bedford Basin site. The joint biological-physical oceanographic study succeeded in "balancing" the daily basic biological budget of the Basin to within a few percent. However, of the 2/3 of the primary production which was exported, only about 1/3 was directly associated with the mean water flows. The larger fraction, nearly 2/3, was associated with the turbulent fluctuations in water flow. That is, the estimates of export would have been ridiculously wrong if we had based them on mean plankton and mean flow measurements. The results show in a dramatic way, how the small scale variabilities which reflect local differences in distributions within these marine systems, are the principle determinants of the systems. In a vague way this is known on a large scale to everyone - in the sense that high productions of food in North America are only a small part of the solution of the problem of how to get food to a hungry Asia. It is now clear that in predicting food-chain production, it is equally important to understand the patterns of distribution and availability of energy and materials in the system. This same phenomenon underlies the biological "magnification" of the concentrations of pesticides, heavy metals and other pollutants in the food-chains. Many of the reports included in this review discuss aspects of this single most important problem in ecosystem studies.

In this review of our present situation in marine ecology, it would be irresponsible not to point to some of the directions in which our discoveries and our needs are leading us. It must be clear that scientists are beginning to agree that ecosystems are truly natural systems. That is, it is possible to define natural systems which will show an overall stability in relation to the fluctuations in their components. It is on this basis that we can aim towards the making of predictions of yields. In man's activities, however, individuals or even communities, have usually been interested in only one or two of the biological components of these natural systems - such as the codfish or herring, the availability of a basin for easy waste disposal, or the "undisturbed" access to a small bay for boating or recreational fishing. In many cases, especially commercial and sports fishing, it is clear that these component parts have larger fluctuations than the whole, and may often show trends which are different from the overall. While in most cases we shall never control or even predict these "component" events with the same reliability as for the whole system, it is still necessary to be able to understand and explain them in relation to the whole. Therefore we can expect a continuing and increasing need for the study of details of systems, much as we now do. This is abundantly clear in the demands for information on sources, distributions and occurrences of heavy

metals such as mercury, or of oil slicks and particles in the North Atlantic. It will continue to be part of our responsibility to help understand these phenomena.

What needs to be said, however, is that this preoccupation of men with the details of their daily existence must not be permitted to divert their attentions from the total impact. Explanations or ameliorations of local events is not enough. Our fishing rates are now so high that we probably remove considerably more than two-thirds of the natural production of the commercial sizes of fish each year. In the same vein, the amounts of DDT, metals, oils and fertilizers that we are pouring into the coastal waters appear to far exceed the natural annual turnover of organic materials, even if we could average them over the entire ocean basins, instead of concentrating them in estuaries and bays along the coast. At the same time we are creating major hydro-electric power dams as the "safest" of power-generating mechanisms. These are substantially altering the patterns of seasonal outflow into coastal waters, and in very many cases must be responsible for major changes in the mixing and flushing properties which give the estuaries their unique character as high biological producers.

In the abstract, these potential effects are disturbing to contemplate. In the concrete, the Gulf of St. Lawrence is almost certainly among the three most affected systems of the world, along with the Gulf of Mexico off the Mississippi and the eastern Mediterranean off the Nile. The Gulf of St. Lawrence may however be more importantly affected than any of these others. In the first place it is smaller in relation to its principle river discharges. In the second place, it is in a major transitional climatic zone, where small changes may substantially affect winter ice cover, with major consequences for climate of the surrounding land, and the biological productivity of both land and the partly enclosed sea. It is our belief that Canada has both a national and international responsibility to understand how and the extent to which this large natural system is being modified at present, and to assess the possibilities and consequences of further major natural system manipulation. The formation, within the Federal Government of a new Department of the Environment, may be an essential step in making it possible in this instance for Canadians to meet their obligation to understand what they are doing. In any such future study the Marine Ecology Laboratory expects to play an important role.

Administrative Review

The Marine Ecology Laboratory celebrated its fifth birthday in 1970. Our vital statistics on birth were a staff of 15, and an operating budget of approximately $200,000. We have now grown to a permanent establishment of 59 with an operating budget of one million dollars.

The Fisheries Research Board's physical facilities at the Bedford Institute to support the Marine Ecology Laboratory have increased from nil at birth to 10,000 sq. ft. of fresh and salt water laboratory facilities, a complex of 14 large laboratory and office trailers, two inshore research vessels, one permanent field station in Prince Edward Island and another smaller field station at St. Margaret's Bay, N.S. about 25 miles from the Institute. Approximately 50% of our laboratory operations are housed in accommodation shared with the Atlantic Oceanographic Laboratory at the Institute and the latter continue to provide considerable large ship, maintenance and other support services to the Marine Ecology Laboratory.

L.M. Dickie

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D.E. Willis, B.Sc. (Carleton) (from November 1970)
W.P. Vass (from Sept. 1970)
Lorraine D. Schnare (from April 1970)

Fisheries Oceanography

P.C. Beamish, B.A.Sc. (Toronto), M.Sc. (MIT), Ph.D. (UBC) (from March 1969)
S. Paulowich
R.G. Dowd
A.D. MacDonald, B.A. (Acadia)
W.B. Fraser

Population Studies

B.S. Muir, Ph.D. (Toronto) - Scientist-in-Charge
Vivien M, Srivastava, (Brawn), B.Sc. (Reading), M.Sc. (Durham), Ph.D. (UBC)
D.D. Sameoto, M.A. (Sask.), Ph.D. (Queens)
J.C. Smith, M.Sc. (UBC)
T.C. Lambert, B.Sc. (Victoria), M.Sc. (Dalhousie)
K. MacKay, M.Sc. (Dalhousie) (Graduate Student - Dalhousie U.)
J.C. Frost

St. Margaret's Bay - Primary Production

The program of study of *in situ* primary production in St. Margaret's Bay in relation to environmental factors was continued in 1969-70. All the data are collected in FRB Technical Report #203. Particular attention was given to the assessment of energy efficiency in primary production, and a technique was developed which allows the comparison of results at different stations and different seasons, even though the data may be subject to chance variations in environmental conditions. This approach can be applied to the prediction of primary production and may be useful in providing one criterion in the suite of criteria which will be required for the definition of marine pollution.

The value of this technique has been enhanced by the availability of a self-contained integrating photometer for use underwater. This instrument, which was designed and built at the Bedford Institute, measures directly in absolute units the total light energy received by the plankton at a given depth during an *in situ* productivity experiment. The response is independent of the wavelength of the incident light. Three of these instruments are now available and they are in active use in the field.

Finally, considerations of efficiency in primary production have made possible an evaluation, based on data collected in the field, of current notions in theoretical ecology concerning energy flow, species diversity and biomass in ecosystems.
T. Platt

Studies of Plankton Distributions

Studies have been continued on the description of the heterogeneity of phytoplankton distributions in relation to physical factors in nearshore environments. This work has three main purposes: first, to estimate the reliability of point samples at preselected stations; second, to provide clues about why phytoplankton tend to be distributed in patches; and third, to assess the significance to the zooplankton of the clumped distribution of their prey - that is, to gain fundamental insight into the understanding of an important element in marine production processes.

Techniques of spectral analysis are used to estimate the average size and spacing of phytoplankton patches, as revealed by measurements of chlorophyll concentration along transects. Early results, based on sampling with bottles, indicated a coupling between the fluctuations in chlorophyll and those in temperature.

A big improvement in both the precision and reliability of the results and in the efficient utilization of sampling effort, was made with the development of a continuous flow chlorophyll system, designed and built at the Bedford Institute. A submersible pump feeds water into a continuous flow fluorometer and thermistor. The outputs from these two sensors are integrated over time (the integration time may be varied at will) and the integral is displayed on a line printer or on punched paper tape. The pump will operate on station or under way. We thus have the opportunity to average chlorophyll and temperature fluctuations on any scale-size in time and space.

On the first cruise with this equipment, in the southwest Gulf of St. Lawrence, very strong correlation was found between the chlorophyll and temperature distributions. The simplest explanation of this result is that the phytoplankton patches are associated with discrete water masses characterized by a particular temperature. Detailed numerical analysis of the data is continuing.

The continuous flow chlorophyll measuring system can also be used to make synoptic maps of phytoplankton distribution over areas of the order of 20 Km^2. This means that it provides a useful tool in pollution investigations in coastal waters, where the areas under study are often quite modest. For example, one can make a detailed map of the distribution of chlorophyll at a given depth in Bedford Basin in 2½ hours. Such maps are now being made as a routine, and it is hoped that they may help to demonstrate the influence of certain effluents on the Basin, and also help to show the effect and extent of tidal flushing through the Narrows on the ecosystem of the Basin.
T. Platt.

Primary Productivity and Nutrients in the Bedford Basin

Primary production is being measured in the Bedford Basin as part of a multidisciplinary study of the trophic dynamics of a eutrophicated marine basin, and as a comparison with St. Margaret's Bay. Production, nitrate, phosphate, silicate, ammonia, chlorophyll, temperature, salinity, water transparency and incident radiation are measured weekly at a station in the centre of the Basin. In addition, chlorophyll, temperature, salinity and nutrients are measured on the same day at three other stations in the Basin. The first data report on these measurements will appear shortly.

Particular emphasis is placed on the flushing of the Basin with respect to biological parameters. This aspect is studied in cooperation with the Coastal Oceanography Group. The preliminary results indicate that much of the primary production inside the Basin is exported through the Narrows.

T. Platt

ToC

Influence of Humic Compounds on Phytoplankton Growth

A significant fraction of the allochthonous organic matter introduced in coastal waters, as a result of drainage from land, is represented by humus or humus-like substances which may be found in dissolved, colloidal or particulate form. Our earlier studies showed that most of the dissolved humus is represented by relatively low molecular weight fulvo-humic fractions which are biologically active for phytoplankton growth. More specifically, small concentrations of low molecular weight humic and fulvic acids fractions generated a positive growth response in marine dinoflagellates which was reflected in increased yield, growth rate and C^{14} assimilation. Further studies carried out on a number of marine diatoms have shown more or less similar growth responses in the presence of humic acid in culture media. *Thalassiosira nordenskioldii* gave the maximum response with humic acid fractions having molecular weights less than 700, whereas, in *Skeletonema costatum,* maximum growth response was observed with humic acid fractions having molecular weights between 700 to 1500. In both cases, humic enrichment resulted in increased chlorophyll *a* synthesis and increased algal cell respiration in addition to the usual growth enhancement.

Another important source of humic material in inshore coastal waters is the phytobenthos. Extracellular exudates and dead thalli of littoral marine algae undergo microbial degradation and chemical condensation resulting in the formation of relatively stable humic compounds. These compounds have been isolated and tested for their growth promoting effect on marine phytoplankton. Chemical characterization of humic and fulvic acids isolated from *Laminaria* and *Fucus* has been accomplished in collaboration with Dr. M.A. Rashid and the results submitted for publication. The identification and isolation of biologically active components of humic matter that stimulate growth of marine phytoplankton is being continued.

A. Prakash

Dark Assimilation of $C^{14}O_2$

Primary productivity studies carried out in 1968 in the North Atlantic, the Sargasso and Caribbean seas indicated that the uptake of $C^{14}O_2$ in the dark tended to be higher in tropical and subtropical waters. Our participation in the HUDSON 70 expedition enabled us to extend these

findings to the South Atlantic (as far south as the Antarctic convergence) as well as to the South, Central and North Pacific along the 150 degree meridian. Much of the analysis is still in progress and it is difficult at this stage to ascertain how much of the C^{14} fixation in the dark was due to biological uptake by the phytoplankton population or bacteria and how much if any could be due to inorganic precipitation of added bicarbonate. Nevertheless, the results obtained during the HUDSON 70 expedition have confirmed our earlier observations. A trend of increased dark-fixation was noticed in oligotrophic nutrient-deficient water masses of the tropics and sub-tropics, whereas, in regions of active upwelling and convergence, dark assimilation was extremely low. Diurnal periodicity in dark fixation was very evident in the Atlantic and the Pacific and this behaviour lends support to the hypothesis that some of the non photosynthetic assimilation of $C^{14}O_2$ is a physiological response on the part of marine micro-organisms and cannot be interpreted entirely as an artifact as some workers believe.

A. Prakash
W.H. Sutcliffe, Jr.

Pollution-Induced Eutrophication

Compared with other coastal embayments, Bedford Basin represents a highly eutrophic ecosystem, in all probability associated with a substantial input of raw sewage from the Halifax-Dartmouth metropolitan area. This basin is not only rich in major nutrients, but also supports a large planktonic population which is qualitatively different from that in less eutrophic outside waters.

A joint program of study to assess the effect of sewage pollution on natural production in Bedford Basin was developed in 1968. Our part in this program is to identify long and short term indices of eutrophication resulting from organic pollution and to understand the interaction between organic enrichment and phytoplankton production and succession.

In order to determine the degree of fecal contamination, four coliform surveys were carried out in spring, summer, fall, and winter in Bedford Basin. Surface and sub-surface samples were collected from 20 stations during each survey and coliform determinations were made using the membrane filtration (MF) method. None of the stations examined were free from fecal pollution at any time and average coliform counts per station per survey ranged between <100 and 600/100 ml sample. In the most polluted part of the Bedford Basin, counts as high as 20,000/100 ml of sample were obtained.

As in previous years, a program of weekly monitoring was continued to investigate the annual phytoplankton cycle in Bedford Basin with

particular reference to succession of diatom and dinoflagellate species. In 1970, dinoflagellates *(Gymnodinium, Peridinium, Ceratium* and *Dinophysis)* dominated the phytoplankton during winter, summer and early fall, whereas diatoms *(Chaetoceros, Skeletonema* and *Thallasiosira)* dominated the spring and autumn blooms. Except for minor variations, the overall pattern of succession was generally similar to that observed in previous years.

K.R. Freeman
A. Prakash

ToC

Studies on Particulate Material in Suspension in the Sea

The physical, chemical, and biological properties of suspended particulate matter have been investigated, both in coastal and oceanic environments The major emphasis has been directed towards the relatively small particles of organic composition because these include most of the phytoplankton which form the first part of the marine food web.

During the course of these studies we have found that some parts of the standard techniques for the analysis of particulate material are not reliable. Many methods depend on a filter, usually of a specific type, to retain particulate material. We have found that not only do filters of different types, but with the same nominal pore size, have quite different retention properties, but also, with any one kind of filter, retention efficiency varies with sample volume. This affects both physical and chemical determinations. Measurements of primary organic production are usually made on samples kept in glass containers. We have found that production rate varies with the size of the container used and that production is usually, though not invariably, less in larger containers.

In the open ocean, both the standing stock and total production of particulate material are moderately high in temperate regions and decrease towards the tropics; but production per unit of biomass increases as standing stock decreases. Primary production has been measured in two ways; by assimilation of radioactive carbon (C^{14}) and by increase in the total volume of particulate material. The latter method often indicates a high production rate. It is possible that some heterotrophic growth, or perhaps flux of non-living material, is being measured.

Particle size distributions vary geographically and with depth. A wide range of particle size occurs everywhere. In temperate oceanic regions the distributions are variable and may show phytoplankton concentrations as distinct peaks. In the low-nutrient oceanic areas of the subtropics the distributions are more uniform without any particular size predominating. Similar uniform distributions occur at depth both

in sub-tropical and temperate regions, but the total amounts are less.

Small-scale variation of the concentration of particulate material has been studied both in relation to proximity to the sea surface and to patterns of Langmuir circulation. The concentration decreases rapidly just below the surface falling to about one half at a depth of 1 m. Significantly higher concentrations of particulate material occur in areas of convergence of Langmuir circulation cells. This could be an important concentrating mechanism for particulate material, particularly in areas of low standing stock. The concentration of particulate material near the sea surface also increases as wind speed increases. A wind speed increase of about 10 knots gives an increase of about a factor of 2 in the concentration of particulate matter in areas of low standing stock.

Two nearshore areas have been studied in Nova Scotia. Work in St. Margaret's Bay formed part of a continuing study in this area, and observations were made in Chedabucto Bay following the stranding of the oil tanker *Arrow.*

In Chedabucto Bay, particle standing stocks were measured on two surveys at about 1½ months and 3 months after the stranding. On the first survey a phytoplankton bloom was easily recognised from the particle size distributions, and was confirmed by microscopic observations. A two layer structure was observed with a particulate material concentration minimum at about 50 m with mainly phytoplankton above and mainly smaller particles below this minimum. On the second survey particle distributions were similar, but the phytoplankton bloom had declined. Some vertical mixing had occurred, and the two layer structure was no longer obvious. Small particles of oil were found in most samples but the concentrations at the second survey were somewhat greater than at the first. At all times only a small proportion of the total particulate material in the sea was oil. The carbon to nitrogen ratio of the particulate matter was greater on the second survey which, along with other chemical evidence suggests that there was more oil in the water at the time of the second survey. The Chedabucto Bay study was carried out in association with K. Kranck (A.O.L.).

In St. Margaret's Bay, samples were analysed over a period of a year. The mean level of total particulate carbon was about 270 µg/l. Four prominent peaks of total particulate carbon occurred: in late winter, mid-spring corresponding with the phytoplankton bloom, early summer, and in the fall (again associated with a bloom). The mean level of living carbon (estimated as ATP) was about 75 µg/l. During most of the year the ratio of total to living carbon varied between 1.5 and 7 with low ratios during blooms but with higher values in winter and mid-summer. Total C/N ratios varied between about 6.5 and 12, with

the highest values occurring in the summer. During winter and spring, C/N ratios of living material were about 6.5. Similar values were probable for the summer and fall.

For most of the year the living portion of the particulate matter was dominated by sizes less than 8 µ (mean of 60%), except for the spring bloom and to a lesser extent during the early summer. Living material smaller than 2 µ (bacterial size) varied at low levels of concentration less than 25 µg/l, although at times during the winter this represented more than 50% of the total living carbon. This is not to say that small living particles are of little relative importance because the methods used could not distinguish between large organisms and quantities of bacteria associated with large non-living particles.

Large quantities (200-400 µg/l) of non-living particulate matter larger than 8 µ were prominent from late winter to early summer. The ratio of C/N in the early spring, although variable, averaged a little more than 12, suggesting erosion of attached algae (C/N ratio about 16). It is to be noted in this connection that a good correlation was found (before the spring bloom) between windspeed and the concentration of particulate carbon at 10 m depth; which lends support to the probability of algal erosion. Non-living particulate material larger than 8 µ occurring in the summer had considerably less nitrogen (C/N ratio > 20). The source of this material is not known.

W.H. Sutcliffe, Jr.
R.W. Sheldon
A. Prakash.

Productivity of the Seaweed Zone

Most commercially important fish species spend part of their life in the highly productive inshore waters, and their growth during this period is a major contribution to the productivity of the fishery. It is known that plankton productivity in coastal waters is higher than in the open ocean on account of the nutrients and growth-enhancing substances in terrestrial runoff, and on account of the mixing processes which are often more vigorous under the influence of tidal movements and river runoff. Seaweeds are in a particularly favoured position, as wave action and tidal movement are constantly renewing the nutrients around them, making possible extremely high levels of primary production.

A 1968 survey showed that in St. Margaret's Bay the seaweeds averaged over 1 metric ton per m of shore line of which more than 80% was kelp *(Laminaria* and *Agarum).* In 1968-69 the growth of over 100 individually numbered plants was studied by SCUBA diving at 3 sites having differing degrees of wave action. Holes were punched at intervals in the blades and it was shown that these blades are "moving belts" of plant tissue, with rapid growth at the base and more or less constant

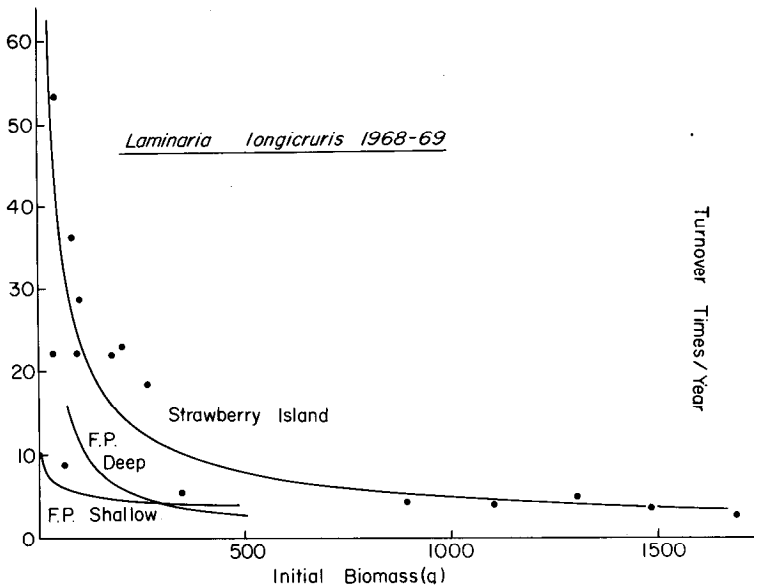
erosion at the tip, so that the total size of blade varies within comparatively narrow limits but the tissue in the blade is renewed several times per year. Rapid growth began very early in 1969 and slowed down in summer and fall. Growth increments, as indicated by the movement of holes in the blade, were summed over the year to give estimates of the total length the blades would have achieved if they had not eroded at the tips. Length was converted to biomass on the basis of observed length/weight relationships, and it was found that the ratio P/B, (biomass increase/initial biomass) varied inversely with the initial biomass according to a power function (Figure). The average value for the P/B ratios were calculated as

$$\frac{1}{B_{max} - B_{min}} \int_{B_{min}}^{B_{max}} (P/B)\, dB$$

and the values obtained were as follows:

Species	Strawberry Island	Fox Point Shallow	Fox Point Deep
Laminaria longicruris	8.3	5.5	4.5
Laminaria digitata		20.3	6.1
Agarum cribrosum			3.0

Taking a mean between shallow and deep stations we may estimate that *L. longicruris* produces 5 times, *L. digitata* 13 times and *A: cribrosum 3* times the summer biomass in the course of a year. When these figures are applied to the standing crop data, it appears that the seaweeds produce about 6.7 metric tons per m of shore line. When converted to carbon equivalent and averaged over the whole bay it amounts to about 310 g C/m^2/year. This is about 50% higher than the 3-year average of phytoplankton production. In addition, it is known that seaweeds produce large amounts of dissolved organic material which may enhance the estimate of their contribution to primary production in the bay by about 40%.



Annual biomass turnover of individual blades of *Laminaria longicruris* plotted against initial biomass of those blades at three stations. The points are for the Strawberry Island line.

The figures are so much higher than any previous estimates of seaweed production that observations were repeated in 1969-70. The results of this study have not yet been fully evaluated, but it is clear that figures of similar magnitude have been obtained. Differences between years will be related to differing inputs of solar energy and energy of water movement.

K.H. Mann

ToC

Zooplankton Studies

In a continuing study of RNA content and related substances in invertebrates and zooplankton, a coherent pattern was found between growth rate and RNA concentration in 24 invertebrates; values were both taken from the literature and obtained in this laboratory. Collections of zooplankton from St. Margaret's Bay and other places showed a positive relation between protein and RNA content, while both were inversely correlated with mean dry weight. Thus the smallest and presumably fastest growing members of the zooplankton community contained the most protein and RNA.

W.H. Sutcliffe, Jr.

Pteropod Biology

The pteropods belonging to the genus *Spiratella (limacina)* frequently contribute more than 20% to the biomass of zooplankton in St. Margaret's Bay. This organism is known to be eaten by certain pelagic fishes but an important predator is the shell-less pteropod *Clione limacina,* for which they are the only known food source. This specialized food chain has been examined in considerable detail over the past two years. In the laboratory, growth of *Clione* feeding *ad libitum* on *Spiratella* can exceed 10% per day for short periods but over a longer period both in nature and in the lab the growth rate is regulated not only by the numbers of prey but also by their size. Hence, in St. Margaret's Bay both *Spiratella* and *Clione* show increasing maximum size throughout the winter and early spring months. Even larger *Clione* (>50 mm length) are brought to the area with the Labrador water and it is presumed that this large size is a result of feeding predominantly on the large *Spiratella helicina* rather than S. *retroversa* which is more common in local waters. In Europe, on the other hand, neoteny is common where the *Spiratella* never becomes so large as in local waters. A few neotenous *Clione* have been found in St. Margaret's Bay in the fall while the *Spiratella* are still small, but in our waters a second, always neotenous species *Paedoclione doliformis* develops in large numbers during the fall when average water temperatures are highest and the food source *Spiratella* smallest.

R.J. Conover

The Distribution and Physiology of Zooplankton in the South Atlantic and South Pacific

Plankton collections were made at HUDSON 70 Stations No. 12 through 31 at the Atlantic, at Stations 277 through 287 in the Pacific and at several intermediate locations when the schedule permitted. In all 99 collections were made. At most stations sampling was carried out at more than one depth, an effort being made to collect from above, in and below the Antarctic intermediate water. All tows were examined before preservation and in certain instances living animals were removed for experimental purposes. A total of 21 experiments were run. The remainder of the tows was preserved in neutral formalin for more detailed analysis. As many of the organisms captured will require the attention of specialists, a final report on the species composition and distribution may take some years to complete.

A primary purpose of the experiments was to determine the effects of prolonged starvation on the metabolism and chemical composition of surface planktonic animals introduced into deep water at the Antarctic convergence. In the Atlantic most experiments were performed on the common Antarctic species *Rhincalanus gigas* but the species was so rare in the Pacific that a number of other species were also studied for comparison. *Rhincalanus gigas,* although an herbivore, is known to make extensive seasonal, vertical migrations and has been reported in deep water quite far north, even though it would seem endemic to the Antarctic region.

Respiration and nitrogen excretion of *R. gigas* was studied at certain stations because the ratio of oxygen respired to nitrogen excreted (O:N ratio) gives an indication of metabolic substrate being used for energy and, hence, information about food sources and nutritional state.

We found late stages of *R. gigas* at least to 30°S and in this northern part of the range O:N ratios and low fat content suggested severe starvation. Nearer the convergence young stages appeared, and the lipid content and O:N ratio indicated that the copepods were subsisting on recently stored fat. South of the convergence *R. gigas* once again appeared near starvation.

In the Pacific *R. gigas* was generally very scarce and only one experiment was carried out. However, a number of surface zone copepods, particularly those belonging to the neuston were studied. In contrast, with *R. gigas* O:N ratios were generally within the range expected for a mixed diet and showed little latitudinal variation. It is postulated that such copepods have little or no storage capacity, and hence, cannot endure prolonged starvation.

R.J. Conover
M. Paranjape

ToC

Sea Urchin Grazing Rates and Productivity in St. Margaret's Bay

The energetics of a population of the sea urchin, *Strongylocentrotus droebachiensis,* was studied from December 1969 to December 1970 as part of a project to quantify the energy flow through the biological community in St. Margaret's Bay. It was shown in another study (see "Productivity of the Seaweed Zone" above), that seaweeds contribute more than half the primary production in St. Margaret's Bay. Sea urchins have the greatest biomass of any herbivore in the seaweed zone. The transfer of energy between these two components of the community was determined by measuring sea urchin ingestion rates, when feeding on seaweed. The growth rates and age structure of the population were measured to assess the yield of sea urchin production to predators, principally rock crabs and lobsters.

The ingestion rate of a sea urchin in the field was estimated by summing the energy needs of growth, reproduction and metabolism, and dividing by the fraction of ingested food assimilated (i.e. not voided as faeces). Metabolic rates and the fraction of ingested food assimilated were determined in the laboratory at two month intervals for a large range of animal sizes. Gonad growth for a large range of animal sizes was estimated from the change of gonad size of animals collected in St. Margaret's Bay at one to three month intervals. Seasonal changes in body growth rates and population density of each of four year classes was estimated by analyzing size (animal diameter) vs. frequency distributions of bimonthly collections from St. Margaret's Bay.

Population ingestion and production rates were estimated by multiplying the rates for an individual of a size corresponding to a particular year class by the number of animals in that year class and then summing over the four year classes. The numbers in each year class were taken from a survey of population density at 24 sampling sites representing a 370 meter wide strip around the edge of St. Margaret's Bay.

The grazing rates of sea urchins on seaweed averaged 532 kcal/m^2/yr. This is only 7.6% of the rate of production of seaweeds estimated to be about 7000 kcal/m^2/yr by Dr. K.H. Mann of this laboratory.

The production of the sea urchin population (and the yield to predators) in the form of body growth was 36 kcal/m^2/yr; gonad production was 11 kcal/m^2/yr; and total population production was 47 kcal/m^2/yr. These values are among the highest measured for any natural animal population.

R.J. Miller

Studies on the Benthos

Production of benthos. An estimate has been made of the production of a single year class of the polychaete *Pectinaria hyperborea* in St. Margaret's Bay, N.S. Both production and elimination (yield to predators) were calculated by following changes in population density and individual size distribution over a period of 20 months.

Production was highest during early life stages while elimination was relatively low so that biomass reached a maximum at 170 days. Between 30 and 370 days the rate of elimination was nearly constant at about 0.9 g/m^2 wet weight for a 50 day period in spite of changing biomass. After 170 days the rate of production became less than that of elimination so that the relatively constant rate of elimination was maintained at the expense of rapidly decreasing biomass. Both production and elimination decreased after 370 days. It was estimated that 80% of mortality was due to predation by fish.

The ratio P/B (P= Production, B mean biomass) for the first year of life was found to be 3.1 while for the second year of life it was 0.8. E/B (E= elimination) was more constant for both first and second year of life (2.3 and 2.5 respectively).

Using the ratio between annual production and biomass and estimates of biomass present in May 1967, annual production was estimated for 24 stations throughout the Bay and found to vary from 4-8 $kcal/m^2$ in the deep muddy part of the bay to 0.5 $kcal/m^2$ in the shallower areas near shore.

Don Peer

Distribution of benthos. To design a sampling pattern which will be most efficient in obtaining ecological information it is necessary to know something about the spatial distribution of the organisms under study. Random grab samples from an anchored vessel have shown that marine benthic organisms have a contagious (patchy) distribution. It is also known that the degree of contagiousness of an organism has an effect on its availability as food to a predator.

An attempt is therefore being made to measure the small scale variations in the abundance of benthic organisms. Using SCUBA techniques 45 adjacent samples of both fauna and sediment were taken along a transect. Small scale spatial variations in faunal abundance will be measured and attempts made to relate these to variations in environmental parameters or to processes within the life history of the organism itself.

Don Peer

Pictou Harbour benthic samples. During November 1969 a series of quantitative benthic samples were taken from the same locations as a similar series taken during October 1967. The 1967 series was done just prior to the start of effluent discharge from the holding pond of the 500 ton/day bleached kraft mill at Abercrombie Point, Pictou County.

Ten samples were taken with a 0.1 m^2 Van Veen grab at each of the following locations: (1) about 0.2 miles off the outlet of Boat Harbour in about 3 m of water (Locations of the 69 and 67 stations were within 0.1 miles of each other). (2) 0.15 miles off MacKenzie Head in 4-5 m of water, (3) 0.5 miles off the outlet of Otter Pond in about 10 m of water.

The most significant changes appear to have taken place in the first two stations which are located closest to the outfall.

At both of these stations Amphipods, the maldanid worm *Axiothella catenata* and the sand dollar *Echinarachnius perma* were not found in the 1969 samples although abundant in the 1967 samples. However the biomass of Amphipods at the Otter Pond Station increased from .036 gm/m^2 to 0.197 gm/m^2.

The Polychaetes *Lumbrinerus sp., Phyllodoce sp.* and the Pelecypod *Tellina agilis* decreased in biomass from 0.133, 0.012 and 1.7 in 1967 in the Boat Harbour location, to .001, <.001 and 0.18 gms/m^2 respectively. Similar reductions were found for these three species at the McKenzie Head locations while at the Otter Pond location their biomass remained unchanged.

Polynoids and Nematodes were found in all of the 1969 samples from both the McKenzie Head and Boat Harbour samples but had not been present in the 1967 samples.

In conclusion it would appear that there have been significant changes in the benthic community since the start of effluent discharge, possibly in response to increased silt and organic matter in the sediment.

Don Peer.

Molluscan Shellfish Studies - Eastern Canada 1969

Ostrea edulis. The European oyster was introduced to Eastern Canada in 1969. Breeding stock from the Milford Laboratory of the U.S. Bureau of Commercial Fisheries were held at Ellerslie in quarantine and released larvae and subsequent spat were reared in the Experimental Hatchery. Larval and spat survival and growth were very good. Spat reared in late July and transferred to field conditions reached 1 - 1½ inches by the end of the growing season. Over-winter mortalities at Ellerslie have been negligible.

Spat have now been transferred to the outer coast of Nova Scotia for observation of growth and mortality and gonad maturation, preparatory to attempts to establish self-sustaining populations or centres of culture for this species.

The utilization of this species promises to extend considerably the area of Eastern Canada suitable for oyster culture, add a desirable diversity to our commercial shellfish species and provide the possibility of a valuable export commodity.

R.E. Drinnan

Stylochus etlipticus. Observations in 1968 and 1969 showed that this species of flatworm, claimed to be an important oyster predator, is widespread and abundant in the oyster areas of the Maritimes. No predation on oysters has been observed in over forty years of intensive oyster culture both in suspension and on the bottom. Laboratory observation in 1969 showed that the flatworm eats oysters only in the absence of other shellfish species. Soft shell clams *Mya arenaria,* were preferred food and were readily eaten, to the exclusion of other species, even when living in a natural state in a sand substrate.

R.E. Drinnan

Experimental hatchery programme. A major effort is now being made to write up the research work carried out at Ellerslie over the past twelve years. A number of stocks are being maintained at Ellerslie for future work on selective breeding. These include (i) relict, resistant, survivors of original wild stocks otherwise exterminated by epidemic disease and subsequent transfers of Prince Edward Island oysters and (ii) stocks which have been selected for rapid growth in the hatchery at Ellerslie.

R.E. Drinnan

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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 Coastal 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.

The field program in St. Margaret's Bay which started in 1967 was diminished, and an increased effort was directed to analyzing the collected data as reported below.

Investigations of the gyres present in the Magdalen Shallows area of the Gulf of St. Lawrence were continued. However, a shipboard computer for processing the STD data rapidly enough to allow close studies of the gyres in real time became available only in November 1970 and no gyres were detected during that cruise. The phenomenon continues to hold high interest and will be investigated with more powerful tools available during the Gulf of St. Lawrence field program.

The Halifax Section continues to be occupied providing information on oceanic conditions on the Scotian Shelf and on Oceanic water outside the inlets along the Eastern Coast of Nova Scotia.

In response to needs of quantitative information on flushing of estuaries and coastal embayments for predicting the capacity of a particular area to accept pollutants, surveys were carried out in Long Harbour, Nfld., Holyrood (Conception Bay area, Nfld.), and Bedford Basin. A survey of certain aspects in Chedabucto Bay were carried out in connection with the grounding of the tanker *Arrow.* The monitoring of the Canso Strait area continues because of the increased industrialization of the area.

Some of these projects are discussed in more detail elsewhere in this report.

E.S.M. Hassan

St. Margaret's Bay and Halifax Harbour

A physical oceanographic study of St. Margaret's Bay was undertaken as part of a more general ecological investigation of basic processes underlying marine production. Commencing in 1967, temperature and salinity measurements were taken at fortnightly intervals over a 14-month period at a network of 39 stations. Subsequently, the network was reduced to a few stations, so as to monitor conditions inside, at the mouth, and immediately seaward of the mouth of the Bay. This survey continued until the end of 1969. Also during that time currents were measured by moored self-recording meters. The circula-

tion patterns were investigated using parachute drogues and Rhodamine dye as well as the moored current meters.

Analyses of these data reveal that both lateral advection as well as vertical-longitudinal circulation contribute to flushing the Bay.

The circulation pattern in the Bay consists of three parts:

1) a regularly periodic part which is dominated by the M_2 component of the current,
2) an anticlockwise current which is deduced from the difference between residual currents (total current minus the tidal components) on the two sides of the entrance,
3) a stratified current (mainly thermohaline circulation).

However, abrupt changes in T-S characteristics occur from time to time suggesting that major flushing action is superimposed on the mean circulation pattern.

From the tide gauge records covering the period 1966-68 in St. Margaret's Bay and Halifax Harbour, the harmonic analyses were computed. Co-spectrum, quad spectrum and coherence were computed from the spectra of the daily mean sea level, the daily residual heights, and of the mean daily atmospheric pressure at Shearwater and Western Head. Significant coherence was found between the daily mean sea levels at Halifax and atmospheric pressure at Shearwater and Western Head.

S.H. Sharaf El Din
E.S.M. Hassan
R.W. Trites

ToC

Lagrangian Measurements

The Lagrangian measurements of surface and bottom circulation in St. Margaret's Bay were investigated using drift experiments during May 1967 to the end of 1969. Moored current meters, drift bottles, sea bed drifters and parachute drogues were used to clarify the circulation pattern. Besides the release of drift bottles and sea bed drifters in St. Margaret's Bay, another experiment was carried out from the Sambro Light Vessel (lat. 44° 21.8'N. long. 63° 24.2'W) during the period 1960-66 to study the long term surface circulation or surface drift as opposed to tidal circulation.

The circulation pattern in the Bay given by the different drifters is nearly identical. Also there is a relationship between the N-S component of the wind and the direction of the surface drift: retention with S wind and escapement with N wind.

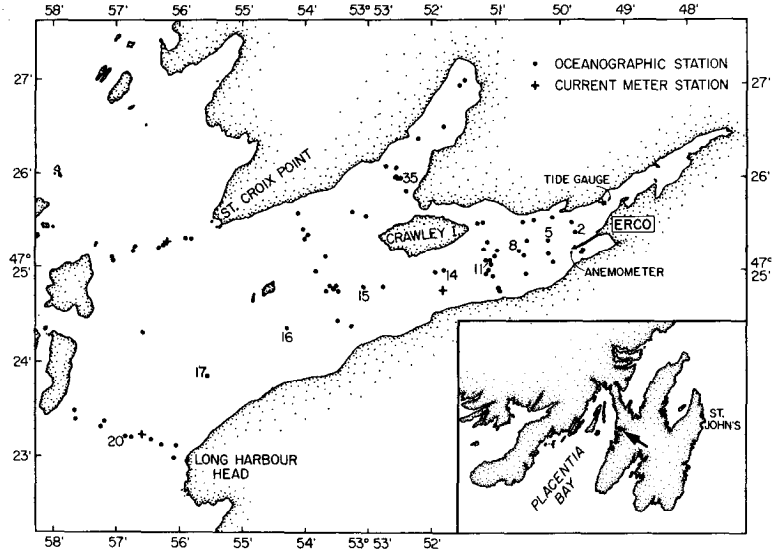
L.M. Lauzier
S.H. Sharaf El Din
R.W. Trites.

Physical Oceanographic Studies, Long Harbour, Newfoundland

Extensive fish kills in Long Harbour and Placentia Bay, Nfld., caused by elemental phosphorus discharged from the Electrical Reduction Company of Canada's plant (ERCO), generated a substantial multi-disciplinary research effort. Only the physical oceanographic studies are reported here; biological studies are discussed in other sections.

A one month survey was undertaken in June-July, 1969 with the purpose of learning something about the circulation and flushing of water in Long Harbour (Figure). The program consisted of measuring temperature, salinity, and dissolved oxygen at a network of stations throughout the embayment, currents at three sites over a 29-day period, continuous release of rhodamine BA dye over a 5-day period through the effluent pipe from the ERCO plant and the tracking of parachute drogues released at selected points in the Harbour. The tide was measured at one location in the inner harbour and an anemometer mounted on the ERCO wharf monitored wind speed and direction and air temperature.

Although the survey was of brief duration, and possibly not typical of other seasons of the year, it was apparent that the surface circulation and flushing characteristics were determined in large part by meteorological conditions, particularly the local wind pattern. Under light offshore winds, dye remained in the upper few metres of the water column, and rather quickly spread throughout much of Long Harbour.



Map showing location of Long Harbour, Newfoundland including locations of oceanographic and meteorological observations June-July, 1969.

Under moderately strong onshore winds the surface layer thickened markedly and dye was retained mostly in the inner harbour area. The survey period was too brief to determine whether or not the observations could be considered typical. Time series measurements at a few selected sites at other seasons of the year are required to define the mean and the extremes.

R.W. Trites

ToC

Operation Oil

General Review. For the residents of the Chedabucto Bay area, the sea represents either directly or indirectly a primary source of livelihood. For many, the fishing industry - either as a fisherman or shore worker - constitutes the main source of income. Any major threat to the fishing industry is therefore of paramount concern. The grounding of the tanker Arrow on Cerberus Rock on February 4, 1970 and the subsequent release of roughly two million gallons of Bunker C oil, naturally brought apprehension to the residents of the area. In the days and weeks that followed a major research effort was mounted that dealt with the environmental aspects of the problem as well as with chemistry and cleanup technology (see Coastal Oceanography, AOL, Part B). Only a brief summary of the ecological studies are reported here.

By mid-February, several field teams comprised of staff from St. Andrews, Dartmouth and the Resource Development Branch of DOFF were established to observe and sample the fauna and flora of the Bay. Surveys were made of the intertidal, subtidal and sublittoral zones, as well as examination of the plankton. One of the early questions concerned the lobster fishery which, although closed at the time of the disaster, was due to be opened in April. Considerable effort was given to determining the effect of Bunker C on the tainting of lobster flesh. A variety of experiments was carried out at St. Andrews to establish under what condition tainting would become a problem. Toxicity testing was carried out at St. Andrews on a number of oil dispersing agents as well as on Bunker C itself.

Intertidal algae seemed little affected by the oil although evidence suggests that some was initially torn away by flotation from covering oil. Continued observations will show the fate of heavily oiled upper shore algae. Intertidal animals exclusive of soft shell clams also appear to be relatively little affected despite heavy oiling. Clams appeared to suffer some mortality as a result of oil on clam beds. Evidence suggests that death was caused by mechanical smothering.

From visual examination, there is no conclusive evidence of significant damage to the sublittoral fauna or flora of Chedabucto Bay. A few fish were dead on the bottom in areas where dead fish had been picked off the beach. However, there is as yet no evidence for attributing this to oil. Sculpins taken in the area where oil globules were present on the bottom revealed that oil was present in the faeces but not on the gills. Periwinkles contained oil in the faeces. Chemical analysis of a variety of animals (clams, scallops, periwinkles, sea urchin, etc.) reveal that oil is present not only in the digestive tract but also in other organs as well as the muscle tissues.

Having established that the fauna will ingest and retain oil in their system, the field sampling is being continued in two selected areas; one of these is at Jerseyman Island, where oil was found on the bottom, and the second site is at Crichton Island where detailed studies of the natural clean-up processes are underway. It is hoped that by continuing with observations and sampling in these two areas, the persistence of oil in the biota can be determined, as well as gaining some insight into whether there are any long range sublethal or toxic effects that can be discerned.

R.W. Trites

Oil in the bottom sediments of Chedabucto Bay. Part of the oil released from the tanker Arrow came and remained ashore at various places around the Bay as discrete blobs and an intermittent sticky cover; part of it remained at sea and was dispersed throughout the water of the Bay. Because some of the oil on its shores and in its water must eventually be deposited on the floor of the Bay, a regional study **was** initiated on the nature, distribution, and oil content, of the bottom sediments in Chedabucto Bay.

Bottom sampling and echo sounding data obtained during cruises of *CSS Dawson,* CNAV *Sackville,* and CNAV *Fort Francis* indicate that the irregular floor of the Bay has a nearly continuous but relatively thin cover of gravel, sand, mud, and glacial till.

In general, gravel and sand are the predominant sediments in water depths less than 20 fathoms and on topographic "highs" or low rising banks offshore. Fine sediments (muds) occur, in elongated submarine valleys which parallel the northern and south sides of the Bay, in isolated depressions nearshore, and at the heads of the numerous bays and inlets which indent the northern side of the Bay. Most of the fine sediments have been deposited recently from suspension in response to the current regimes. They are mainly derived from the reworking (erosion and deposition) of glacial till which is exposed along the adjacent coasts. Glacial till is found on offshore banks, but elsewhere in the Bay it is buried beneath recent marine sediments. Bedrock exposures

are frequent nearshore and in some places in the Bay where the sediment cover is absent.

Chemical analysis of 32 samples showed that 4 of them contained small but significant amounts of oil (4-5 ppm). These samples came from Arichat Harbour, Fox Bay and a location 2-3 miles from Guysborough. The results indicate that some oil was deposited in the Bay. The source of these low concentrations of oil is not clear, however, because there is also a natural occurrence of oil in the sediments, and it is difficult to analyse accurately such low concentrations of oil.

D.H. Loring

Oil on Sable Island. In mid-February, after reports had been made that the shores of Sable Island had been contaminated by oil (possibly by oil that had drifted southeastward from Chedabucto Bay), a brief inspection of the eastern end of the Island was made by helicopter and on foot.

Brown and black discolorations in the sand, which on ground inspection proved to be due to oil, were seen along the northern shore from the air. The oil contamination extended along all the north shore in the intertidal zone in the form of fresh looking black blobs, 3 to 10 inches in diameter.

The spit at the eastern tip of the island was inspected on foot. On the central and south sides of the spit, about 10 to 15% of the surface area was oiled in patches ranging from 10 inches to 50 feet, apparently formed by oil impregnation of the sand to a depth of about 0.2 inches. Coring and digging revealed that the oil was also interbedded in places with clean sand. These formed layers 1 to 5 inches thick between oil horizons to a depth of at least 3 feet. On the surface, the oil impregnated sands were stable whereas the clean sands were constantly shifting. Sand coated oil was also present as 1 to 2-inch lumps in a band 10 to 30 feet wide extending for one-half mile along the shore above the tide level.

Black fresh looking blobs containing 25% water were present in the intertidal zone at the end of the spit and along a 10 to 20 foot band on the north shore for about 10 miles. Analysis of the oil samples indicated that the oil had the same origin as the *Arrow* oil.

Since the sands of the island are in constant motion, a second investigation was made in August to re-examine the oiled area and assess the amount of self-cleaning that had occurred in the interval. It was found that the oil in the intidal zone had all but disappeared, whereas the sand coated lumps about the high tide level remained in much the same amounts as before.

D.H. Loring.

Chemical Oceanography

The use of chemical indicators to identify and trace watermasses was a major part of the chemistry program for HUDSON 70. This program was carried out jointly with Mr. A. Coote, of AOL, who was the program leader. The work consisted of determining concentrations of the nutrients $P0_4$, NO_3, and SiO_2, using the Technicon Autoanalyser $^{(R)}$, and determining dissolved oxygen by the Winkler technique. The data are presently being worked up, and parameters such as apparent oxygen utilization and preformed nutrients are being calculated. A report of the results should be available in about one year.

The chemistry program in the Chilean fjords consisted also of the determination of the nutrients and dissolved oxygen. These were the first chemical studies of the Chilean fjords and a report is being prepared jointly with the Chilean scientists who participated in collecting the data.

A program to study sea water while it is subjected to hydrostatic pressures equivalent to ocean depths has been started. The experimental work will consist of determining the extent to which each of the major salts in sea water contribute to the bulk compressibility of sea water. The aim of the program is to determine the molecular structure of the deep sea water.

I.W. Duedall

ToC

Sediment Map of the Gulf of St. Lawrence

A sediment map of the River and Gulf of St. Lawrence which covers an area of 95,000 square miles has been prepared on the scale of 1:750,000 as part of a forthcoming FRB Bulletin on the Marine Geology of this area. This map, accompanied by a bathymetric chart at the same scale, will be published in color by the Canadian Hydrographic Service early in 1971. This map reveals that, in general, the sediment distribution is controlled by the various elements of the submarine morphology. Fine grained sediments (pelites and sandy pelites and their calcareous equivalents) occupy the floor of the submarine troughs. Sediments of increasing grain size (very sandy pelites, pelitic sands, sands and gravels, and locally glacial drift) cover the trough slopes and adjacent submarine shelves. These sediments and their regional distribution reflect the present depositional conditions and, to a certain extent, the depositional conditions that have been effective earlier in this region. It is considered that this map will be (1) an immediate practical benefit to those engaged in the search for commercial species such as shrimps and crabs which are closely associated with specific types of sediments and (2) an immediate scientific and practical benefit to those engaged in assessing the fate of suspended pollutants entering the Gulf through the rivers which drain most of the industrial areas of eastern Canada.

D.H. Loring

Sedimentary Environments on the Magdalen Shelf, Southern Gulf of St. Lawrence

Acoustical and sampling surveys have delineated a variety of sedimentary environments on the Magdalen Shelf, Southern Gulf of St. Lawrence. Oblique sonagrams, echograms, and bottom samples reveal that a relict sedimentary environment composed of large areas of uncovered bedrock and unsorted deposits of sands and gravel exists on the sea floor north of Prince Edward Island and in the nearshore areas of the Magdalen Islands. In contrast, recent depositional processes have produced major changes in the micro-topography and texture of relict sediments on offshore banks such as Bradelle and Orphann banks. In these areas, the sediments have been and are being reworked, sorted, and redistributed in response to the present current regime to form lag gravel deposits and sand wave fields.

A depositional environment exists in the shelf valleys and to a lesser extent in the intervening lows between the banks. In these areas, accumulation of fine grained sediments has buried an older sediment cover and modified its morphology.

D.H. Loring

ToC

Physiographic Changes in an Oyster Producing Area

The typical habitat of oysters, shallow bays and estuaries, is physiographically unstable over short periods of time (tens of years). In the long term (hundreds of years) a slow unidirectional change is usually apparent. This short term physiographic instability, together with other environmental changes (e.g. temperature or salinity) tends to cause fairly rapid changes in oyster populations. Environmental factors of biological significance have been studied extensively but relatively little attention has been paid to the fact that normal physiographic changes may have biological effects.

We have investigated the change in the pattern or erosion and deposit of sediment in Malpeque Bay, P.E.I. during the last 100 years. Parts of the bay have filled with sediment but other parts have suffered erosion. There has been a net gain of material, as would be expected, but this has not been excessive. The net rate of sedimentation was not significantly different from other estuarine areas in similar situations. However, the rate of sediment deposition on most of the established oyster growing areas was rapid and was much greater than normal. We have suggested that the traditional oyster growing areas may not now be suitable and other areas of the bay should be considered. There is no reason to believe that, when considered as a physiographic unit, the bay environment has changed significantly.

R.W. Sheldon
D.H. Loring
S. Deleu

Heavy Metals in the Bottom Sediments from the Gulf

A regional study has been initiated to assess the concentrations, distribution, partition, and source of heavy metals (Zn, Cu, Pb, Cr, V, Co, Ni, and Hg) in the bottom sediments from major depositional areas of the Gulf of St. Lawrence. Preliminary results indicate that the heavy metal concentrations vary with the texture and location of the sediments in the Gulf. In general, the heavy metal concentrations increase with decreasing grain size of the sediments with the highest concentrations (up to 204 ppm Zn, 76 ppm V, 442 ppm Pb, 188 ppm Cr. 190 ppm Li, 32 ppm Ni, 84 ppm Co) occurring in the clay size (<2 micron) fraction, which is being deposited on the floor of the Gulf from suspension. Regionally, the highest heavy metal values in the clay size fraction are found in the St. Lawrence River and estuary. Mercury concentrations in the Gulf are usually less than 0.5 ppm but higher concentrations have been found in the St. Lawrence River and estuary and in the Saguenay River. In the river, below the mouth of the Saguenay, mercury concentrations vary from 0.3 to 30 ppm with the highest concentration (30 ppm) being found on the floor of the Laurentian trough off Rimouski, Quebec. In the Saguenay River, values were mostly in the range of 1 to 17 ppm. The high concentrations in the river are presumably related to the dispersal of mercury compound from industrial sources.

D.H. Loring.

Trace Metal Concentration in Shrimp

Very little is known about trace metals in crustaceans but there is some evidence that certain of these elements, notably Cu and Zn are absorbed and concentrated. These concentrations may be localized in various organs and may vary with the concentration in the water. In addition, animals in the open sea concentrate less metal than those living in lightly polluted waters.

It is known that absorption and resorption are usually not in balance, i.e. heavy metal concentrations progressively increase. If this increase is mainly time dependent then crustacean populations should show discrete concentration levels according to age groups. Environmental conditions can be minimized by comparing concentrations in the exoskelton and the body. The exoskelton is younger than the body and hence accumulates lower concentrations.

A preliminary investigation of the shrimp *Pandalus montaquie* and *P. borealis* showed that (1) Fe and Zn were present in lower concentrations in the exoskeltons than in meat (2) concentrations of the trace metals, Fe, Zn, Co, Ni, and have possibly varied with age, and (3). in general, the offshore species *(P. borealis)* contains lower concentrations than the nearshore species *(P. montaquie).* In another investigation, the

trace metal concentrations in the meat (Fe, Zn, Mn) and exoskleton (Fe, Zn, Cu, Ni, Co, Pb, Sr, and Ca) of 27 individual shrimp, which varied in weight from 1.3 to 7.10 grams, were determined. Preliminary analysis of the data indicate that (1) in general, the trace metal concentrations in the meats increase and those in the exoskelton decrease with increasing weight (age), (2) the Zn concentrations are much higher in the meats than in the exoskeltons (467 ppm vs 200 ppm) and (3) the ratio at Zn in the meat to Zn in the exoskelton has a stepwise variation which may reflect the age structure of the population. Further work on using the variation in metal concentrations as means of identifying different age groups and the sensitivity of shrimps to trace metal pollution is planned.

D.H. Loring
R.W. Sheldon

Analysis of Fish Growth

The productivity of fish populations depends directly upon the availability of food resources, and the efficiency with which they are used to support fish growth. Previous investigations have suggested that growth efficiency of fishes is importantly affected by qualitative attributes of the prey resource, in addition to the more obvious importance of prey abundance.

Mechanistic analysis of fish growth in both laboratory and natural environments enable construction of an analytic model of fish growth. Evaluation of the model indicated that prey size may often influence fish growth more profoundly than does simple prey abundance. The prediction by the model was confirmed by utilising parameters of the prey resource to synthesize the growth curves observed for a fish population both prior and subsequent to modification of the size composition of its prey resource. The model accurately predicted the observed growth response without any modification for absolute prey abundance, demonstrating that yield forecasts for fish populations must take into account the size composition of the prey resource.

This study is essentially completed, with publication of the results, in three parts, now in progress. Nevertheless, as time permits, further development of the system will be made.

S.R. Kerr

Macrozooplankton and Ichthyoplankton Studies

St. Margaret's Bay. The field work has been completed on a three-year study of macrozooplankton and the results show a succession of dominant forms which feed on copepods. From January to March *Sagitta elegans* is the main invertebrate predator. The first euphausiids arrive from the coastal waters in March and by April they completely dominate the zooplankton. Their numbers start to decline in May and they virtually disappear by June. The Bay zooplankton is dominated by *Mysis mixta* and *Sagitta elegans* from July to December. The number of *Mysis* declines and the number of *Sagitta* increases in December. *Sagitta* remains abundant until April.

The population of *Sagitta elegans* was studied in detail and found to be polymodal throughout the year; the modes were distinct enough to be considered subpopulations. Four sub-populations were present in the Bay during the early winter, with a fifth entering the Bay later in the winter. The growth of the subpopulations was followed through the year and related to the mean water temperature. A mathematical model describing the effect of temperature on the life cycle and reproductive potential was made and proved adequate for predicting changes in population size as a function of temperature and mortality rate. The yearly net production of the *Sagitta* was 0.2 g C/m^2 per year or 0.1% of the total net primary production.

The euphausiids *Thysanoëssa rashii* and *T. inermis* were the main species collected with *Meganyctiphanes norvegica* occasionally being found. *T. rashii* which made up from 50 to 100% of the euphausiid catch was the first species to arrive in the winter and the last species to be found in the spring. The euphausiid biomass reached a maximum of 6.6 g/100m^3 live weight in March of 1968, 14 g/100 m^3 in April 1969 and 16 g/100 m^3 in April 1970.

The sharp decrease in numbers of euphausiids between May and June in all years coincided with the appearance of the mackerel *(Scomber scombrus)* in the Bay. Stomach analyses showed that the mackerel were feeding heavily on euphausiids in St. Margaret's Bay.

Mysis mixta was very abundant in samples taken from July to December and the numbers declined quickly in the winter as the animals reproduced and died. None were collected from March to late May. The newly hatched animals remain near the bottom at all times in their early life. The yearly pattern of biomass changes of *Mysis* appeared to be similar from one year to the next, with the maximum occurring in September. The highest biomass value was found in September 1969 with 4.5 g live weight/100 m^3.

These species play a major role in the food web leading to commercial fish production. When their annual energy budget is finally calculated it will make a significant contribution to our understanding of the total energy budget of the Bay and the portion available for transfer to pelagic fish stocks. While these predatory planktonic invertebrates are important food for adult fish, it has been recently reported that they can greatly influence the recruitment of young fish through directly preying upon the larval fish and by competing with them for the copepod food supply. Such relations are a part of this study.

D.D. Sameoto

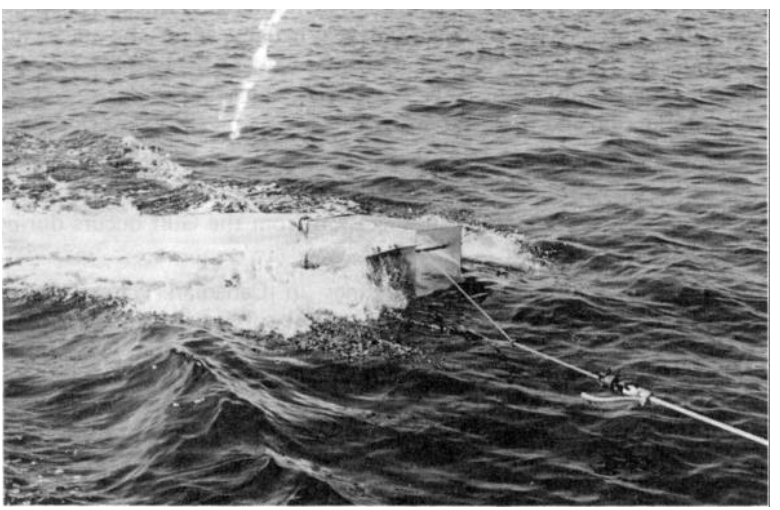
Herring larval studies on the Scotian Shelf. An extensive survey for herring larvae *(Clupea harengus)* on the Scotian Shelf was conducted in May and October 1969. Sampling was carried out at approximately 65 stations using a modified version of the Icelandic highspeed sampler. No larvae were found during the May cruise. In October, large numbers of larvae were located along the entire coast concentrated within the fifty fathom contour. There was no evidence that spawning occurred on the shelf beyond the fifty fathom contour. The distribution of the larvae agreed well with a map of spawning beds compiled from information gathered from fishermen and federal fisheries officers along the Nova Scotia coast from Canso to Cape Sable.

The results including data on the simultaneous distribution of macro-zooplankton will be published as a technical report.

D.D. Sameoto

Bedford Basin. A study of the macrozooplankton of Bedford Basin is being made to determine the differences in species composition and production between the Basin, which is polluted by domestic sewage and the unpolluted St. Margaret's Bay. Preliminary results show that the fauna is less diverse in the Basin with *Sagitta elegans* the dominant predatory invertebrate. The biomass of *Sagitta* is 5 to 10 times greater in the Basin than it is in St. Margaret's Bay. This may be attributable to the higher production of copepods that results from the increased primary production.

D.D. Sameoto



Aluminum model of Otter Surface Sampler developed by MEL for collecting zooplankton and ichthyoplankton (Sameoto and Jaroszynski, 1969). This sampler has also proved useful in detecting surface oil particles.

ToC

Mackerel Biology Study

This study combines laboratory and field work in an attempt to understand the seasonal energy budget for Atlantic mackerel and to determine its component role in the marine ecosystem. Laboratory studies primarily involve estimates of oxygen requirements in relation to food consumption and swimming speed and the cost of respiration. As oxygen demand increases following a meal, the mouth gape increases to allow more water to cross the gill and results in an increase in the cost of swimming. Doubling the quantity of respiratory water raises the cost of swimming by about 25%. The cost of straining additional quantities of water in filter feeding appears to be relatively small. Provided the abundance of small organisms is adequate, indiscriminant filter feeding may be more economical than selective feeding on larger organisms.

Field studies include food and feeding habits, growth and fat storage and schooling behavior. During the past two years data have been collected in St. Margaret's Bay and the Gulf of St. Lawrence to supplement and complete earlier work on growth, recruitment and migration carried out (by K.T.M.) in conjunction with the FRB Biological Station at St. Andrews.

The northern population of mackerel over-winters in mid-water, possibly on the outer edge of the Scotian Shelf and of Georges Bank, where there appears to be little or no feeding; the energy requirements may be met mainly by stored fat. During the spring migration heavy feeding on euphausiids and small fish (herring and sand lance) is observed along the outer coast of Nova Scotia. Virtually all of the successful spawning of this population occurs in the Gulf of St. Lawrence during June and early July. A negative correlation exists between size of year class production and first year growth.

Post spawning feeding is almost exclusively by filtering on copepods and other small zooplankters. During this time a large portion of the energy intake is stored as fat. Emigration from the Gulf occurs during September to November.

Increases in the commercial landings in Canadian waters during 1969-1970 reflect mainly a very successful survival of the 1967 year class. In general, the mackerel stock appears to be very much underexploited by the commercial fishery.

B.S. Muir
K.T. MacKay
T.C. Lambert

School of mackerel in laboratory tank.

St. Margaret's Bay Fish Studies

Estimates of fish production in St. Margaret's Bay are difficult to make because some of the important species are very transitory. Large migrating schools of mackerel invade the Bay and consume unknown quantities of the planktonic production. Part of this study is directed towards providing estimates of the average relationship between the quantity of food consumed in the Bay and the quantity of fish removed from the migratory schools. Total removal and the relative strength and duration of the invasions is estimated from trap-net fishermen's log-books. The food consumed while these fish are in the Bay is being estimated by periodic sampling and from results of the Mackerel Biology Study.

A benefit which was not expected from our log-book survey has been the extension of the recorded ranges for several species of fish. While some may reflect increased survey and attention, some are certainly valid and recent extensions. Because they may be associated with climatic or oceanographic phenomena the documentation of such extensions is important and is being continued with the collaboration of Mr. John Gilhen of the Nova Scotia Museum and Dr. W.B. Scott of the Royal Ontario Museum. Two records in particular are unusual both for the area and for shallow water. One specimen of *Ariomma bondii,* a normally deep-water oceanic species, is only the second record for north of Cape Cod. Twelve specimens of the Eastern Atlantic oceanic *Centrolophus niger* (black ruff) collected during 1968 and 1970 are more than the total number of specimens previously reported for the entire NW Atlantic.

K.T. MacKay
B.S. Muir

ToC

Functional Morphology of fish Gills

The fish gill functions not only in gas exchange but also in ion and water exchange and it may have an important involvement in the accumulation of compounds such as pesticide residues. The great variation among species in the total respiratory surface area, and in the geometry of the gill, roughly correlates with habits and habitats and a comparative study of functional morphology contributes to the understanding of the organism-environment interaction that is peculiar to each species. Such understanding serves a number of purposes, the present one being, in part, a cost-efficiency analysis of respiration and its contribution to ecological efficiency as a function of fish size and species.

Studies completed have dealt mainly with the highly specialized, continuously swimming, tunas, which have the greatest respiratory surface area of all species examined. A number of morphological modifications are found in the tunas and these may be essential to the combination of large fish size, large gill area and the economical extraction of oxygen. Because the large gill area is attained in part by increasing the number of secondary lamellae per unit of filament length, their thickness must be kept small so as not to further decrease the thickness of the water passage area - which would increase the cost of moving water. As the secondary lamellae grow in length, the potential blood pressure drop, and the cardiac work, increases. Most teleosts overcome this by increasing the blood vessel diameter, and therefore the lamellar thickness, at the expense of the water passage thickness. Tunas have achieved remarkable economy by re-organizing the blood pathway so that control of blood pressure drop does not require so great an increase in lamellar thickness.

An analytic model for the tuna gill is being developed which will enable a quantitative description of these findings and especially an assessment of the effect of fish size on the cost-efficiency of oxygen extraction. Data are being collected for other species (mackerel, cod, salmon) which will allow extension of the model to an interspecies comparison.

Atlantic mackerel are also continuous swimmers relying solely on ram ventilation, but we find they have a much smaller gill area and lack most of the tuna modifications. Although they are fairly active fish it may be significant that they do not grow to a large size; many teleost species that do tend to be relatively less active.

B.S. Muir

Studies on Trophic Relationships

Caloric content differences between areas. Caloric content values for invertebrates from St. Margaret's Bay collected in 1966 were higher, per unit weight, than recent values determined by Dr. A.V. Tyler for Passamaquoddy Bay. A collaborative study has been made to determine the reasons for the difference. Samples of *Lumbrinereis fragilis* from Passamaquoddy Bay were split for analysis at both the St. Andrews Station and at MEL. Samples of the same species from St. Margaret's Bay, collected less than eight weeks later, were also analysed at MEL. These, 1969, analyses showed no difference between areas nor between investigators. Values obtained for two St. Margaret's Bay collections were 4480 and 4699 cal/g dry weight and for two Passamaquoddy collections were 4467 and 4468.

The mean weight of animals analysed in 1966 however was 2.7 g compared with 0.6 to 1.3 g in 1969 and the high value of 4857 for 1966 may be associated with the weight difference. Examination of the earlier data from the two areas led to the conclusion that apparent differences in caloric contents between species might be accounted for on the basis of differences in the size of animals sampled.

V.M. Srivastava (Brawn)

Activity studies on cod. Ultrasonic activity monitors, utilizing the Doppler shift, were tested for suitability in cod activity studies. Unfrightened, locomotory movements of the cod however, were normally so slow that the frequency shift was too small to activate the sensor and only escape movements were adequately detected. The sensitivity of the instrument could not be increased because spurious echoes from the tank wall quickly became a problem.

The design and testing of a more suitable detector is continuing. In the meantime studies have turned to the higher levels of cod activity. Cod are encouraged, by food stimulus, to swim in a water tunnel type of apparatus. Preliminary results indicate it is feasible to impose standard levels of effort which must be exerted to obtain food.

V.M. Srivastava (Brawn)

Studies on American Plaice Energetics

The dynamics of the unexploited population of American plaice in St. Margaret's Bay have been previously studied. The present work is concerned with modelling the population in terms of energy transfer and conversion processes. The analytic model will then be used to explore, through simulation, the effects of various fishing strategies. Critical evaluation of the model will be made by applying it to other, exploited, populations such as those in the Gulf of St. Lawrence and at Grand Banks.

The energy content of a mature female American plaice of 35 cm length varies between 250 and 336 kcal during the annual sequence of spawning, feeding and overwintering processes. Preliminary analysis of data indicates that the annual production of materials associated with changes in weight relative to length (i.e. condition) is 105 kcal; the energy change associated with overall body growth of a fish of this size is 60 kcal. Energy content of the ovaries increases from 4 kcal after spawning to 42 kcal prior to spawning. Assuming a 5-month winter period of essentially no feeding, it appears that 18 kcal of ovary energy is stored during the feeding period and 20 kcal is transferred from body material during the overwintering period.

Larger plaice divert relatively greater amounts of energy to reproduction. A power curve relationship between ovary weight and gutted body weight for 50 fish taken near the time of peak spawning in 1970 had an exponent of 1.261. Applying the appropriate conversion factors the ratios of ovary energy to total body energy for 150 gm and 500 gm fish are 0.13 and 0.17 respectively. Ratios of annual increase in body energy as growth to total body energy for the 150 and 500 gm fish are 0.25 and 0.15 respectively.

The oxygen consumption rate of a 300 gm plaice at temperatures averaging 3°C is 6 mg/hr. This figure is based on measurements with 45 fish, weighing 150 to 550 gm, in a continuous flow respirometer. Additional measurements will be made during different seasons of the year at temperatures from 1 to 6°C, corresponding to bottom water temperatures in St. Margaret's Bay.

Theoretical studies on the response of the unexploited, equilibrium stock to various fishing strategies will be carried out with a computer simulation model which will be based on the analytical energetics model. The simulation model will include postulates concerning fishing strategy and adaptations in population structure that might result from fishing. The main features of interest in these studies are the predicted yields from fishing and the resultant alterations in the magnitude and distribution of energy feed-back for reproduction, the amounts of energy requirements as food and the magnitude and pattern of body materials production.

J.C. McKinnon

Metabolism and Enzyme Activity in Fishes

The eventual aims of the studies carried on by this investigation in 1969-70 are:

1. To determine what changes occur in selected internal parameters in certain fish in response to changes in external factors which either occur seasonally in nature or which can be brought about in the laboratory.
2. To learn something of the biochemical mechanisms by which these internal factors are altered.
3. To apply the information so acquired as a tool in the study of the energy relationships of natural fish populations.

Thus far only those problems included in group 1 have received significant study and are reported on below.

Studies on fish blood. The variations in some blood parameters of the American plaice *(Hippoglossoides platessoides)* in St. Margaret's Bay,

N.S. are being evaluated with respect to season and to size and sex of the fish. The blood parameters currently under investigation are hematocrit, concentrations of hemoglobin and serum proteins, and cell number and size distribution. In addition to these field studies, laboratory experiments involving *Tilapia mossambica* are being carried on to determine the effect of environmental factors such as ration level, temperature and salinity and the effect of biotic factors such as sex and size on the hematological state of the fish.

The results are quite encouraging although the analysis is not advanced. The plaice blood behaves as expected, the parameters studied being generally greater during those times of year when it is expected that the need for oxygen carrying capacity would be enhanced. Males appear to have larger numbers of smaller cells and higher hematocrit, serum protein and hemoglobin levels than females. Size and hematological factors are related in the same way as in other fish, small fish having lower values which increase with size until a plateau is reached. In *Tilapia,* all blood parameters increase markedly with ration levels.

J.C. Smith

Studies on seasonal variation in enzyme activity in the American Plaice. The specific activities of the enzymes glucose-6-phosphatase (liver), tryptophan pyrrolase (liver), uricase (liver) and lactic dehydrogenase (liver, heart, skeletal muscle) have been followed on a seasonal basis. In some cases, the effects of sex and size have been investigated.

Preparations have been made to determine the effects of season, size and sex on the activities and Michaelis constants of pyruvate kinase and fructose diphosphatase and on the Michaelis constants of the enzymes mentioned above.

J.C. Smith

Growth and enzyme studies *on Tilapia.* Growth studies on *Tilapia* have been carried on during parts of 1969-70 with the exception of a period during which a serious epidemic made this impossible and necessitated a complete reorganization of fish-holding and experimental facilities. The effects of ration on growth and enzyme activity is the only portion of the study very advanced and the data are still incomplete.

J.C. Smith

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Marine Bio-Acoustics

Active sonar has become increasingly useful for studies of the biological content of the oceans. Because of the complicated nature of the biological targets however, the optimal acoustic characteristics of the sonar are to a large extent unknown. This is particularly true for zooplankton echolocation, where the animals may be "acoustically transparent" at too low a transmitted frequency, but at too high a frequency the water will absorb most of the reflected acoustic energy. Compromises in the acoustic properties of the transmitted sound are often required and a study of such compromises involves a close interaction of both biology and physics.

Cetacean bio-acoustics. In consideration of zooplankton echolocation it was noted that the large baleen whales must locate and consume tons of zooplankton each day. In May, 1969, hypotheses were developed regarding the existence and nature of echolocation sonar from these whales. Obviously, if the signals existed their properties might be useful to aid in the design of man-made sonar. Of particular interest would be the variation of sonar signals between whales that preferred different zooplankton prey species.

During a Fisheries Research Board whale tagging cruise in late May and in June, ultrasonic sonar signals from a blue whale were discovered and recorded for laboratory analysis. This and subsequent cetacean research has been carried out in co-operation with Dr. Edward Mitchell of the Fisheries Research Board, Arctic Biological Station, Ste.-Anne -de Bellevue, Quebec.

A second approach to the study of acoustic parameters of cetacean sonar has involved measuring the frequency response of bones of the middle ear. This approach offers an independent but complementary method of learning how whales through evolution have adapted their food-finding sonar mechanisms to a complex acoustic ocean environment. Bio-acoustic studies carried out at the Blandford Whaling Station included experiments to measure pathways of sound reception through the head of baleen whales, the ability of these animals to focus their transmitted sound pulses and the frequency response of the middle ear. Bio-acoustics experiments at the Blandford Station involved the co-operation of Mr. David Prentiss of the Nova Scotia Research Foundation.

Further at-sea recordings were made aboard the first two legs of HUDSON 70, and in the Windward Islands and Puerto Rico during the southern migration of the mysticete whales. In conjunction with the U.S. Navy at Argus Island near Bermuda, research on measurements of the source level and target strength, as well as ultrasonic sonar, was carried out in the Spring of 1970.

During the summer of 1970, five cruises were held on the Nova Scotia shelf in attempts to obtain additional data on echolocation sonar of the baleen whales. Work has recently been completed on a preliminary analytical model of acoustic windows suitable for marine mammal echolocation sonar.

P. Beamish

Echo Counting System for Demersal Fishes

The acoustic echo counting system for fishes has progressed to a point where the prototype, hard wired, data acquisition system is an operational unit. The addition of a 50 KHZ scientific echo sounder and a 4 KW transmitter, incremental magnetic tape and high speed printer allows the recording on tape of each transmission of the data on fish counts in each of the 44-meter layers of water just above bottom. The data are available for computer analysis. The data on totalized counts for 4- and 16-meter layers at selected time intervals are also recorded and written out for data reductions and on-the-spot analysis while fish surveys are in progress.

Trial groundfish surveys were conducted in co-operation with the St. Andrews Biological Station during January 1969 in the Cabot Strait area. MEL staff carried out further surveys on the Nova Scotia Banks in March 1970. Echo counts were made on planned survey lines or grids, data were reduced to density per unit volume, and where feasible, contour maps of densities drawn up. Samples of bottom fish were taken with otter trawl by the *E.E. Prince,* and the *A.T. Cameron.* Numbers caught and distributions derived from catches compared favorably with the densities plotted from the sounder data.

During March 1969 a joint cruise was conducted with the Institute of Marine Research, Bergen, Norway on the Research Vessel *G.O. Sars* in the Lofoten area of Norway. The purpose of this cruise was to compare the Bergen Integrator system to the MEL counting system. A good correlation was obtained with linear relationship being obtained over a wide range of densities.

During November 1970 a survey was conducted in the Emerald, Wesern Bank area on small redfish to test for persistence of schools. Over a 36-hour period the geographical position of local concentrations showed high variability which affected net hauls. Preliminary analyses of the sounder records showed, however, that catches were being taken from the same basic statistical distribution, suggesting that the redfish concentrations were highly dynamic aggregations within their area of occurrence. Searching with the echo-counter appeared likely to confer a significant advantage to a fisherman. Tests were also made for.

coincidence counting of fish at the high densities encountered among the redfish schools. This is accomplished by raising and lowering of the outboard transducer, permitting the experimenter to change the volume of water or of school sampled. No indication of coincidence counting was obtained even with densities calculated to be as high as 7.0 per 1000 cubic metres.

A small computer has been purchased to supplement the hard wired data acquisition system and increase its flexibility. This will allow real time analysis and data reductions at sea, and in addition make it possible to extract considerable additional information, such as size distributions. Digital decca and plotters are being considered for addition to the system to permit automatic plotting of reduced data on ship, a development which may have particular relevance to fish resource-inventory surveys.

R.G. Dowd

ToC

Design Studies for Proposed Fisheries Research Vessel

A number of design studies were initiated in order to provide statements of requirements and target design figures to a scientific consultant engaged to carry out preliminary planning for a large deep sea fisheries research vessel.

Noise suppression. Figures on allowable radiated noise levels versus frequencies were required to enable engineering studies on noise reduction techniques to limit the transmission of noise into the water. Target figures were obtained by reviewing our past acoustic work, endeavouring to project our future spectrum of interest, consulting with designers, and visiting shipyards in Vancouver and Port of Glasgow to examine noise suppression equipment and installations on ships.

Deep-trawling winch. The deep-trawling winch is a central feature of the proposed vessel. Before a contract could be let for the deep-trawl winch design studies, it was necessary to determine the size, length, and weight of the fishing warps. Information on loading imposed by bottom trawls and large midwater trawls is available in the literature and from engineers engaged in fishing gear research and design. Values for loading caused by the cable drag and its own weight as a function of diameter and length were determined by computer analyses at the National Institute of Oceanography. After consultation with engineers at British Rope Works, a tapered configuration was selected.

Net monitoring. Preliminary studies were undertaken to determine the feasibility of having electrical conductors in the tapered warp to monitor the performance of the net. It was found that cable manufacturers could make long splices in the tapered cable without breaking the electrical conductors but that the cost would be

prohibitive. Furthermore, the cable would be fragile, and have a large radius of curvature necessitating an increase in the size of the pulleys and winch drums. Other methods of net monitoring are being considered.

S. Paulowich

ToC

Salmon Counting

The use of hull-mounted acoustic equipment to count salmon entering bays and estuaries of British Columbia rivers poses a number of problems. One of the problems is associated with the lack of mixing between the fresh water discharge and salt water. The interface between fresh and salt water causes high reverberation levels which mask the targets below this area. To assist in overcoming this problem, a system was constructed, which is similar to the acoustic echo-counting system (AECS) developed at MEL to study ground fish. The basic difference in the salmon counter is that the transducer in the towed body is mounted to look towards the surface. The body is towed at various depths and sounding is in an upward mode enabling the echoes to be counted below the interface. The handling gear and towed body system used for ground fishing is not suitable for small coastal vessels, and considerable effort will be required to design a small stable towed system and handling gear suitable for small vessels and use in restricted waters.

S. Paulowich.

Computer Selection

Specifications for a 16-bit computer were drawn up in co-operation with the Bedford Institute small computer committee and a contract has been awarded.

This computer will be used primarily for data acquisition and processing at sea. The principle users are expected to be the ground fish study group, which will use the computer in conjunction with their AECS, and the coastal oceanography section, with the NRC-developed STD unit and an oxygen probe.

Equipment to interface the computer with the AECS and the STD unit is under development.

S. Paulowich

Continuous Chlorophyll Measurements

A system has been constructed to continuously measure and record chlorophyll concentrations. The system consists of a fluorometer modified for continuous water flow, with its sensitivity extended and increased at the longer wave lengths. A submersible pump is used to provide the continuous water flow. This pump can be towed

at high speed at predetermined depths or may be raised and lowered for vertical profiling. The pump body is fitted with a depth gauge and thermistor.

The data acquisition system will measure and record chlorophyll, temperature, depth, and time at preselected intervals. These values can be instantaneous or integrated, with integration times of up to 100 seconds. These measurements are digitized and can be recorded as printed copy and/or on punched paper tape. A multi-channel recorder is also fitted to supply an immediate analog output.

S. Paulowich

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Pollution Studies

In 1970 a new section was formed within the Marine Ecology Laboratory for pollution studies. In part, initial efforts have necessarily been directed toward development of essential facilities. Among the more time-consuming of these have been the development of plans for a new experimental facility for pollution studies, and the design of a data retrieval system to enable rapid searching for information on a wide spectrum of pollutants. Both projects are scheduled for completion early in 1971. Some of the projects fisted below were initiated at the FRB Halifax laboratory by Drs. Addison and Fletcher and were transferred to MEL during 1970 when these investigators joined the Environmental Quality group there.

Pesticide Studies

Pesticide transfer. Accumulation of pesticides, end residues of other persistent compounds, in biological systems has long been known to occur. While numerous observational reports of the phenomenon are available, little effort has as yet been directed toward analysis of the transfer process in itself. A predictive model of the behaviour of pesticides in ecosystems would have obvious import for public health consideration, apart from ecological interest.

Since the inception of this study in mid-1970, an initial model has been devised using the methods of compartmental analysis. Evaluation and elaboration of the model is now proceeding as time permits, and is expected to provide a conceptual frame for laboratory investigation of pesticide transfer when facilities become available.

S.R. Kerr

Organochlorine pesticide residues in marine oils. A survey of organochiorine pesticide residues, including PCBś, in commercial marine oils (mainly from marine mammals and herring) is underway. Results show that the most common residues are those of DDT and its metabolites, whose levels range from about 1-20 ppm in oils so far examined.

R.F. Addison

Organochiorine pesticide residues in marine species. The levels of organochlorine residues, including PCBś, in representatives of various trophic levels are being analysed. Results to date show that in the tower trophic levels, e.g., euphausiid shrimp, the only residues detectable are those of the DDT group. The levels of these pesticides are at least one order of magnitude lower than those found in larger fish.

R.F. Addison
S.R. Kerr

Phosphorus Studies

Toxicity of yellow phosphorus. In response to the yellow phosphorus pollution which occurred in Placentia Bay, Nfld. in 1969, a number of laboratory investigations were carried out to determine the effects of this element on marine organisms.

Utilizing continuous flow testing procedures the acute toxicity of yellow phosphorus to smelt, cod, seawater-maintained salmon smolts and seawater-maintained brook trout was determined. In all cases yellow phosphorus was found to be extremely toxic and no indication of a safe concentration was observed. One interesting observation was that yellow phosphorus was equally lethal to all species studied. The lowest concentration tested and the LT50 (time to 50% mortality) observed were as follows: Smelt 0.5 µg/lP_4, LT50 180 hrs., Cod 20 µg/lP_4, LT50 125 hrs., salmon 0.8 µg/l, LT50 195 hrs., trout 0.5 µg/l, LT50 121 hrs.

During their exposure to phosphorus, salmon and trout turned a bright red color and showed signs of extensive hemolysis. In contrast cod and smelt did not exhibit any of these phenomena.

In a second series of experiments salmon and cod were subjected to brief (1-2 hrs.) exposure of yellow phosphorus which resulted in mortalities which were delayed as much as two to three weeks. These results indicate that even short exposure to this element can result in permanent damage to the fish.

Chemical analysis of fish, marine invertebrates and seaweed which had been exposed to yellow phosphorus indicated that this element accumulated and concentrated within their tissues. In cod the highest concentrations were found in liver where they were as high as 2000 times sea water, and 50 times muscle levels. Phosphorus distribution in salmon tissues was fairly uniform being some 20 to 40 times sea water concentration. Among the invertebrates examined the American Lobster concentrated phosphorus to the greatest extent with 90% of the uptake concentrated in the hepatopancreas (2000 times sea water).

G.L. Fletcher

Analyses for elemental phosphorus. As a result of needs arising from the Long Harbour phosphorus pollution disaster, a rapid and sensitive method for the analysis of the elemental phosphorus was developed. Phosphorus is extracted into a suitable organic solvent, isolated by gas-liquid chromatography, and measured in a highly sensitive and specific flame photometric detector. Phosphorus in water at levels as low as 10^{-12} grams can be measured in a few minutes and the methodology has been extended to muds and biological samples. With the cooperation of the Department of Fisheries, St. John's, Nfld., thousands of water samples from Long Harbour were examined to

establish and monitor the distribution of elemental phosphorus down to the parts-per-thousand million level.

R.F. Addison

Phosphorus deposit survey operations. The spillage of elemental phosphorus into the waters of Long Harbour, Newfoundland, required extensive surveys of bottom deposits which were carried out by divers from other laboratories and agencies. However, all analyses were carried out in the Halifax laboratory. Some samples were bucket or grab hauls, but the majority were cores which required sectioning and individual treatment of the sections. In all, over 500 analyses were carried out on Long Harbour bottom deposits. Mud samples with as high as 5% by weight elemental phosphorus were found in the vicinity of the ERCO wharf, and lower levels were found over a substantial area of the inner harbour. After each of two dredging operations further surveys were carried out and these indicated that, after a year, local deposits of elemental phosphorus still existed in the vicinity of the ERCO wharf.

R.F. Addison

Phosphorus assimilation by Long Harbour marine life. In various stages of the Long Harbour pollution disaster, and subsequently during dredging operations, biological samples were monitored to establish the uptake of elemental phosphorus from sea water. As a result of nearly 1200 tissue analyses it was established that elemental phosphorus was preferentially concentrated into lipid-rich tissues of fish and other marine life. Elemental phosphorus in fish, after the initial mass mortalities, was restricted to the inner harbour.

R.F. Addison.

Hydroxamate Studies.

The toxicity of the commercial iron ore flotation agent, di-methyl ammonium alkyl hydroxamate (DMAH), to brook trout was studied under laboratory conditions. Results indicated that at a water temperature of 16-17 C, 6 ppm DMAH was lethal in 180 hrs. and at 3-4°C, 25 ppm was lethal in 120 hrs. Since DMAH consists of a number of molecular species in equilibrium, several of these were synthesized and experiments were conducted with them in an attempt to evaluate their contribution to its toxicity. Of the compounds tested, dimethylamine proved to be relatively non-toxic, hydroxylamine was equally as lethal as DMAH and NaC_{10} hydroxamate was 5 to 10 times more toxic than hydroxylamine or DMAH. These results suggest that although hydroxylamine may contribute in part to the toxicity of DMAH the hydroxamic acid moiety appears to be the major lethal component.

G.L. Fletcher
R.F. Addison

Miscellaneous Studies

Project Oil contribution. A two-dimensional thin-layer chromatographic technique was evolved, as a contribution to "Project Oil", which could distinguish between certain Bunker C oils of distinct origins through separation of polynuclear aromatic compounds into distinct groups. The procedure requires only simple equipment and chemicals and is suitable for use in the field.

R.F. Addison

Herring oils. Studies started in 1965 revealed two annual patterns in the iodine values of Atlantic herring oils produced commercially in Nova Scotia and Newfoundland. A reproducible systematic decline in iodine value of 20 units through July and August in the southwestern Nova Scotia fishery, and of 10 units from December to the end of March in the southwestern Newfoundland fishery, are believed to have a common origin in basic biochemical changes in fatty acids carried out by the fish. These short-term patterns were superimposed on year to year iodine value variations of ±5 units which probably reflected long-term environmental changes. The majority of iodine values for these oils were in the 135-105 range. The free fatty acids in freshly produced commercial herring oils were shown by the long-term study to seldom exceed 0.2-0.3% when fresh fish were reduced. A separate study showed that rapid phospholipid hydrolysis before reduction was the principal source of these fatty acids, but that any very extensive lipid hydrolysis involved triglycerides as well. Some evidence for slow post-reduction chemical processes was also obtained.

R.F. Addison

Odd-numbered fatty aids in Jeddore Harbour smelt. In mid-winter smelt from Jeddore Harbour, near Halifax, contain up to 10% fatty acids of odd-numbered chain lengths, an exceptional value for any species of Canadian fish so far investigated. In smelt collected at the same time of year from Digby, Pictou, and the Miramichi estuary, and from the adjacent waters of Musquodoboit Harbour and Porter's Lake, odd-numbered fatty acids amounted to only the normal 2-3% of the total. The excess acids follow the same metabolic pathways as the normal amounts of these acids. An etectrophoretic comparison of numbers of smelt from Jeddore Harbour, the Miramichi estuary, and Heney Lake in Gatineau County, Quebec, revealed a unique absence of mutant forms of several common isoenzyme systems. For this reason, and from preliminary assessment of stomach contents, the seasonal occurrence of odd-numbered fatty acids in Jeddore Harbour smelt, is believed to reflect unknown dietary factors peculiar to the one area.

R.F. Addison

Halosphaera taxonomy. *Halosphaera viridis* is an interesting phytoplankter which has at times a very large (pinhead size) pelagic cyst stage. A natural bloom in Newfoundland waters permitted a study of the fatty acid composition which supported recent taxonomical revisions based on morphological studies. In addition, the analytical results were close enough to those of laboratory cultures of related species to suggest that the latter provide a reliable indication of fatty acid composition under natural growth conditions.

R.F. Addison

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Appendix C-1
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